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ELECTRONICS DIGEST

Vol.3 No.4
£1.85

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MPSA77	50p
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2N1893	35p
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2N2222	25p
2N2222A	25p
2N2369A	20p
2N2904A	25p
2N2905	25p
2N2905A	25p
2N2906A	25p
2N2907A	25p
2N3053	30p
2N3054	70p
2N3055	45p
2N3439	80p
2N3440	60p
2N3771	160p
2N3772	160p
2N3773	250p
2N3819	25p
2N3821	120p
2N3822	120p
2N3823	95p
2N3824	95p
2N3866	90p
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2N3905	15p
2N3906	15p
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2N4125	25p
2N4391	70p
2N4392	70p
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2N4401	25p
2N4402	25p
2N4403	25p
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ED/184

ELECTRONICS DIGEST

Volume 3 No. 4

GATEWAY TO ELECTRONICS

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PUBLISHED BY: Argus Specialist Publications Ltd., 145 Charing Cross Road, London WC2H 0EE. DISTRIBUTED BY: Argus Press Sales & Distribution Ltd., 12-18 Paul Street, London EC2A 4JS (British Isles). PRINTED BY: QB Limited, Colchester.

INTRODUCTION

This is the first of two editions of Digest DATA specials. This edition contains discrete components, linear ICs, CMOS and TTL. The second edition, which will appear in the near future, will be devoted to microprocessors and their support ICs.

Whatever your interest in electronics, there's bound to be something in this magazine that you'll need to know sooner or later. If you still haven't decided to buy it, are you sure you're standing at the right rack in the newsagents?

Note: While very effort has been made by the manufacturers and by the Editor to make the data contained in this edition as accurate as possible, no liability in respect of its use is accepted by the Editor or the manufacturers.

COMMON ABBREVIATIONS

A	Ampere or Anode
AC	Alternating Current
ACC	Automatic Chroma Control
Ae	Aerial
AF	Audio Frequency
AFC	Automatic Frequency Control
ALC	Automatic Level Control
AM	Amplitude Modulation
ANL	Automatic Noise Limiter
ATU	Aerial Tuning Unit
AVC	Automatic Volume Control
b	Base of transistor
B&S	Wire Gauge (US)
BCD	Binary Coded Decimal
C	Capacitor
c	Collector
CCD	Charge Coupled Device
CCTV	Closed Circuit Television
cgs	Centimetre-Gramme-Second
Ck	Clock
CMOS	Complementary Metal Oxide Semiconductor
CPU	Central Processing Unit
CW	Continuous Wave
D	Diode
d	Drain of FET
dB	Decibel
DC	Direct Current
DF	Direction Finding
DIL	Dual In Line
DIN	German Standards Institute
DNL	Dynamic Noise Limiter
DPDT	Double Pole Double Throw
DPST	Double Pole Single Throw
DTL	Diode Transistor Logic
DX	Long Distance
E	Voltage
ECL	Emitter Coupled Logic
EHT	Extra High Tension
EMF	Electro-Motive Force
ERP	Effective Radiated Power
F	Farad or Farenheit
f	Frequency
FET	Field Effect Transistor
FM	Frequency Modulation
G	Giga (10^9)
g	Grid or Gate
Gnd	Ground
H	Henry
HF	High Frequency
hfe	Transistor gain
HT	High Tension
Hz	Hertz
I	Current
Ib	Base Current (Transistor)
Ic	Collector current
IC	Integrated Circuit
IF	Intermediate Frequency
I^2L	Integrated Injection Logic
i/p	Input
ips	Inches per Second
K	Kilo (10^3) or Cathode
L	Inductance
LCD	Liquid Crystal Display
LDR	Light Dependent Resistor
LED	Light Emitting Diode
LF	Low Frequency
Lin	Linear
Log	Logarithmic
mA	Milliamp
mH	Millihenry
MHz	Megahertz
MOSFET	Metal Oxide Semiconductor FET
MPU	Microprocessing Unit
MSI	Medium Scale Integration
MOST	Metal Oxide Semiconductor Transistor
LS	Loudspeaker
LSI	Large Scale Integration
M	Mega (10^6)
m	Milli (10^{-3})
MPX	Multiplex
mV	Millivolt
mW	Milliwatt
n	Nano (10^{-9})
Ni-Cad	Nickel Cadmium
NR	Noise Reduction
NTSC	National Television Standards Committee
o/c	Open Circuit
o/p	Output
Op-Amp	Operational Amplifier
p	Pico (10^{-12})
PA	Power Amplifier or Public Address
PAL	Phase Alternate Line
PCB	Printed Circuit Board
pd	Potential Difference
PIL	Precision In Line
PIV	Peak Inverse Voltage
PLL	Phase Locked Loop
PROM	Programmable Read Only Memory
Ptot	Total Power Dissipation
PU	Pick Up
PUJT	Programmable Unijunction Transistor
Q	Factor of Tuned Circuit
R	Resistance
RAM	Random Access Memory
ROM	Read Only Memory
RF	Radio Frequency
RFC	Radio Frequency Choke
RMS	Root Mean Square
RTL	Resistor Transistor Logic
RX	Receiver
s	Source (FET)
s/c	Short Circuit
SCR	Silicon Controlled Rectifier
SHF	Super High Frequency
SPDT	Single Pole Double Throw
SPST	Single Pole Single Throw
SSB	Single Side Band
SSI	Small Scale Integration
SWG	Standard Wire Gauge
SWL	Short Wave Listener
SWR	Standing Wave Ratio
TRF	Tuned Radio Frequency
TTL	Transistor Transistor Logic
TVI	Television Interference
Tx	Transmitter
uF	Micro Farad
UHF	Ultra High Frequency
UJT	Unijunction Transistor
V	Volt
VA	Volt Amperes
Vcc	Supply Voltage (TTL)
VCO	Voltage Controlled Oscillator
Vdd	Supply Voltage (CMOS)
VDR	Voltage Dependent Resistor
VDU	Video Display Unit
VHF	Very High Frequency
VLF	Very Low Frequency
VMOS	Vertical Metal Oxide Semiconductor
W	Watts
X	Reactance
Xtal	Crystal
Z	Impedance

COMPONENT CONVENTIONS

SUFFIXES 'k', 'm', 'M' etc after component values indicate a numerical multiplier or divider – thus

Multipliers

k = X 1000
M = X 1000 000
G = X 1000 000 000
T = X 1000 000 000 000

Dividers

m = ÷ 1000
u = ÷ 1000 000
n = ÷ 1000 000 000
p = ÷ 1000 000 000 000

Where the numerical value includes a decimal point the traditional way of showing it was, for example, 4.7k. Experience showed that printing errors occurred due to accidental marks being mistaken for decimal points. The Standard now calls for the ex-suffix to be used in place of the decimal point. Thus a 4.7 k resistor is now shown as 4k7. A 2.2 uF capacitor is now shown as 2u2 etc.

Some confusion still exists with capacitor markings. Capacitors used to be marked with multiples or sub-multiples of microfarads – thus 0.001 uF, 470 uF etc. Markings are now generally in sub-multiples of a Farad. Thus –

1 microfad (1u) = 1×10^{-6}F
1 nanofarad (1n) = 1×10^{-12}F
1 picofarad (1p) = 1×10^{-12}F

0V on our circuits means the same as –ve (an abbreviation for 'negative').

Unless otherwise specified all components in our drawings are shown as seen from above – note however that component manufacturers often show them as seen looking *into* the pins.

Pin numbering of ICs – with the IC held so that the pins are facing away from you and with the small cut-out downwards pins are numbered anti-clockwise starting with pin number 1 at bottom right.

The thin line on a battery schematic drawing is positive – (+ve or just +).

If a circuit won't work the most probable causes of trouble in the most probable order of occurrence are:–

(a) Components inserted the wrong way round or in the wrong places.
(b) Faulty soldering.
(c) Bridges of solder between tracks (particularly with Veroboard) – breaks in Veroboard omitted – and/or whiskers of material bridging across Veroboard breaks.
(d) Faulty components.

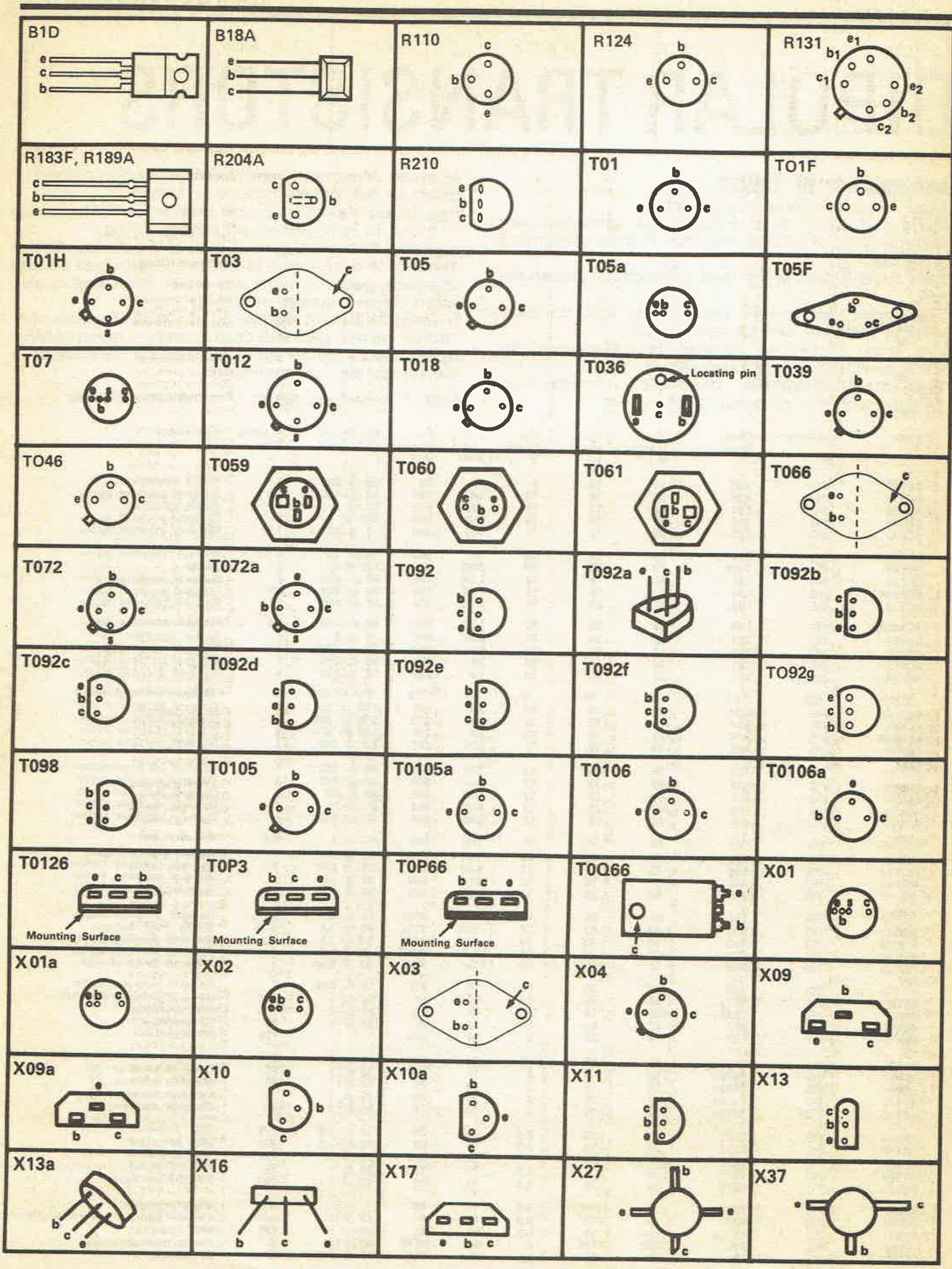
BIPOLAR TRANSISTORS

Explanation of Tables

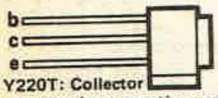
Type Manufacturer's code number.
Pol/Mat Polarity of transistor and semiconductor material used. N is NPN; P is PNP; G is germanium; S is silicon.
Case Style Refers to the lead connections shown below.
V_{CB} (max) Maximum permissible collector-base voltage with the emitter open-circuit.
V_{CE} (max) Maximum permissible collector-emitter voltage with the base open-circuit.
V_{EB} (max) Maximum permissible emitter-base voltage with the collector open-circuit.
I_C (max) Maximum permissible collector current – given in mA unless otherwise stated.
P_{TOT} (max) Maximum power dissipation of the device – given in mW unless otherwise stated.
h_{FE} (min) Minimum current gain of the device. As this depends to a large extent on the collector bias current at which measurements are made, the value is also listed (in mA unless otherwise stated).
f_T (min) Minimum frequency at which the common-emitter current gain will drop to unity – given in MHz.
Application A guide (although necessarily limited) to the typical device application.

Note: * = average value; ** = maximum value

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
AC107	PG	X01	15	15	5	10	80	35 @ 300	1	Audio amplifier
AC117	PG	X04	32	18	10	1A	1W	40 @ 150	0.5	General purpose audio
AC125	PG	T01	32	12	10	100	500	50 @ 2	1	Audio amplifier
AC126	PG	T01	32	12	10	100	500	100 @ 2	1	General purpose audio
AC127	NG	T01	32	12	10	500	340	50 @ 500	1.5	General purpose audio
AC128	PG	T01	32	16	10	1A	267	45 @ 1A	1	General purpose audio
AC132	PG	T01F	32	32	10	200	500	115 @ 50	2	Audio
AC141	NG	T01	32	18	10	1.2A	720	40 @ 400	1	General purpose audio
AC141K	NG	X04	32	18	10	1.2A	720	40 @ 400	0.5	General purpose audio
AC142	PG	T01	32	20	10	1.2A	720	40 @ 400	1	General purpose audio
AC142K	PG	X04	32	20	10	1.2A	860	40 @ 400	0.5	General purpose audio
AC151	PG	T01	32	24	10	200	900	30 @ 2	1	Audio amplifier
AC152	PG	T01	32	24	10	500	900	30 @ 100	1	General purpose audio
AC153	PG	T01	32	18	10	2A	1W	50 @ 300	1	General purpose audio
AC176	NG	T01	32	20	10	1A	220	52 @ 500	1	General purpose audio
AC187	NG	T01	25	15	10	2A	225	100 @ 300	1	General purpose audio
AC187K	NG	X04	25	15	10	2A	1W	100 @ 300	1	General purpose audio
AC188	PG	T01	25	15	10	2A	225	100 @ 300	1	General purpose audio
AC188K	PG	X04	25	15	10	2A	1W	100 @ 300	1	General purpose audio
ACY17	PG	T05	70	32	12	500	260	50 @ 300	1	General purpose audio
ACY18	PG	T05	50	30	12	500	260	40 @ 300	1	General purpose audio
ACY19	PG	T05	50	30	12	500	260	80 @ 300	1	General purpose audio
ACY20	PG	T05	40	20	12	500	260	50 @ 50	1	General purpose audio
ACY21	PG	T05	40	20	12	500	260	90 @ 50	1	General purpose audio
ACY22	PG	T05	20	15	12	500	260	30 @ 300	1	General purpose audio
ACY28	PG	T01	40	15	30	200	200	45 @ 1	0.8	RF amplifier
ACY39	PG	T05	110	40	25	500	260	50 @ 300	1	Audio, high voltage
ACY40	PG	T05	32	18	12	500	260	30 @ 300	1	General purpose audio
ACY41	PG	T05	21	18	12	500	260	50 @ 300	1	General purpose audio
ACY44	PG	T05	50	30	12	500	260	40 @ 300	1	General purpose audio
AD140	PG	T03	55	55	10	3A	35W	30 @ 1A	0.2	General purpose audio
AD142	PG	T03	80	50	10	10A	30W	30 @ 1A	0.45	Audio, high voltage
AD149	PG	T03	50	30	20	3.5A	27W	30 @ 1A	0.2	General purpose audio
AD150	PG	T03	32	30	10	3.5A	27W	30 @ 1A	0.45	General purpose audio
AD161	NG	X03	32	20	10	1A	4W	80 @ 500	1	General purpose audio
AD162	PG	X03	32	20	10	1A	6W	50 @ 500	1	General purpose audio
AF106	PG	T072	20	15	0.3	10	60	25 @ 1	100	General purpose FM/VHF
AF109	PG	T072	25	18	0.3	12	60	20 @ 2	100	VHF amplifier
AF114	PG	T07	32	15	2	10	75	50 @ 1	75	RF amplifier
AF118	PG	T07	70	20	2	30	375	–	125	RF amplifier
AF121	PG	T01H	25	25	–	10	140	30 @ 3	270	VHF amplifier
AF124	PG	T072a	32	15	2	10	75	50 @ 1	75	General purpose, RF
AF125	PG	T072a	32	15	2	10	75	50 @ 1	75	General purpose, RF
AF126	PG	T072a	32	15	2	10	75	50 @ 1	75	General purpose, RF
AF127	PG	T072a	32	15	2	10	75	50 @ 1	75	General purpose, RF
AF139	PG	T072	20	15	0.3	10	60	10 @ 1.5	275	UHF amplifier
AF178	PG	T072	20	15	0.3	10	60	10 @ 1.5	275	UHF amplifier
AF180	PG	T012	25	25	–	25	156	10 @ 14	150	VHF amplifier
AF186	PG	T012	25	–	0.5	15	100	20 @ 1	50	FM/VHF/general purpose
AF239	PG	T072	15	15	0.3	10	60	10 @ 2	400	TV/UHF oscillator
AF240	PG	T072	–	15	0.3	10	60	–	650	High frequency
AF279	PG	X37	15	15	0.3	10	60	10 @ 2	400	TV/UHF gain controlled amplifier
AFZ11	PG	T072a	20	10	0.5	10	83	20 @ 1	135	VHF amplifier
AL102	PG	T03	130	130	2	6A	30W	40 @ 1A	4	Audio, medium power
ASY26	PG	T05	30	15	20	200	150	30 @ 100	4	RF switch


B1D
B18A
R110
R124
R131
R183F, R189A
R204A
R210
T01
T01F
T01H
T03
T05
T05a
T05F
T07
T012
T018
T036
Locating pin
T039
T046
T059
T060
T061
T066
T072
T072a
T092
T092a
T092b
T092c
T092d
T092e
T092f
TO92g
T098
T0105
T0105a
T0106
T0106a
T0126
Mounting Surface
T0P3
Mounting Surface
T0P66
Mounting Surface
T0Q66
X01
X01a
X02
X03
X04
X09
X09a
X10
X10a
X11
X13
X13a
X16
X17
X27
X37

Y220



X59/S14

Notes:

S= Shield (Case)

Transistors are seen from below

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
ASY27	PG	T05	25	15	20	200	150	30 @ 100	6	RF switch
ASY50	PG	T01	20	10	20	200	200	15 @ 5	0.4	RF amplifier
ASY76	PG	T05	40	32	10	500	260	26 @ 300	1	General purpose audio
ASZ21	PG	T018	20	15	–	50	120	30 @ 10	300	VHF switch
AU110	PG	T03	160	160	2	10A	30W	20 @ 1A	–	Audio/switching
AU113	PG	T03	–	250	3	10A	5W	15 @ 6A	–	Switching
BC107	NS	T018	50	45	6	100	300	125 @ 2	300	General purpose
BC107A	NS	T018	50	45	6	100	300	220* @ 2	300	General purpose
BC107B	NS	T018	50	45	6	100	300	330* @ 2	300	General purpose
BC107C	NS	T018	50	45	6	100	300	450 @ 2	150	
BC108	NS	T018	30	20	5	100	300	125 @ 2	300	General purpose
BC108A	NS	T018	30	20	5	100	300	220* @ 2	300	General purpose
BC108B	NS	T018	30	20	5	100	300	330* @ 2	300	General purpose
BC108C	NS	T018	30	20	5	100	300	600* @ 2	300	General purpose
BC10 9	NS	T018	30	20	5	100	300	180 @ 2	150	Audio, low noise
BC109B	NS	T018	30	20	5	100	300	200 @ 2	150	Audio, low noise
BC109C	NS	T018	30	20	5	100	300	420 @ 2	150	Audio, low noise
BC113	NS	T0106	30	25	6	50	200	200 @ 1	60	Audio, low noise
BC114	NS	T0106	30	25	6	50	200	200 @ 1	60	Audio, low noise
BC115	NS	T0105	40	30	5	100	300	80 @ 10	40	General purpose audio
BC116	PS	T0105	45	40	5	100	300	35 @ 10	130	General purpose audio
BC117	NS	T0105	120	120	5	50	300	30 @ 30	60	Audio, high voltage
BC118	NS	T0106	45	45	4	100	200	50 @ 5	200	General purpose audio
BC119	NS	T039	60	30	5	1A	800	40 @ 150	40	General purpose audio
BC123	NS	X16	45	30	5	50	90	25 @ 250μA	20	Audio, low noise
BC132	NS	T0106	30	25	6	200	200	60 @ 10	40	General purpose audio
BC134	NS	T0106	45	45	4	200	200	150 @ 10	200	General purpose audio
BC135	NS	T0106	45	45	5	200	200	50 @ 10	200	General purpose audio
BC136	NS	T0105a	60	40	5	100	300	40 @ 10	60	General purpose audio
BC137	PS	T0105	40	40	4	600	300	40 @ 10	60	General purpose audio
BC139	PS	T039	40	40	5	500	700	40 @ 100	100	General purpose audio
BC140	NS	T039	80	40	7	1A	3.7W	40 @ 100	50	General purpose audio
BC141	NS	T039	100	60	7	1A	3.7W	40 @ 100	50	General purpose audio
BC142	NS	T039	80	60	5	1A	800	20 @ 200	40	General purpose audio
BC143	PS	T039	60	60	5	1A	800	20 @ 300	100	General purpose audio
BC147	NS	X09	50	45	6	100	350	125 @ 2	300	General purpose
BC147A	NS	X09	50	45	6	100	350	220 @ 2	300	General purpose
BC147B	NS	X09	50	45	6	100	350	330 @ 2	300	General purpose
BC148	NS	X09	50	45	5	100	350	125 @ 2	300	General purpose
BC148A	NS	X09	50	45	5	100	350	220* @ 2	300	General purpose
BC148B	NS	X09	50	45	5	100	350	330* @ 2	300	General purpose
BC148C	NS	X09	50	45	5	100	350	600* @ 2	300	General purpose
BC149	NS	X09	30	20	5	200	250	200 @ 2	150	Audio, low noise
BC149B	NS	X09	30	20	5	200	250	200 @ 2	150	Audio, low noise
BC149C	NS	X09	30	20	5	200	250	420 @ 2	150	Audio, low noise
BC153	NS	T0106	40	40	5	100	200	50 @ 10	40	General purpose audio
BC154	NS	T0106	40	40	5	100	200	160 @ 10	40	Audio, low noise
BC157	PS	X09	50	45	5	100	300	70 @ 2	130	Audio amplifier
BC158	PS	X09	30	25	5	100	300	70 @ 2	100	Audio amplifier
BC158A	PS	X09	30	25	5	100	350	125 @ 2	150	General purpose
BC158B	PS	X09	30	25	5	100	350	240* @ 2	150	General purpose
BC159	PS	X09	25	20	5	100	300	120 @ 2	100	Audio, low noise
BC160	PS	T039	40	40	5	1A	3.2W	40 @ 100	50	General purpose audio
BC161	PS	T039	60	60	5	1A	3.2W	40 @ 100	50	General purpose audio
BC167	NS	T092	50	45	5	100	300	330* @ 2	300*	General purpose
BC167A	NS	T092	45	45	6	100	300	120 @ 2	85	General purpose audio
BC168	NS	T092	30	20	5	100	300	330* @ 2	300*	General purpose
BC168B	NS	T092	30	20	5	100	300	290* @ 2	250*	General purpose
BC168C	NS	T092	30	20	5	100	300	520* @ 2	250*	General purpose
BC169	NS	T092	30	20	5	100	300	330* @ 2	300*	General purpose
BC169B	NS	T092	30	20	5	100	300	290* @ 2	300*	General purpose
BC169C	NS	T092	30	20	5	100	300	520* @ 2	300*	General purpose
BC170	NS	X10	20	20	5	100	300	35 @ 1	60	General purpose audio
BC171	NS	X10	45	45	6	100	300	125 @ 2	100	Audio, low noise
BC172	NS	X10	25	25	5	100	300	125 @ 2	100	General purpose audio
BC173	NS	X10	25	25	5	100	300	125 @ 2	150	Audio, low noise
BC177	PS	T018	45	45	5	100	300	70 @ 2	130	General purpose audio
BC177A	PS	T018	50	45	5	100	300	180* @ 2	200	General purpose
BC177B	PS	T018	50	45	5	100	300	290* @ 2	200*	General purpose
BC178	PS	T018	20	20	5	100	300	240 @ 2	200*	General purpose
BC178A	PS	T018	30	25	5	100	300	180* @ 2	200	General purpose
BC178B	PS	T018	30	25	5	100	300	290* @ 2	200	General purpose
BC179	PS	T018	20	20	5	100	300	240 @ 2	200*	General purpose
BC179A	PS	T018	25	20	5	100	300	125 @ 2	150*	General purpose
BC179B	PS	T018	25	20	5	100	300	290* @ 2	200*	General purpose

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
BC179C	PS	T018	25	20	5	50	300	500* @ 2	130*	General purpose
BC181	PS	X10a	40	25	5	200	300	60 @ 2	100	General purpose audio
BC182	NS	X10	60	50	5	20	300	120 @ 2	150	General purpose audio
BC182	PN	X10	60	50	5	200	300	500** @ 2	150	General purpose
BC182A	PN	X10/T092g	60	50	5	200	300	170* @ 2	150	General purpose
BC182B	PN	X10/T092g	60	50	5	200	300	500** @ 2	150	General purpose
BC182L	PN	T092	60	50	5	200	300	500** @ 2	150	Audio, low noise
BC182LA	PN	T092	60	50	5	200	300	260** @ 2	150	Audio, low noise
BC182LB	PN	T092	60	50	5	200	300	500** @ 2	150	Audio, low noise
BC183	NS	X10	45	30	5.0	200	300	900** @ 2.0	150	General purpose
BC183A	NS	X10	45	30	5.0	200	300	260** @ 2.0	150	General purpose
BC183B	NS	X10	45	30	5.0	200	300	500** @ 2.0	150	General purpose
BC183C	NS	X10	45	30	5.0	200	300	900** @ 2.0	150	General purpose
BC183L	NS	T092	45	30	5.0	200	300	900** @ 2.0	150	Audio, low noise
BC183LA	NS	T092	45	30	5.0	200	300	260** @ 2.0	150	Audio, low noise
BC183LB	NS	T092	45	30	5.0	200	300	500** @ 2.0	150	Audio, low noise
BC183LC	NS	T092	45	30	5.0	200	300	900** @ 2.0	150	Audio, low noise
BC184	NS	X10	45	30	5.0	200	300	900** @ 2.0	150	General purpose
BC184B	NS	X10	45	30	5.0	200	300	500** @ 2.0	150	General purpose
BC184C	NS	X10	45	30	5.0	200	300	450 @ 2.0	150*	General purpose
BC184K	NS	X10	45	30	5	200	300	240 @ 2	150	Audio, low noise
BC184L	NS	T092	45	30	5.0	200	300	900** @ 2.0	150	Audio, low noise
BC184LB	NS	T092	45	30	5.0	200	300	500** @ 2.0	150	Audio, low noise
BC184LC	NS	T092	45	30	5.0	200	300	900** @ 2.0	150	Audio, low noise
BC186	PS	T018	40	25	5	100	300	40 @ 2	50	Audio amplifier
BC187	PS	T018	30	25	5	100	300	100 @ 2	50	Audio amplifier
BC204	PS	R110	50	45	5.0	100	200	50 @ 2.0	160*	General purpose audio
BC205	PS	T0106	20	20	5	100	300	75 @ 2	100	General purpose audio
BC209C	NS	R110	25	20	5.0	100	200	550* @ 2.0	200*	Audio input stage
BC212	PS	X10	60	50	5.0	200	300	100 @ 2.0	200	General purpose
BC212A	PS	X10	60	50	5.0	200	300	300** @ 2.0	200	General purpose
BC212B	PS	X10	60	50	5.0	200	300	400** @ 2.0	200	General purpose
BC212L	PS	T092	60	50	5.0	200	300	100 @ 2.0	200	Audio, low noise
BC212LA	PS	T092	60	50	5.0	200	300	300** @ 2.0	200	Audio, low noise
BC212LB	PS	T092	60	50	5.0	200	300	400** @ 2.0	200	Audio, low noise
BC213	PS	X10	45	30	5.0	200	300	100 @ 2.0	200	General purpose
BC213A	PS	X10	45	30	5.0	200	300	300** @ 2.0	200	General purpose
BC213B	PS	X10	45	30	5.0	200	300	400** @ 2.0	200	General purpose
BC213C	PS	X10	45	30	5.0	200	300	600** @ 2.0	200	General purpose
BC213L	PS	T092	45	30	5.0	200	300	100 @ 2.0	200	Audio, low noise
BC213LA	PS	T092	45	30	5.0	200	300	300** @ 2.0	200	Audio, low noise
BC213LB	PS	T092	45	30	5.0	200	300	400** @ 2.0	200	Audio, low noise
BC213LC	PS	T092	45	30	5.0	200	300	600** @ 2.0	200	Audio, low noise
BC214	PS	X10	45	30	5.0	200	300	140 @ 2.0	200	General purpose
BC214B	PS	X10	45	30	5.0	200	300	400** @ 2.0	200	General purpose
BC214C	PS	X10	45	30	5.0	200	300	600** @ 2.0	200	General purpose
BC214L	PS	T092	45	30	5.0	200	300	140 @ 2.0	200	Audio, low noise
BC214LB	PS	T092	45	30	5.0	200	300	400** @ 2.0	200	Audio, low noise
BC214LC	PS	T092	45	30	5.0	200	300	600** @ 2.0	200	Audio, low noise
BC237	NS	R210	50	45	5.0	100	350	120 @ 2.0	200*	General purpose
BC237A	NS	R210	50	45	5.0	100	350	220* @ 2.0	200*	General purpose
BC237B	NS	R210	50	45	5.0	100	350	330* @ 2.0	200*	General purpose
BC237C	NS	R210	50	45	5.0	100	350	600* @ 2.0	200*	General purpose
BC238	NS	R210	30	20	5.0	100	350	120 @ 2.0	240*	General purpose
BC238A	NS	R210	30	20	5.0	100	350	220* @ 2.0	240*	General purpose
BC238B	NS	R210	30	20	5.0	100	350	330* @ 2.0	240*	General purpose
BC238C	NS	R210	30	20	5.0	100	350	330 @ 2.0	240*	General purpose
BC239	NS	R204A	30	20	5.0	100	300	240 @ 2.0	300	Audio, low noise
BC239A	NS	T092	30	20	5.0	100	300	200 @ 2.0	300	Audio, low noise
BC239B	NS	R204A	30	20	5.0	100	300	450** @ 2.0	300	Audio, low noise
BC239C	NS	R204A	30	20	5.0	100	300	800** @ 2.0	300	Audio, low noise
BC250	PS	X10	20	20	5	100	300	35 @ 1	100	General purpose audio
BC251	PS	T092a	45	45	5	100	300	125 @ 1	100	General purpose audio
BC253	PS	T092a	20	20	5	100	300	125 @ 2	80	General purpose audio
BC256	PS	T092a	64	64	5	100	300	125 @ 2	100	General purpose audio
BC258	PS	T092	25	25	5	100	300	70 @ 2	130	General purpose audio
BC260	PS	T018	20	20	5	100	300	35 @ 1	100	Audio amplifier
BC261	PS	T018	45	45	5	100	300	125 @ 2	100	Audio amplifier
BC262	PS	T018	25	25	5	100	300	125 @ 2	100	Audio amplifier
BC266	PS	T018	64	64	5	100	300	125 @ 2	200	Audio amplifier
BC266A	PS	T018	64	64	5	100	300	125 @ 2	200	Audio amplifier
BC266B	PS	T018	64	64	5	100	300	240 @ 2	200	Audio amplifier
BC300	NS	T039	130	130	7.0	1.0A	7.0W	40 @ 150	120*	Audio driver
BC301	NS	T039	90	60	7	1A	850	40 @ 150	60	General purpose audio
BC301/5	NS	T039	90	60	6.0	500	850	70 @ 150	120*	Medium power audio
BC302	NS	T039	80	45	7	1A	850	40 @ 150	60	General purpose audio
BC303	PS	T039	90	65	7	1A	850	40 @ 150	40	General purpose audio
BC303/5	PS	T039	85	60	5.0	500	850	70 @ 150	75*	Medium power audio
BC304	PS	T039	80	45	7	1A	850	40 @ 150	40	General purpose audio
BC307B	PS	X10	50	45	5	100	300	240 @ 2	130	General purpose audio

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
BC308	PS	X10	30	25	5	100	300	75 @ 2	100	General purpose audio
BC309	PS	X10	25	20	5	100	300	125 @ 2	100	Audio, low noise
BC317	NS	T092b	50	45	6	150	310	110 @ 2	100	General purpose audio
BC318	NS	T092b	40	30	5	150	310	110 @ 2	100	General purpose audio
BC327	PS	X10	50	45	5	800	500	63 @ 100	60	General purpose audio
BC328	PS	X10	30	25	5	800	500	63 @ 100	60	General purpose audio
BC337	NS	X10	50	45	5	800	360	100 @ 100	60	General purpose audio
BC338	NS	X10	30	20	5	800	360	100 @ 100	60	General purpose audio
BC347	NS	T092b	50	45	5	100	300	40 @ 2	125	General purpose audio
BC350	PS	T092b	50	45	5	100	300	40 @ 2	125	General purpose audio
BC382	NS	X10	50	45	6	100	300	100 @ 2	150	General purpose audio
BC383	NS	X10	45	30	6	100	300	100 @ 2	150	General purpose audio
BC383C	NS	X10	45	30	6	100	450	450 @ 2	150	Audio, low noise
BC384	NS	X10	45	30	6	100	300	250 @ 2	150	Audio, low noise
BC384C	NS	X10	45	30	6	100	300	450 @ 2	150	Audio, low noise
BC414	NS	X10	50	45	5	100	300	180 @ 2	250	General purpose audio
BC415	PS	X10	45	35	5	100	300	120 @ 2	200	General purpose audio
BC416	PS	X10	50	45	5	100	300	120 @ 2	200	Audio, low noise
BC440	NS	T039	50	40	5.0	2.0A	10W	40 @ 500	50*	Medium power audio
BC441	NS	T039	75	60	5	2A	1W	40 @ 500	50	General purpose audio
BC447	NS	T092C	80	80	5	200	350	70 @ 10	100	Audio, high voltage
BC460	PS	T039	50	40	5.0	2.0A	10W	40 @ 500	50*	Medium power audio
BC461	PS	T039	75	60	5	2A	1W	40 @ 500	50	Audio, high voltage
BC516	PS	X10	40	30	10	400	625	30,000 @ 20	150	Darlington, audio
BC517	NS	X10	40	30	10	400	625	30,000 @ 20	120	Darlington, audio
BC547	NS	R189A	50	45	6.0	100	500	125 @ 2.0	300*	General purpose
BC547A	NS	R189A	50	45	6.0	100	500	220* @ 2.0	300*	General purpose
BC547B	NS	R189A	50	45	6.0	100	500	450** @ 2.0	300*	General purpose
BC548	NS	R189A	30	30	5.0	100	500	125 @ 2.0	300	General purpose
BC548A	NS	R189A	30	20	5.0	100	500	220** @ 2.0	300	General purpose
BC548B	NS	R189A	30	30	5.0	100	500	330* @ 2.0	300	General purpose
BC548C	NS	R189A	30	20	5.0	100	500	800** @ 2.0	300	General purpose
BC549	NS	R189A	30	30	5.0	100	500	240 @ 2.0	200*	General purpose
BC549B	NS	R189A	30	20	5.0	100	500	450** @ 2.0	300*	General purpose
BC549C	NS	R189A	30	20	5.0	100	500	800** @ 2.0	250*	General purpose
BC550	NS	R189A	50	45	5.0	100	500	240 @ 2.0	300*	General purpose
BC550C	NS	R183F	50	45	5.0	100	500	600* @ 2.0	250*	General purpose
BC557	NS	R189A	50	45	5.0	100	500	140* @ 2.0	150*	General purpose
BC557A	PS	R189A	50	45	5.0	100	500	180* @ 2.0	150*	General purpose
BC557B	PS	R183F	50	45	5.0	100	500	330* @ 2.0	150*	General purpose
BC558	PS	R189A	30	30	5.0	100	500	75 @ 2.0	150*	General purpose
BC558A	PS	R189A	30	30	5.0	100	500	180* @ 2.0	150*	General purpose
BC558B	PS	R189A	30	25	5.0	100	500	220 @ 2.0	150*	General purpose
BC558C	PS	R183F	30	30	5.0	100	500	600* @ 2.0	150*	General purpose
BC559	PS	R189A	30	30	5.0	100	500	125 @ 2.0	150*	General purpose
BC559B	PS	R189A	30	30	5.0	100	500	290* @ 2.0	150*	General purpose
BC559C	PS	R183F	30	30	5.0	100	500	600* @ 2.0	150*	General purpose
BC560	PS	T092F	50	45	5.0	200	500	125 @ 2.0	150*	General purpose
BC560C	PS	R183F	50	45	5.0	100	500	600* @ 2.0	150*	General purpose
BCY30	PS	T05	64	50	45	100	250	10 @ 20	0.25	Audio amplifier
BCY31A	PS	T05	64	64	45	100	600	15 @ 20	–	General purpose audio
BCY32A	PS	T05	64	64	32	100	600	20 @ 20	–	General purpose audio
BCY33A	PS	T05	32	32	32	100	600	10 @ 20	–	General purpose audio
BCY34	PS	T05	32	25	16	100	250	15 @ 20	0.25	Audio amplifier
BCY39	PS	T039	64	60	12	250	410	10 @ 150	0.45	Audio switch
BCY40	PS	T039	32	24	12	250	410	15 @ 150	0.85	Audio switch
BCY42	NS	T018	40	25	5	200	300	45 @ 10	100	General purpose audio
BCY43	NS	T018	40	25	5	200	300	75 @ 10	100	General purpose audio
BCY54	PS	T05	50	50	12	250	410	12 @ 150	0.45	Audio switch
BCY58	NS	T018	32	32	7	200	1W	120 @ 2	125	General purpose audio
BCY59	NS	T018	45	45	7	200	1W	120 @ 2	125	General purpose audio
BCY70	PS	T018	50	40	5	200	350	50 @ 10	250	General purpose audio
BCY71	PS	T018	45	45	5	200	350	100 @ 10	300	Audio, low noise
BCY72	PS	T018	25	25	5	200	350	50 @ 10	200	General purpose audio
BCY78	PS	T018	32	32	5	200	1W	120 @ 2	180	General purpose audio
BCY79	PS	T018	45	45	5	200	1W	120 @ 2	180	General purpose audio
BCZ11	PS	X02	25	25	20	50	250	25 @ 1	0.4	Audio amplifier
BD106A	NS	X03	36	36	5	2.5A	12W	50 @ 500	50	General purpose RF
BD112	NS	T03	80	60	5	12A	20W	50 @ 1A	30	General purpose audio
BD115	NS	T039	245	180	5	150	6W	22 @ 50	80	RF, high voltage
BD116	NS	T03	80	60	5	3A	10W	30 @ 1A	–	General purpose audio
BD121	NS	T03	60	35	6	5A	45W	30 @ 1A	60	General purpose audio
BD123	NS	T03	90	60	6	5A	45W	30 @ 1A	60	General purpose audio
BD124	NS	X03	70	45	–	2A	15W	35 @ 500	60	General purpose VHF
BD131	NS	T0126	70	45	6	3A	11W	40 @ 500	60	General purpose audio
BD132	PS	T0126	45	45	4	3A	11W	40 @ 500	60	General purpose audio
BD133	NS	T0126	90	60	6	3A	11W	40 @ 500	60	Audio, high voltage
BD135	NS	T0126	45	45	5	1A	12W	40 @ 150	50	General purpose audio
BD136	PS	T0126	45	45	5	1A	12W	40 @ 150	50	General purpose audio
BD137	NS	T0126	60	60	5	1A	12W	40 @ 150	50	General purpose audio

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
BD138	PS	T0126	60	60	5	1A	12W	40 @ 150	50	General purpose audio
BD139	NS	T0126	80	80	5	1A	12W	40 @ 150	50	Audio, high voltage
BD140	PS	T0126	80	80	5	1A	12W	40 @ 150	50	Audio, high voltage
BD144	NS	T03	400	400	5	250	8W	5 @ 5A	6	Audio, extra high voltage
BD153	NS	T0126	70	60	5	3A	25W	30 @ 1A	–	Audio, high voltage
BD158	NS	T0126	325	300	5	500	20W	30 @ 150	–	Audio, extra high voltage
BD160	NS	T03	250	–	–	5A	10W	5 @ 5A	–	TV line output
BD187	NS	T0126	55	45	5	4A	40W	40 @ 500	2	General purpose audio
BD201	NS	T0P66	60	45	5	8A	55W	30 @ 3A	3	General purpose audio
BD203	NS	T0P66	60	60	5	8A	55W	80 @ 2A	3	Audio, high voltage
BD204	PS	T0P66	60	60	5	8A	55W	30 @ 2A	3	Audio, high voltage
BD205	NS	T0P66	55	45	5	10A	90W	30 @ 2A	1.5	General purpose audio
BD206	PS	T0P66	55	45	5	10A	90W	30 @ 2A	1.5	General purpose audio
BD222	NS	T0P66	–	60	–	4A	36W	20 @ 1.5A	0.8	General purpose audio
BD232	NS	T0126	500	300	5	250	11W	25 @ 50	10	Audio, extra high voltage
BD235	NS	T0126	60	60	5	2A	25W	25 @ 1A	3	General purpose audio
BD236	PS	T0126	60	60	5	2A	25W	25 @ 1A	3	General purpose audio
BD237	NS	T0126	100	80	5	2A	25W	40 @ 150	3	Audio, medium power
BD238	PS	T0126	100	80	5	2A	25W	40 @ 150	3	Audio, medium power
BD239A	NS	T0P66	70	60	5	2A	30W	15 @ 1A	3	General purpose audio
BD239C	NS	T0P66	115	100	5	2A	30W	15 @ 1A	3	General purpose audio
BD240A	PS	T0P66	70	60	5	2A	30W	15 @ 1A	3	General purpose audio
BD240C	PS	T0P66	115	100	5	2A	30W	15 @ 1A	3	General purpose audio
BD241A	NS	B18	70	60	5	2A	40W	20 @ 1.0A	3	Audio, medium power
BD241C	NS	B18	115	100	5	3A	40W	20 @ 1.0A	3	Audio, medium power
BD242A	PS	T0P66	70	60	5	3A	40W	25 @ 1A	3	General purpose audio
BD242C	PS	T0P66	115	100	5	3A	40W	25 @ 1A	3	General purpose audio
BD243A	NS	T0P66	70	60	5	6A	65W	30 @ 300	3	General purpose audio
BD244A	PS	T0P66	70	60	5	6A	65W	30 @ 300	3	General purpose audio
BD244C	PS	T0P66	115	100	5	6A	65W	30 @ 300	3	General purpose audio
BD245	NS	TOP3	50	45	5	10A	80W	25 @ 1A	3	Audio power
BD245A	NS	TOP3	70	60	5	10A	80W	25 @ 1A	3	Audio power
BD245C	NS	TOP3	115	100	5	10A	80W	25 @ 1A	3	Audio power
BD246A	PS	T0P3	70	60	5	15A	80W	40 @ 1A	–	General purpose audio
BD246C	PS	T0P3	115	100	5	15A	80W	40 @ 1A	–	General purpose audio
BD249A	NS	TOP3	70	60	5	25A	125W	20 @ 5A	3	Audio power
BD249C	NS	TOP3	115	100	5	25A	125W	20 @ 5A	3	Audio power
BD250A	PS	T0P3	70	60	5	40A	125W	25 @ 1.5A	–	General purpose audio
BD250C	PS	T0P3	115	100	5	40A	125W	25 @ 1.5A	–	General purpose audio
BD378	PS	T0126	75	60	5	2A	25W	30 @ 500	–	Audio power amplifier
BD434	PS	T0126	22	22	5	4A	36W	50 @ 2A	3	General purpose audio
BD437	NS	T0126	45	45	5	4A	36W	40 @ 2A	3	General purpose audio
BD438	PS	T0126	45	45	5	4A	36W	30 @ 10	3	Audio, medium power
BD439	NS	T0126	60	60	5	4A	36W	20 @ 10	3	Audio, medium power
BD440	PS	T0126	60	60	5	4A	36W	20 @ 10	3	Audio, medium power
BD441	NS	T0126	80	80	5	4A	36W	15 @ 2A	3	Audio, high voltage
BD442	PS	T0126	80	80	5	4A	36W	15 @ 10	3	Audio, medium power
BD529	NS	B18A	100	100	4	2A	1W	60 @ 50	100	Switching
BD530	PS	B18A	100	100	4	2A	1W	60 @ 50	100	Switching
BD535	NS	T0P66	60	60	5	4A	40W	40 @ 500	3	General purpose audio
BD536	PS	T0P66	60	60	5	4A	40W	40 @ 500	3	General purpose audio
BD537	NS	T0P66	80	80	5	4A	40W	40 @ 500	3	General purpose audio
BD538	PS	T0P66	80	80	5	4A	40W	40 @ 500	3	General purpose audio
BD539	NS	TOP66	40	40	5	5A	45W	30 @ 1A	3	Audio power
BD539C	NS	TOP66	100	100	5	5A	45W	30 @ 1A	3	Audio power
BD540	PS	TOP66	40	40	5	5A	45W	30 @ 1A	3	Audio power
BD540C	PS	TOP66	100	100	5	5A	45W	30 @ 1A	3	Audio power
BD675	NS	T0126	45	45	5	4A	40W	750 @ 2A	1	Darlington, audio
BD676	PS	T0126	45	45	5	4A	40W	750 @ 2A	1	Darlington, audio
BD677	NS	T0126	60	60	5	4A	40W	500* @ 4A	1	Darlington
BD695A	NS	T0P66	45	45	5	8A	70W	750 @ 4A	–	Darlington, audio
BD696A	PS	T0P66	45	45	5	8A	70W	750 @ 4A	–	Darlington, audio
BD711	NS	Y220	100	100	5	12A	75W	15 @ 4A	3	Audio power
BD712	PS	Y220	100	100	5	12A	75W	15 @ 4A	–	Audio power
BDX14	PS	T066	90	55	7	4A	29W	25 @ 500	0.8	Audio power
BDX18	PS	T03	100	60	7	15A	117W	20 @ 4A	4	Audio, high voltage
BDX32	NS	T03	1700	1700	–	4A	40W	2 @ 3.5A	–	RF, extra high voltage
BDY17	NS	T03	80	60	7	15A	115W	10 @ 10A	1	General purpose audio
BDY18	NS	T03	120	70	7	15A	115W	10 @ 10A	1	Audio, high voltage
BDY24	NS	T03	100	90	10	6A	87W	15 @ 2A	10	RF, high voltage
BDY25	NS	T03	200	140	10	6A	87W	15 @ 2A	10	RF, extra high voltage
BDY38	NS	T03	50	40	–	6A	115W	30 @ 2A	0.5	General purpose audio
BDY54	NS	T03	180	120	7	12A	60W	20 @ 2A	10	RF, extra high voltage
BDY55	NS	T03	100	60	7	15A	115W	20 @ 4A	10	RF, high voltage
BDY56	NS	T03	150	120	7	15A	115W	20 @ 4A	10	RF, high voltage
BDY57	NS	T03	120	80	10	25A	175W	20 @ 10A	10	RF, high voltage
BDY60	NS	T03	120	60	5	10A	30W	45 @ 500	30	General purpose RF
BDY61	NS	T03	100	60	5	10A	30W	45 @ 500	30	General purpose RF
BDY62	NS	T03	60	30	5	10A	30W	45 @ 500	30	General purpose RF
BDY92	NS	T03	80	60	6	15A	40W	30 @ 5A	35	RF, high voltage

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
BF115	NS	T072a	50	30	5	30	145	45 @ 1	115	FM/AM radio, general purpose
BF118	NS	T05	250	250	5	100	800	25 @ 30	60	Audio, extra high voltage
BF153	NS	T0106	30	12	2	25	200	20 @ 3	300	FM/AM radio, general purpose
BF154	NS	T0106	30	20	4	50	300	25 @ 10	200	TV IF amplifier, gain controlled
BF157	NS	T039	150	150	5	100	800	30 @ 30	30	TV video, extra high voltage
BF158	NS	T0106	30	12	2	50	200	20 @ 4	600	TV IF amplifier
BF160	NS	T0106	30	12	2	50	200	20 @ 3	400	FM/AM radio, general purpose
BF161	NS	T072	50	50	4	20	175	20 @ 3	400	TV, VHF oscillator
BF166	NS	T072	40	40	3	25	175	20 @ 2	400	FM/VHF general purpose
BF167	NS	T072a	40	30	4	25	150	30 @ 4	300	TV IF amplifier, gain controlled
BF170	NS	T05	160	160	–	50	300	15 @ 2	50	TV video, extra high voltage
BF173	NS	T072a	40	25	4	25	260	40 @ 7	350	TV IF amplifier
BF177	NS	T039	100	60	5	50	600	20 @ 10	60	TV video output
BF178	NS	T039	185	115	5	50	600	20 @ 15	60	TV video output
BF179	NS	T039	250	115	5	50	600	20 @ 20	60	TV video output, high voltage
BF180	NS	T072	30	20	3	20	150	13 @ 2	335	TV UHF amplifier, gain controlled
BF181	NS	T072	30	20	3	20	150	13 @ 2	300	TV UHF oscillator
BF182	NS	T072	25	20	3	15	150	10 @ 2	325	TV UHF mixer
BF183	NS	T072	25	20	3	15	150	10 @ 3	400	TV UHF oscillator
BF184	NS	T072a	30	20	5	30	145	75 @ 1	150	FM/AM, general purpose high gain
BF185	NS	T072a	30	20	5	30	145	34 @ 1	110	FM/AM, general purpose medium gain
BF194	NS	X09a	30	20	5	30	250	67 @ 1	130	FM/AM, general purpose high gain
BF195	NS	X09a	30	20	5	30	250	36 @ 1	100	FM/AM, general purpose medium gain
BF196	NS	X09a	40	30	4	25	250	27 @ 4	200	TV IF amplifier, gain controlled
BF197	NS	X09a	40	20	4	25	250	38 @ 7	275	TV IF amplifier
BF198	NS	X10b	40	30	4	25	250	27 @ 4	200	TV IF amplifier, gain controlled
BF199	NS	X10b	40	20	4	25	250	38 @ 7	275	TV IF amplifier
BF200	NS	T072	30	20	3	20	150	15 @ 2	325	FM/VHF general purpose
BF224	NS	X10a	45	30	4	50	360	30 @ 7	300	TV IF amplifier
BF224A	NS	X10	45	30	4	50	360	–	300	TV IF amplifier
BF232	NS	T072a	25	25	4	30	270	30 @ 7	300	TV IF amplifier
BF240B	NS	X13	40	40	–	25	250	110 @ 1	225	RF amplifier
BF250	NS	T018	15	15	3	600	400	75 @ 100μA	20	General purpose RF
BF251	NS	T072a	30	30	4	25	150	30 @ 4	300	TV IF amplifier, gain controlled
BF253	NS	X10a	30	25	–	35	280	50 @ 1	75	RF amplifier
BF254	NS	X10a	30	20	5	30	300	67 @ 1	130	FM/AM, general purpose high gain
BF255	NS	X10a	30	20	5	30	300	36 @ 1	100	FM/AM, general purpose medium gain
BF257	NS	T039	160	160	5	100	500	25 @ 30	55	TV video output, medium voltage
BF258	NS	T039	250	250	5	100	800	25 @ 30	55	TV video output, high voltage
BF259	NS	T039	300	300	5	100	500	25 @ 30	90	VHF, extra high voltage
BF271	NS	T072	30	30	4	50	250	30 @ 10	450	TV IF amplifier
BF274	NS	T0106a	25	25	4	50	200	70 @ 1	400	TV IF amplifier
BF324	PS	X10	30	30	4	25	250	25 @ 4	350	General purpose FM/VHF
BF336	NS	T039	185	180	5	100	800	20 @ 30	80	TV video output, high voltage
BF337	NS	T039	300	225	–	100	800	20 @ 30	80	TV video output, extra high voltage
BF338	NS	T039	250	200	–	100	800	20 @ 30	80	TV video output, high voltage
BF355	NS	T039	300	225	5	100	800	16 @ 160	–	TV video output, high voltage
BF394	NS	T092d	30	30	4	50	310	65 @ 1	80	FM/AM, general purpose high gain
BF451	PS	X10a	40	40	4	25	150	30 @ 1	325	TV IF amplifier
BF457	NS	T0126	160	160	5	100	6W	26 @ 30	40	RF, extra high voltage
BF458	NS	T0126	250	250	5	100	6W	26 @ 30	40	RF, extra high voltage
BF459	NS	T0126	300	300	5	100	6W	26 @ 30	40	RF, extra high voltage
BF594	NS	T092e	30	20	5	30	250	65 @ 1	130	FM/AM, general purpose high gain
BF595	NS	T092e	30	20	5	30	250	35 @ 1	130	FM/AM, general purpose medium gain
BF597	NS	T092e	40	25	4	30	360	38 @ 7	275	TV IF amplifier
BFR39	NS	T092	90	80	–	2A	800	50 @ 100	100	Audio, high voltage
BFR40	NS	T092	70	60	–	2A	800	75 @ 100	100	General purpose audio
BFR41	NS	T092	60	50	5	1A	800	100 @ 100	100	General purpose audio
BFR79	PS	T092	90	80	–	2A	800	50 @ 100	100	Audio, high voltage
BFR80	PS	T092f	70	50	–	2A	800	75 @ 100	100	General purpose audio
BFR81	PS	T092	60	50	–	2A	800	100 @ 100	100	General purpose audio
BFR98	NS	T039	40	20	3.5	360	3.5W	10 @ 100	500	General purpose UHF
BFX29	PS	T05	60	60	5	600	600	50 @ 10	100	General purpose RF
BFX30	**PS**	**T05b**	**65**	**65**	**5**	**600**	**500**	**50 @ 10**	–	**General purpose/switching**
BFX81	PS	T05	25	20	10	500	30	–	–	General purpose
BFX84	NS	T05	100	60	6	1A	800	30 @ 150	50	General purpose audio
BFX85	NS	T05	100	60	6	1A	800	70 @ 150	50	Audio, high voltage
BFX86	NS	T05	40	35	6	1A	800	70 @ 150	50	General purpose audio
BFX87	PS	T05	50	50	5	600	600	40 @ 10	100	General purpose audio
BFX88	PS	T05	40	40	5	600	600	40 @ 10	100	General purpose audio
BFY18	NS	T018	60	40	3	100	300	30 @ 10	200	General purpose RF
BFY41	NS	T05	100	60	7	500	500	50 @ 10	60	Audio, high voltage
BFY50	NS	T05	80	35	6	1A	800	30 @ 150	60	General purpose audio
BFY51	NS	T05	60	30	6	1A	800	40 @ 150	50	General purpose audio
BFY52	NS	T05	40	20	6	1A	800	60 @ 150	50	General purpose audio
BFY53	NS	T05	40	20	6	1A	800	30 @ 150	50	General purpose audio
BFY55	NS	T05	80	35	7	1A	800	40 @ 150	60	General purpose audio
BFY56	NS	T039	80	55	7	1A	800	30 @ 150	40	General purpose audio
BFY64	PS	T05	40	40	5	–	700	80 @ 10	200	General purpose RF
BFY80	NS	T018	100	80	7	100	865	30 @ 2	50	Audio, high voltage

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_c (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_c (mA)	f_T (min) MHz	Application
BFY90	NS	T072	30	15	2	20	200	25 @ 2	1000	UHF amplifier
BFY90B	NS	T072	28	15	2.5	20	100	20 @ 3	1000	UHF amplifier
BSX19	NS	T018	40	15	5	500	360	20 @ 10	400	UHF switch
BSX20	NS	T018	40	15	5	500	360	40 @ 10	500	UHF switch
BSX26	NS	T018	40	15	4	200	360	30 @ 30	350	UHF switch
BSX29	PS	T018	12	12	4	200	360	30 @ 30	–	VHF switch
BSX78	NS	T018	40	20	5	100	300	80 @ 10	100	RF switch
BSY24	NS	T05	40	20	6	500	600	15 @ 20	40	General purpose audio
BSY25	NS	T05	40	20	6	500	600	30 @ 20	60	General purpose audio
BSY26	NS	T018	20	15	6	100	300	20 @ 10	200	RF switch
BSY28	NS	T018	15	12	3	100	300	20 @ 10	150	RF switch
BSY38	NS	T018	20	15	5	100	300	30 @ 10	300	VHF switch
BSY51	NS	T039	60	25	5	500	800	40 @ 150	100	General purpose audio
BSY52	NS	T039	60	25	5	500	800	100 @ 150	130	RF switch
BSY53	NS	T039	75	30	5	750	800	40 @ 150	100	RF switch
BSY54	NS	T039	75	30	7	750	800	100 @ 150	145	RF switch
BSY68	NS	T05	120	100	5	50	300	10 @ 10	20	Audio, extra high voltage
BSY78	NS	T018	80	64	7	250	300	80 @ 1	90	General purpose audio
BSY80	NS	T018	25	18	5	100	300	200 @ 1	100	Audio, low noise
BSY95A	NS	T018	20	15	5	200	300	50 @ 10	200	VHF switch
BU104	NS	T03	400	–	10	7A	85W	10 @ 5A	5	TV line output, high voltage
BU105	NS	T03	750	500	5	2.5A	10W	1 @ 2A	3	TV line output, extra high voltage
BU109	NS	T03	330	–	10	7A	85W	5 @ .5A	5	TV line output, high voltage
BU126	NS	T03	750	300	–	6A	30W	15 @ 1A	4	RF switch
BU204	NS	T03	1300	600	–	3A	10W	2 @ 2A	4	TV line output, extra high voltage
BU205	NS	T03	1500	700	–	3A	10W	2 @ 2A	4	TV line output, extra high voltage
BU206	NS	T03	1700	800	–	3A	10W	2 @ 2A	4	TV line output, extra high voltage
BU208	NS	T03	1500	700	–	7.5A	12W	2 @ 4.5A	3	TV line output, extra high voltage
BU326S	NS	T03	–	800	7	6A	60W	3.5 @ 4A	20	Line output
BU406	NS	Y220	400	200	6	7A	60W	10 @ 5A	10	High power switching
BU407	NS	Y220	330	150	6	7A	60W	10 @ 5A	10	High power switching
BU408	NS	Y220	400	200	6	7A	60W	5 @ 6A	10	High power switching
BU500	NS	T03	1k5	1k5	5	6A	75W	3 @ 4A5	–	Line output
BUV20	NS	T03	160	125	7	50A	250W	20 @ 20A	8	High power audio or switching
BUV21	NS	T03	250	200	7	40A	250W	20 @ 12A	8	High power audio or switching
BUX20	NS	T03	160	125	7	50A	250W	20 @ 20A	8	High power audio or switching
BUY47	NS	T039	150	160	6	7A	1W	40 @ 500	90	Switching
ME1120	NS	T0106	130	120	4	200	200	20 @ 10	30	Audio, high voltage
ME4101	NS	T0106	60	45	5	30	200	70 @ 1	150	Audio, low noise
ME4102	NS	T0106	60	45	5	30	200	200 @ 1	150	Audio, low noise
ME6002	NS	T0106	40	30	5	–	360	75 @ 50	200	General purpose RF
ME8001	NS	T0105	40	30	5	–	400	30 @ 150	100	General purpose audio
MJ400	NS	T066	350	325	5	1A	2.5W	30 @ 50	15	TV video output, extra high voltage
MJ480	NS	T03	40	40	5	4A	87W	10 @ 3A	4	Audio power amplifier
MJ481	NS	T03	60	60	5	4A	87W	10 @ 3A	4	Audio power amplifier
MJ490	PS	T03	40	40	5	4A	87W	10 @ 3A	4	Audio power amplifier
MJ491	PS	T03	60	60	5	4A	87W	10 @ 3A	4	Audio power amplifier
MJ802	NS	T03	100	90	4	30A	200W	25 @ 7.5A	2	Audio power amplifier
MJ900	PS	T03	60	60	5	8A	90W	1k @ 4A	–	Darlington
MJ901	PS	T03	80	80	5	8A	90W	750 @ 4A	–	Darlington, audio
MJ1000	NS	T03	60	60	5	8A	90W	1k @ 4A	–	Darlington
MJ1001	NS	T03	80	80	5	8A	90W	1k @ 4A	–	Darlington
MJ1800	NS	T03	–	250	5	5A	100W	40 @ 400	–	Audio power
MJ2500	PS	T03	60	60	5	10A	150W	1000 @ 5A	–	Darlington, audio
MJ2501	PS	T03	80	80	5	10A	150W	1000 @ 5A	–	Darlington, audio
MJ2955	PS	T03	100	60	7	15A	150W	5 @ 10A	4	General purpose audio
MJ3000	NS	T03	60	60	5	10A	150W	1000 @ 5A	–	Darlington, audio
MJ3001	NS	T03	80	80	5	10A	150W	1000 @ 5A	–	Darlington, audio
MJ3701	PS	T066	50	40	5	25A	25W	20 @ 250	3	Audio medium power
MJ4502	PS	T03	100	90	4	30A	200W	25 @ 7.5A	2	Audio power amplifier
MJ15003	NS	T03	140	140	5	20A	250W	25 @ 5A	2	Audio power
MJ15004	PS	T03	140	140	5	20A	250W	25 @ 5A	2	Audio power
MJ15015	NS	T03	200	120	7	15A	180W	10 @ 4A	0.8	Audio power
MJ15016	PS	T03	200	120	7	15A	180W	10 @ 4A	2.2	Audio power
MJE170	PS	T0126	40	40	7	3A	12W	50 @ 100	50	General purpose audio
MJE180	NS	T0126	40	40	–	3A	12W	50 @ 100	50	General purpose audio
MJE340	NS	T0126	300	300	3	500	20W	30 @ 50	10	Audio, extra high voltage
MJE350	PS	T0126	–	300	3	500	20W	30 @ 50	–	Audio medium power
MJE370	PS	T0126	30	30	4	3A	25W	25 @ 1A	–	General purpose audio
MJE371	PS	T0126	40	40	4	4A	40W	40 @ 1A	–	General purpose audio
MJE520	NS	T0126	30	30	4	3A	25W	25 @ 1A	–	General purpose audio
MJE521	NS	T0126	40	40	4	4A	40W	40 @ 1A	–	General purpose audio
MJE2955	PS	T0P66	70	60	5	10A	90W	20 @ 4A	2	Audio, high voltage
MJE3054	NS	T0P66	90	55	5	4A	40W	25 @ 500	1	Audio, high voltage
MJE3055	NS	T0P66	70	60	5	10A	90W	20 @ 4A	2	Audio, high voltage
MPS3638	PS	T092b	25	25	4	350	360	30 @ 50	100*	General purpose
MPS3638A	PS	T092b	25	25	4	500	310	100 @ 10	150	General purpose/switching
MPS3638A(GE)	PS	T092b	25	25	4	350	360	100 @ 50	100*	General purpose
MPSA05	NS	T096b	60	60	4	500	500	50 @ 10	100	General purpose audio
MPSA06	NS	T092b	80	80	4	500	500	50 @ 10	100	General purpose audio

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
MPSA10	NS	T092b	40	40	4	100	310	40 @ 5	50	General purpose audio
MPSA12	NS	T092b	20	20	10	300	310	20000 @ 10	125	Audio, low noise
MPSA13	PS	T092b	–	30	8	300	1W5	20k @ 100	15	Darlington
MPSA14	NS	T092b	30	30	10	300	310	10000 @ 10	125	Audio, low noise
MPSA16	NS	T092b	40	40	12	100	350	200 @ 5	100	General purpose audio
MPSA18	NS	T092b	45	45	6.5	200	350	1k1* @ 10	160	Pulsed operation
MPSA20	NS	T092g	–	40	4	100	1W	40 @ 5	125	Audio driver
MPSA42	NS	T092g	300	300	8	500	625	40 @ 30	50	General purpose
MPSA43	NS	T092g	200	200	6	500	625	50 @ 30	50	General purpose
MPSA55	PS	T092b	60	60	4	500	625	50 @ 10	50	General purpose audio
MPSA56	PS	T092b	80	80	4	500	625	50 @ 10	50	General purpose audio
MPSA65	PS	T092g	30	30	8	300	1W5	20k @ 100	175	Darlington
MPSA66	PS	T092g	30	30	8	300	1W5	30k @ 100	175	Darlington
MPSA70	PS	T092b	40	40	4	100	310	40 @ 5	125	General purpose audio
MPSA92	PS	T092b	300	300	5	500	625	25 @ 30	50	Audio, extra high voltage
MPSA93	PS	T092g	200	200	5	500	625	30 @ 30	50	General purpose
MPSL01	NS	–	140	120	5	150	625	30 @ 10	60	High-V, low power
MPSL51	PS	T092g	100	100	4	600	310	20 @ 1	60	General purpose
MPSU01	NS	X17	30	30	–	1.5A	8W	50 @ 1A	50	General purpose audio
MPSU02	NS	X17	60	40	5	800	6W	50 @ 150	150	General purpose audio
MPSU04	NS	B18A	180	180	5	1A	10W	40 @ 10	35	High-V switching
MPSU05	NS	X17	60	60	4	2A	10W	80 @ 50	75	General purpose audio
MPSU06	NS	X17	80	80	4	2A	10W	80 @ 50	75	General purpose audio
MPSU07	NS	X17	100	100	4	2A	10W	60 @ 50	75	Audio, high voltage
MPSU51	PS	X17	30	30	–	1.5A	8W	50 @ 1A	50	General purpose audio
MPSU52	PS	X17	60	40	5	800	6W	50 @ 50	150	General purpose audio
MPSU55	PS	X17	60	60	4	2A	1W	80 @ 50	50	Audio, high voltage
MPSU56	PS	X17	80	80	4	2A	1W	80 @ 50	50	Audio, high voltage
MPSU57	PS	X17	100	100	4	2A	1W	60 @ 50	50	Audio, high voltage
OC20	PG	T03	100	75	40	8A	30W	20 @ 6A	250k	Audio output
OC22	PG	T03	47	32	12	1A	15W	50 @ 1A	2.5	Audio output
OC23	PG	T03	55	24	12	1A	16W	50 @ 1A	2	General purpose RF
OC25	PG	T03	40	40	10	4A	23W	15 @ 1A	0.2	General purpose audio
OC26	PG	T03	32	32	–	3.5A	13W	20 @ 1A	0.2	General purpose audio
OC28	PG	T03	80	60	40	8A	30W	20 @ 1A	0.2	Audio, high voltage
OC35	PG	T03	60	32	20	8A	30W	25 @ 1A	0.2	General purpose audio
OC36	PG	T03	80	32	40	8A	30W	30 @ 1A	0.2	General purpose audio
OC41	PG	X01a	16	15	10	50	50	17 @ 50	4	RF switch
OC42	PG	X01a	16	15	10	50	50	35 @ 50	7	RF switch
OC44	PG	X01a	15	12	12	10	83	50 @ 1	8	RF switch
OC45	PG	X01a	15	15	12	10	83	25 @ 1	4	RF amplifier
OC46	PG	X01a	20	20	15	125	83	40 @ 3	2	RF amplifier
OC70	PG	X01a	20	20	10	10	125	15 @ 5	0.2	General purpose audio
OC71	PG	X01a	20	20	10	10	125	30 @ 5	0.3	General purpose audio
OC72	PG	X02	16	16	10	125	165	30 @ 80	0.25	General purpose audio
OC74	PG	X02	20	20	6	300	550	40 @ 50	0.1	General purpose audio
OC75	PG	X01a	20	20	10	10	125	55 @ 10	0.1	General purpose audio
OC76	PG	X02	32	32	10	125	125	30 @ 80	0.1	General purpose audio
OC77	PG	X02	60	60	10	250	125	45 @ 10	0.25	Audio, high voltage
OC81	PG	X02	32	10	3	200	600	50 @ 100	1	General purpose audio
OC82	PG	X02	16	16	6	200	600	15 @ 3	0.4	General purpose audio
OC83	PG	T01	32	20	3	500	600	40 @ 300	1	General purpose audio
OC84	PG	T01	32	20	3	500	600	50 @ 300	1	General purpose audio
OC170	PG	T07	20	20	1	10	80	75 @ 1	60	RF amplifier
OC171	PG	T07	20	20	1	10	80	75 @ 1	60	RF amplifier
OC200	PS	X02	30	25	20	100	250	15 @ 1	0.45	Audio amplifier
OC202	PS	X02	15	10	10	100	250	40 @ 1	1	Audio amplifier
OC204	PS	X02	32	32	12	250	300	10 @ 150	0.45	Audio amplifier
PN3643	NS	T092b	60	30	5	500	600	100 @ 150	250	General purpose
TIP29	NS	T0P66	40	40	5	1A	30W	40 @ 200	3	General purpose audio
TIP29A	NS	T0P66	60	60	5	1A	30W	40 @ 200	3	Audio, high voltage
TIP29B	NS	T0P66	80	80	5	1A	30W	40 @ 200	3	Audio, high voltage
TIP29C	NS	T0P66	100	100	5	1A	30W	40 @ 200	3	Audio, high voltage
TIP30	PS	T0P66	40	40	5	1A	30W	40 @ 200	3	General purpose audio
TIP30A	PS	T0P66	60	60	5	1A	30W	40 @ 200	3	General purpose audio
TIP30B	PS	T0P66	80	80	5	1A	30W	40 @ 200	3	Audio, high voltage
TIP30C	PS	T0P66	100	100	5	1A	30W	40 @ 200	3	Audio, high voltage
TIP31	NS	T0P66	40	40	5	3A	40W	20 @ 1A	3	General purpose audio
TIP31A	NS	T0P66	60	60	5	3A	40W	20 @ 1A	3	General purpose audio
TIP31B	NS	T0P66	80	80	5	3A	40W	20 @ 1A	3	Audio, high voltage
TIP31C	NS	T0P66	100	100	5	3A	40W	20 @ 1A	3	Audio, high voltage
TIP32	PS	T0P66	40	40	5	3A	40W	20 @ 1A	3	General purpose audio
TIP32A	PS	T0P66	60	60	5	3A	40W	20 @ 1A	3	General purpose audio
TIP32B	PS	T0P66	80	80	5	3A	40W	20 @ 1A	3	Audio, high voltage
TIP32C	PS	T0P66	100	100	5	3A	40W	20 @ 1A	3	Audio, high voltage
TIP33	NS	T0P3	40	40	5	10A	80W	20 @ 3A	3	General purpose audio
TIP33A	NS	T0P3	60	60	5	10A	80W	20 @ 3A	3	General purpose audio
TIP33B	NS	T0P3	80	80	5	10A	80W	20 @ 3A	3	Audio, high voltage
TIP33C	NS	T0P3	100	100	5	10A	80W	20 @ 3A	3	Audio, high voltage
TIP34	PS	T0P3	40	40	5	10A	80W	20 @ 3A	3	General purpose audio

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
TIP34A	PS	T0P3	60	60	5	10A	80W	20 @ 3A	3	General purpose audio
TIP34B	PS	T0P3	80	80	5	10A	80W	20 @ 3A	3	Audio, high voltage
TIP34C	PS	T0P3	100	100	5	10A	80W	20 @ 3A	3	Audio, high voltage
TIP35	NS	T0P3	40	40	5	25A	90W	10 @ 15A	3	General purpose audio
TIP35A	NS	T0P3	60	60	5	25A	90W	10 @ 15A	3	General purpose audio
TIP35B	NS	T0P3	80	80	5	25A	90W	10 @ 15A	3	Audio, high voltage
TIP35C	NS	T0P3	100	100	5	25A	90W	10 @ 15A	3	Audio, high voltage
TIP36	PS	T0P3	40	40	5	25A	90W	10 @ 15A	3	General purpose audio
TIP36A	PS	T0P3	60	60	5	25A	90W	10 @ 15A	3	General purpose audio
TIP36B	PS	T0P3	80	80	5	25A	90W	10 @ 15A	3	Audio, high voltage
TIP36C	PS	T0P3	100	100	5	25A	90W	10 @ 15A	3	Audio, high voltage
TIP41A	NS	T0P66	60	60	5	6A	2W	15 @ 3A	3	General purpose audio
TIP41B	NS	T0P66	80	80	5	6A	2W	15 @ 3A	3	Audio, high voltage
TIP41C	NS	T0P66	100	100	5	6A	2W	15 @ 3A	3	Audio, high voltage
TIP42A	PS	T0P66	60	60	5	6A	2W	15 @ 3A	3	General purpose audio
TIP42B	PS	T0P66	80	80	5	6A	2W	15 @ 3A	3	Audio, high voltage
TIP50	NS	TOP66	500	400	5	1A	2W	30 @ 300	10	High-V switching
TIP53	NS	TOP66	450	350	5	3A	3W5	30 @ 300	2.5	High-V switching
TIP54	NS	TOP66	500	400	5	3A	3W5	30 @ 300	2.5	High-V switching
TIP110	NS	Y220	80	80	5	2A	50W	500 @ 2A	–	Darlington/switching
TIP112	NS	Y220	100	100	5	2A	50W	500 @ 2A	–	Darlington/switching
TIP115	PS	Y220	60	60	5	2A	50W	500 @ 2A	–	Darlington/switching
TIP117	PS	Y220	100	100	5	2A	50W	500 @ 2A	–	Darlington/switching
TIP120	NS	T0P66	60	60	5	5A	60W	1000 @ 3A	–	Darlington, audio
TIP121	NS	T0P66	80	80	5	5A	60W	1000 @ 3A	–	Darlington, audio
TIP122	NS	T0P66	100	100	5	5A	60W	1000 @ 3A	–	Darlington, audio
TIP127	PS	TOP66	100	100	5	5A	100W	1k @ 3A	–	Darlington/switching
TIP132	NS	TOP66	100	100	5	8A	70W	1k @ 4A	–	Darlington/switching
TIP135	PS	TOP66	60	60	5	8A	70W	1k @ 4A	–	Darlington/switching
TIP137	PS	TOP66	100	100	5	8A	70W	1k @ 4A	–	Darlington/switching
TIP140	NS	TOP66	60	60	5	10A	125W	500 @ 10A	–	Darlington/switching
TIP141	NS	T0P3	80	80	5	10A	125W	500 @ 10A	–	Darlington, audio
TIP142	NS	T0P3	100	100	5	10A	125W	500 @ 10A	–	Darlington, audio
TIP145	PS	TOP66	60	60	5	10A	125W	500 @ 10A	–	Darlington/switching
TIP147	PS	T0P3	100	100	5	10A	125W	500 @ 10A	–	Darlington, audio
TIP2955	PS	T0P3	100	60	7	15A	90W	20 @ 4A	3	Audio, high voltage
TIP3055	NS	T0P3	100	70	7	15A	90W	20 @ 4A	3	Audio, high voltage
TIS44	NS	T092	25	–	3	50	250	20 @ 10	200	VHF switch
TIS45	NS	T092	40	15	5	200	250	30 @ 10	300	RF switch
TIS46	NS	T092	40	15	5	200	250	30 @ 10	300	RF switch
TIS48	NS	T092	40	15	4.5	200	250	40 @ 10	500	VHF switch
TIS49	NS	T092	40	15	4.5	200	250	40 @ 10	500	VHF switch
TIS50	PS	T092	12	12	4	200	250	40 @ 30	400	VHF switch
TIS60	NS	T092	40	25	5	400	300	100 @ 50	–	General purpose audio
TIS90	NS	T092	40	40	5	400	625	100 @ 50	–	General purpose audio
TIS91	PS	T092	40	40	5	400	625	100 @ 50	–	General purpose audio
TIS93	PS	X10	40	40	5	400	625	100 @ 50	–	General purpose audio
ZTX107	NS	X11	60	45	5	100	300	125 @ 2	150	General purpose audio
ZTX108	NS	X11	45	30	5	100	300	125 @ 2	150	General purpose audio
ZTX109	NS	X11	45	30	5	100	300	240 @ 2	150	Audio, low noise
ZTX212	PS	X11	60	50	5	200	500	60 @ 2	200	General purpose audio
ZTX300	NS	X11	25	25	5	500	300	50 @ 10	150	General purpose audio
ZTX301	NS	X11	35	35	5	500	300	50 @ 10	150	General purpose audio
ZTX302	NS	X11	35	35	5	500	300	100 @ 10	150	General purpose audio
ZTX303	NS	X11	45	45	5	500	300	50 @ 10	150	General purpose audio
ZTX304	NS	X11	70	70	5	500	300	50 @ 10	150	Audio, high voltage
ZTX310	NS	X59	25	12	3	500	300	20 @ 10	200	General purpose/switching
ZTX311	NS	X11	20	15	5	200	300	50 @ 10	200	RF switch
ZTX312	NS	X59	30	12	5	500	300	40 @ 10	400	General purpose/switching
ZTX313	NS	X59	40	15	5	500	300	40 @ 10	500	General purpose/switching
ZTX314	NS	X11	40	15	5	200	300	40 @ 10	500	VHF switch
ZTX320	NS	X11	30	15	3	50	250	20 @ 3	600	VHF amplifier
ZTX326	NS	X11	30	15	2	50	200	25 @ 2	1000	UHF amplifier
ZTX330	NS	X59	30	30	5	500	300	60 @ 1	30	General purpose/switching
ZTX331	NS	X59	45	45	5	500	300	60 @ 1	30	General purpose/switching
ZTX341	NS	X11	100	100	5	100	300	30 @ 2	50	Audio, high voltage
ZTX500	PS	X11	25	25	5	500	300	50 @ 10	150	General purpose audio
ZTX501	PS	X11	35	35	5	500	300	50 @ 10	150	General purpose audio
ZTX502	PS	X11	35	35	5	500	300	100 @ 10	150	General purpose audio
ZTX503	PS	X11	45	45	5	500	300	50 @ 10	150	General purpose audio
ZTX504	PS	X11	70	70	5	500	300	50 @ 10	150	Audio, high voltage
ZTX510	PS	X59	12	12	4	200	300	30 @ 30	400	General purpose
ZTX530	PS	S14	30	30	5	500	500	60 @ 1	30	General purpose
ZTX531	PS	X11	45	45	5	500	300	40 @ 100μA	30	Audio, low noise
ZTX541	PS	X59	100	100	5	100	300	30 @ 2	80	General purpose
ZTX542	PS	X59	120	120	5	100	300	30 @ 2	80	General purpose
2N388	NG	T05	25	20	15	200	150	60 @ 30	7	RF switch
2N404	PG	T05	15	–	1	100	150	15 @ 1	13	Small signal audio
2N441	PG	T036	40	25	20	4A	50W	20 @ 5A	–	General purpose audio
2N526	PG	T05	45	30	15	500	225	32 @ 1	1	General purpose audio

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
2N696	NS	T05	60	40	5	500	600	20 @ 150	40	General purpose audio
2N697	NS	T05	60	40	5	500	600	40 @ 150	50	General purpose audio
2N698	NS	T05	120	60	7	500	800	20 @ 150	40	General purpose audio
2N699	NS	T05	120	80	5	500	600	40 @ 150	50	Audio, high voltage
2N706A	NS	T018	25	15	5	200	300	20 @ 10	200	RF switch
2N707	NS	T018	56	25	4	200	300	9 @ 10	200	General purpose RF
2N708	NS	T018	40	15	5	200	300	30 @ 10	300	RF switch
2N718	NS	T018	60	28	5	500	400	40 @ 150	50	General purpose audio
2N753	NS	T018	25	15	5	200	300	40 @ 10	200	RF switch
2N914	NS	T018	40	15	5	200	360	30 @ 10	300	RF switch
2N916	NS	T018	45	25	5	100	360	50 @ 10	300	General purpose RF
2N917	**NS**	**T092**	**30**	**15**	3	–	200	**20 @ 3**	**500**	**General purpose**
2N918	NS	T072	30	15	3	50	200	20 @ 3	600	VHF amplifier
2N919	NS	T018	25	15	5	220	360	20 @ 10	200	RF switch
2N920	NS	T018	25	15	5	220	360	40 @ 10	200	RF switch
2N930	NS	T018	45	45	5	30	300	100 @ 10μA	30	Audio, low noise
2N930A	**NS**	**T018**	**60**	**45**	**6**	**30**	**500**	**150 @ 1**	**45**	**General purpose**
2N961	PG	T018	12	12	2	100	150	20 @ 10	300	VHF switch
2N987	PG	T072a	40	40	1	10	86	40 @ 1	50	RF amplifier
2N1091	NG	T05	25	15	20	400	120	40 @ 20	6	RF switch
2N1131	PS	T05	50	35	5	600	600	20 @ 150	50	General purpose audio
2N1132	PS	T039	50	35	5	600	600	30 @ 150	60	General purpose audio
2N1302	NG	T05	25	25	25	300	150	20 @ 10	1	RF switch
2N1303	PG	T05	30	25	25	300	150	20 @ 10	1	RF switch
2N1304	NG	T05	25	20	25	300	150	40 @ 10	4	RF switch
2N1305	PG	T05	30	20	25	300	150	40 @ 10	4	RF switch
2N1306	NG	T05	25	15	25	300	150	60 @ 10	8	RF switch
2N1307	PG	T05	30	15	25	300	150	60 @ 10	8	RF switch
2N1308	NG	T05	25	15	25	300	150	80 @ 10	12	RF switch
2N1309	PG	T05	30	15	25	300	150	80 @ 10	12	RF switch
2N1507	NS	T05	60	30	5	1A	600	100 @ 150	50	General purpose audio
2N1613	NS	T05	75	50	7	600	800	40 @ 150	80	General purpose audio
2N1637	PG	T05	–	34	1.5	10	80	40 @ 1	20	General purpose RF
2N1638	PG	T01	34	–	1	10	80	37 @ 1	20	General purpose RF
2N1711	NS	T05	75	50	7	600	800	100 @ 150	70	General purpose audio
2N1893	NS	T05	120	80	7	500	800	40 @ 150	50	Audio, high voltage
2N1974	**NS**	**T05**	100	60	7	–	**800**	**36 @ 1**	**50**	**General purpose**
2N1986	NS	T05	50	25	5	1A	600	60 @ 150	40	General purpose audio
2N1990	NS	T05	100	60	3	1A	600	20 @ 30	40	Audio, high voltage
2N1991	PS	T05	30	20	5	1A	600	15 @ 150	40	General purpose audio
2N2060	**NS**	**R131**	**100**	**60**	**7**	**500**	**500**	**50 @ 1**	**60**	**Dual general purpose**
2N2100	PG	T05	40	20	4	500	300	200 @ 400	1000	UHF switch
2N2102	NS	T05	120	60	7	1A	1W	40 @ 10	60	Audio, high voltage
2N2193	NS	T05	80	50	8	1A	800	40 @ 150	50	General purpose audio
2N2193A	NS	T05	80	50	8	1A	800	40 @ 150	50	General purpose audio
2N2194	NS	T05	60	40	5	1A	800	20 @ 150	50	General purpose audio
2N2217	NS	T05	60	30	5	800	800	20 @ 150	250	RF switch
2N2218	NS	T05	60	30	5	800	800	40 @ 150	250	General purpose RF
2N2218A	NS	T05	75	40	6	800	800	40 @ 150	250	General purpose RF
2N2219	**NS**	**T05**	**60**	30	5	800	**800**	**50 @ 1**	**250**	**General purpose**
2N2219A	**NS**	**T05**	**75**	40	6	800	**800**	**50 @ 1**	**300**	**General purpose**
2N2220	**NS**	**T018**	**60**	30	5	800	**400**	**12 @ 1**	**250**	**Switching**
2N2220A	NS	T018	75	40	6	800	500	20 @ 150	250	RF switch
2N2221	NS	T018	60	30	5	800	500	40 @ 150	250	General purpose RF
2N2221A	NS	T018	75	40	6	800	500	40 @ 150	250	General purpose RF
2N2222	NS	T018	60	30	5	800	500	100 @ 150	250	General purpose RF
2N2222A	NS	T018	75	40	6	800	500	100 @ 150	300	General purpose RF
2N2223	**NS**	**R131**	**100**	**60**	**7**	**500**	**500**	**40 @ 1**	**50**	**Dual general purpose**
2N2223A	**NS**	**R131**	**100**	**70**	**7**	**500**	**500**	**40 @ 1**	**50**	**Dual general purpose**
2N2297	NS	T05	80	35	7	1A	800	40 @ 150	60	General purpose audio
2N2303	PS	T05	50	35	5	500	600	75 @ 150	60	General purpose audio
2N2368	NS	T018	40	15	4	500	360	–	400	UHF switch
2N2369	**NS**	**T018**	**40**	**15**	**4.5**	**500**	**360**	**40 @ 10**	**500**	**General purpose**
2N2369A	NS	T018	40	15	4	500	360	40 @ 10	500	UHF switch
2N2411	PS	T018	25	20	5	100	300	20 @ 10	140	General purpose audio
2N2476	NS	T05	60	20	5	500	600	20 @ 150	250	RF switch
2N2483	NS	T018	60	60	6	50	360	40 @ 10μA	50	Audio, low noise
2N2484	NS	T018	60	60	6	50	360	100 @ 10μA	50	Audio, low noise
2N2714	NS	T098	18	18	5	100	200	80 @ 2	–	General purpose audio
2N2846	NS	T05	60	30	5	500	800	30 @ 150	250	RF switch
2N2848	NS	T05	60	20	5	500	800	40 @ 150	250	RF switch
2N2891	NS	T039	100	800	5	2A	800	50 @ 1A	30	General purpose audio
2N2892	NS	T059	100	80	–	5A	30W	30 @ 1A	30	RF, high voltage
2N2894	PS	T018	12	12	4	200	360	30 @ 30	400	VHF switch
2N2904A	PS	T05	60	60	5	600	600	40 @ 150	200	General purpose audio
2N2905	PS	T05	60	40	5	600	600	100 @ 150	200	General purpose audio
2N2905A	PS	T05	60	60	5	600	600	100 @ 150	200	General purpose audio
2N2906	**PS**	**T092g**	**60**	**60**	**4**	**500**	**625**	**50 @ 10**	**100**	**General purpose**
2N2906A	PS	T018	60	40	5	600	400	40 @ 150	200	General purpose audio
2N2907	PS	T018	60	40	5	600	400	100 @ 150	200	General purpose audio

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
2N2907A	PS	T018	60	60	5	600	400	100 @ 150	200	General purpose audio
2N2920	NS	R131	60	60	6	30	300	150 @ 10µA	60	Dual small signal
2N2922	NS	T098	25	25	5	100	360	55 @ 2	100	General purpose audio
2N2923	NS	T098	25	25	5	100	360	90 @ 2	100	General purpose audio
2N2924	NS	T098	25	25	5	100	200	150 @ 2	–	General
2N2925	NS	T098	25	25	5	100	200	235 @ 2	–	General
2N2926	NS	T098	18	18	5	100	200	35 @ 2	–	General
2N2926R	NS	T098	25	25	5	100	200	55 @ 2	100	General purpose audio
2N2926O	NS	T098	25	25	5	100	200	90 @ 2	100	General purpose audio
2N2926Y	NS	T098	25	25	5	100	200	150 @ 2	100	General purpose audio
2N2926G	NS	T098	25	25	5	100	200	235 @ 2	100	Audio, low noise
2N2959	NS	T05	60	20	5	600	600	100 @ 150	250	General purpose RF
2N3011	NS	T018	30	12	5	200	360	30 @ 10	400	VHF switch
2N3019	NS	T05	140	80	7	1A	800	100 @ 150	100	Audio, high voltage
2N3020	NS	T05	140	80	7	1A	800	40 @ 150	80	Audio, high voltage
2N3053	NS	T05	60	40	5	700	1W	50 @ 150	100	General purpose audio
2N3054	NS	T066	90	60	7	4A	25W	25 @ 500	0.75	General purpose audio
2N3055	NS	T03	100	70	7	15A	115W	20 @ 4A	10k	Audio power
2N3055H	NS	T03	100	60	7	15A	115W	20 @ 4A	800k	Audio power
2N3107	NS	T05	100	60	7	1A	800	100 @ 150	70	Audio, high voltage
2N3108	NS	T05	100	60	7	1A	800	40 @ 150	60	Audio, high voltage
2N3109	NS	T05	80	40	7	1A	800	100 @ 150	70	General purpose audio
2N3121	PS	T018	45	45	4	500	360	30 @ 50	130	General purpose audio
2N3133	PS	T05	50	35	4	600	600	40 @ 150	200	General purpose audio
2N3135	PS	T018	50	35	4	600	400	40 @ 150	200	General purpose RF
2N3232	NS	T03	60	60	6	7A	117W	18 @ 3A	1	General purpose audio
2N3250	PS	T018	50	40	5	200	360	50 @ 10	250	General purpose RF
2N3251	PS	T018	50	40	5	200	360	100 @ 10	300	General purpose RF
2N3252	NS	T05	60	30	5	1A	1W	30 @ 500	200	RF switch
2N3295	NS	T05	60	–	5	250	800	20 @ 10	200	VHF power amplifier
2N3302	NS	T018	60	30	5	500	360	100 @ 150	250	General purpose RF
2N3392	NS	T098	25	25	5	100	200	150 @ 2	70	Audio, low noise
2N3393	NS	T098	25	25	5	100	200	90 @ 2	70	General purpose audio
2N3394	NS	T098	25	25	5	100	200	55 @ 2	70	General purpose audio
2N3397	NS	T098	25	25	5	100	200	55 @ 2	60	General purpose audio
2N3415	NS	T098	25	25	5	500	360	180 @ 2	60	General purpose audio
2N3420	NS	T05	85	60	8	3A	1W	40 @ 1A	40	General purpose audio
2N3439	NS	T05	450	350	7	1A	1W	40 @ 40	15	Audio, extra high voltage
2N3440	NS	T05	300	250	7	1A	1W	40 @ 40	15	Audio, extra high voltage
2N3441	NS	T066	160	140	7	3A	25W	25 @ 500	0.2	Audio, high voltage
2N3442	NS	T03	160	140	7	10A	117W	20 @ 3A	0.5	Audio, high voltage
2N3442RCA	NS	T03	160	140	7	10A	117W	20 @ 3A	–	Audio power
2N3444	NS	T05	80	50	5	1A	1W	20 @ 500	150	Audio driver
2N3445	NS	T03	80	60	6	7A5	115W	20 @ 3A	10	Audio power
2N3446	NS	T03	100	80	10	7A5	115W	20 @ 3A	10	Audio power
2N3447	NS	T03	80	60	6	7A5	115W	40 @ 5A	10	Audio power
2N3448	NS	T03	100	80	10	7A5	115W	40 @ 5A	10	Audio power
2N3468	PS	T05	50	–	5	1A	1W	25 @ 500	150	Audio driver
2N3478	NS	T072	30	15	2	50	200	25 @ 2	750	VHF amplifier
2N3487	NS	T061	80	60	10	7A	117W	20 @ 3A	10	General purpose RF
2N3512	NS	T05	60	35	5	–	800	10 @ 500	250	General
2N3553	NS	T039	65	40	4	1A	7W	10 @ 250	250	UHF power amplifier
2N3563	NS	T0106	30	12	2	50	200	30 @ 1	600	VHF amplifier
2N3565	NS	T0106	30	25	6	50	200	70 @ 100µA	40	Audio, low noise
2N3566	NS	T0105	40	30	5	200	300	150 @ 10	40	General purpose audio
2N3567	NS	T0105	80	40	5	500	300	40 @ 150	60	General purpose audio
2N3568	NS	T0105	80	60	5	500	300	40 @ 150	60	General purpose audio
2N3569	NS	T0105	80	40	5	500	300	100 @ 150	60	General purpose audio
2N3570	NS	T072	30	15	3	50	200	20 @ 5	1500	UHF amplifier
2N3571	NS	T072	25	15	3	50	200	20 @ 5	1200	UHF amplifier
2N3572	NS	T072	25	13	3	50	200	20 @ 2	1000	UHF amplifier
2N3606	NS	T098	18	14	5	200	200	30 @ 10	300	VHF switch
2N3607	NS	T098	18	14	5	200	200	30 @ 10	300	VHF switch
2N3614	PG	T03	60	35	30	15A	77W	60 @ 3A	0.3	General purpose audio
2N3615	PG	T03	80	50	40	15A	77W	30 @ 3A	0.3	Audio, high voltage
2N3632	NS	T060	65	40	4	3A	23W	10 @ 250	–	Medium power audio
2N3638	PS	T0105	25	25	4	500	300	30 @ 50	100	General purpose audio
2N3638A	PS	T0105	25	25	4	500	300	100 @ 10	150	General purpose RF
2N3642	NS	T0105	60	45	5	500	350	40 @ 150	150	General purpose audio
2N3643	NS	T0105	60	30	5	500	350	100 @ 150	250	General purpose RF
2N3646	NS	T0106	40	15	5	200	200	30 @ 30	350	RF switch
2N3663	NS	T098	30	12	3	25	200	20 @ 8	700	VHF amplifier
2N3694	NS	T0106	50	30	5	500	200	350* @ 150	200	High speed switching
2N3702	PS	T092	40	25	5	200	360	60 @ 50	100	General purpose audio
2N3703	PS	T092	50	30	5	200	360	30 @ 50	100	General purpose audio
2N3704	NS	T092	50	30	5	800	360	300 @ 50	100	General purpose audio
2N3705	NS	T092	50	30	5	800	625	150 @ 50	100	General purpose audio
2N3706	NS	T092	40	20	5	800	625	600 @ 50	100	General purpose audio
2N3707	NS	T092	30	30	6	30	360	100 @ 100µA	100	Audio, low noise
2N3708	NS	T092	30	30	6	30	360	45 @ 1	100	Audio, low noise

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
2N3709	NS	T092	30	30	6	30	360	45 @ 1	100	General purpose audio
2N3710	NS	T092	30	30	6	30	360	90 @ 1	100	Audio, low noise
2N3711	NS	T092	30	30	6	30	360	180 @ 1	100	Audio, low noise
2N3713	NS	T03	80	60	7	10A	150W	25 @ 1A	4	General purpose RF
2N3714	NS	T03	100	80	7	10A	150W	25 @ 1A	4	General purpose RF
2N3715	NS	T03	80	60	7	10A	150W	50 @ 1A	4	General purpose RF
2N3716	NS	T03	100	80	7	10A	150W	50 @ 1A	4	General purpose RF
2N3732	PG	T03	100	100	0.5	3A	3W	35 @ 700	1	Audio, high voltage
2N3740	PS	T066	60	60	7	10A	25W	30 @ 250	4	General purpose RF
2N3741	PS	T066	80	80	7	10A	25W	30 @ 250	4	RF, high voltage
2N3771	NS	T03	50	40	5	30A	150W	15 @ 10A	0.2	Audio, high voltage
2N3772	NS	T03	100	60	7	30A	150W	15 @ 10A	0.2	Audio, high voltage
2N3773	NS	T03	160	140	7	30A	150W	15 @ 8A	0.2	Audio, high voltage
2N3789	PS	T03	60	60	7	10A	150W	25 @ 1A	4	General purpose RF
2N3790	PS	T03	80	80	7	10A	150W	25 @ 1A	4	RF, high voltage
2N3791	PS	T03	60	60	7	10A	150W	50 @ 1A	4	General purpose RF
2N3792	PS	T03	80	80	7	10A	150W	50 @ 1A	4	RF, high voltage
2N3794	NS	X13	40	20	5	500	250	35 @ 1	100	General purpose audio
2N3860	NS	T098	30	30	4	100	200	150 @ 2	90	Small signal low frequency
2N3854A	NS	T098	30	30	4	100	200	35 @ 2.	100	FM/AM, general purpose medium gain
2N3856A	NS	T098	30	30	4	100	200	100 @ 2	140	FM/AM, general purpose high gain
2N3866	NS	T039	55	30	3.5	400	5W	10 @ 50	500	UHF power amplifier
2N3877A	NS	T098	85	85	4	50	200	20 @ 2	–	Low power switching
2N3879	NS	T066	120	75	7	7A	35W	20 @ 4A	40	RF switch
2N3902	NS	T03	700	325	5	3.5A	100W	30 @ 1A	2.8	General purpose RF
2N3903	NS	T092b	60	40	6	200	310	50 @ 10	250	General purpose audio
2N3904	NS	T092b	60	40	6	200	310	100 @ 10	250	Audio, low noise
2N3905	PS	T092b	40	40	5	200	310	50 @ 10	200	General purpose audio
2N3906	PS	T092b	40	40	5	200	310	100 @ 10	250	General purpose audio
2N3962	PS	T018	60	60	6	200	360	60 @ 1μA	40	Audio, low noise
2N4031	PS	T05	80	80	5	1A	800	40 @ 100	100	General purpose audio
2N4036	PS	T05	90	65	7	1A	1W	40 @ 150	60	Audio, high voltage
2N4037	PS	T05	60	40	7	1A	1W	50 @ 150	60	General purpose audio
2N4041	NS	X27	65	40	4	500	18W	10 @ 100	400	VHF power amplifier
2N4058	PS	T092	30	30	6	30	360	100 @ 100μA	–	Audio, low noise
2N4059	PS	T092	30	30	6	30	360	45 @ 1	–	General purpose audio
2N4060	PS	T092	30	30	6	30	360	45 @ 1	–	General purpose audio
2N4061	PS	T092	30	30	6	30	360	90 @ 1	–	General purpose audio
2N4062	PS	T092	30	30	6	30	360	180 @ 1	–	Audio, low noise
2N4064	NS	T05F	300	250	7	1A	10W	40 @ 20	15	RF, extra high voltage
2N4123	NS	T092b	40	30	5	200	310	50 @ 2	250	General purpose audio
2N4126	PS	T092b	25	25	4	200	310	120 @ 2	250	General purpose audio
2N4234	PS	T05	40	40	7	3A	1W	30 @ 250	3	General purpose RF
2N4236	PS	T05	80	80	7	3A	1W	30 @ 250	3	RF, high voltage
2N4237	NS	T05	50	40	6	1A	5W	15 @ 1A	80	General purpose audio
2N4239	NS	T05	100	80	6	1A	800	30 @ 100	1	Audio driver/switching
2N4240	NS	T066	500	300	6	5A	35W	10 @ 750	15	High-V driver
2N4247	PG	T03	40	40	20	10A	106W	60 @ 5A	–	Audio power
2N4249	PS	T0106	60	60	5	100	200	100 @ 1	100	General purpose audio
2N4250	PS	T0106	40	40	5	100	200	250 @ 1	100	Audio, low noise
2N4251	NS	T046	15	10	4.5	250	100	32 @ 10	1G3	High frequency
2N4264	NS	T092b	30	15	6	200	310	40 @ 10	300	VHF switch
2N4284	PS	X13a	25	25	35	50	250	35 @ 1	7	Audio amplifier
2N4286	NS	X13	30	25	6	100	250	150 @ 1	40	Audio, low noise
2N4288	PS	X13	30	25	6	100	250	100 @ 100μA	40	Audio, low noise
2N4289	PS	X13	60	45	7	–	250	100 @ 100μA	40	Audio, low noise
2N4313	PS	T0106	12	12	4	100	200	30 @ 10	700	VHF switch
2N4314	PS	T039	90	65	7	–	1W	50 @ 150	60	General purpose audio
2N4400	NS	T092b	60	40	6	600	310	50 @ 150	200	General purpose audio
2N4401	NS	T092b	60	40	6	600	310	100 @ 150	250	General purpose audio
2N4402	PS	T092b	40	40	5	600	350	30 @ 1	150	General purpose
2N4403	PS	T092b	40	40	5	600	350	60 @ 1	200	Switching
2N4409	NS	T092b	80	50	5	250	625	60 @ 20	60	General purpose
2N4410	NS	T092b	120	80	5	250	310	60 @ 1	60	Audio, high voltage
2N4427	NS	T039	40	20	2	400	1W	10 @ 100	500	VHF power amplifier
2N4428	NS	T039	55	35	3.5	425	3.5W	20 @ 50	700	UHF power amplifier
2N4440	NS	T060	65	40	4	1A5	11W	10 @ 25	400	General purpose medium power
2N4888	PS	R124	150	150	6	100	300	500** @ 1	160**	General
2N4896	NS	T039	120	60	6	5A	7W	100 @ 2A	80	General purpose audio
2N4898	PS	T066	40	40	5	4A	25W	20 @ 500	3	General purpose RF
2N4901	PS	T03	40	40	5	5A	87W	20 @ 1A	4	General purpose RF
2N4902	PS	T03	60	60	5	5A	87W	20 @ 1	4	Audio power
2N4903	PS	T03	80	80	5	5A	87W	20 @ 1A	4	RF, high voltage
2N4904	PS	T03	40	40	5	5A	87W	25 @ 2.5A	4	General purpose RF
2N4905	PS	T03	60	60	5	5A	87W	25 @ 2.5A	4	RF, high voltage
2N4906	PS	T03	80	80	5	5A	87W	25 @ 2.5A	4	RF, high voltage
2N4907	PS	T03	40	40	5	10A	150W	20 @ 4A	2	General purpose audio
2N4908	PS	T03	60	60	5	10A	150W	20 @ 4A	2	General purpose audio
2N4909	PS	T03	80	80	5	10A	150W	20 @ 4A	2	General purpose audio
2N4913	NS	T03	40	40	5	5A	87W	25 @ 2.5A	4	General purpose RF

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
2N4915	NS	T03	80	80	5	5A	87W	25 @ 2.5A	4	RF, high voltage
2N4918	PS	T0126	40	40	5	1A	30W	30 @ 500	3	Medium power audio
2N4919	PS	T0126	60	60	5	1A	30W	30 @ 500	3	Medium power audio
2N4920	PS	T0126	80	80	5	3A	30W	20 @ 500	3	Audio, high voltage
2N4921	NS	T0126	40	40	5	3A	30W	20 @ 500	3	General purpose audio
2N4922	NS	T0126	60	60	5	3A	30W	20 @ 500	3	General purpose audio
2N4923	NS	T0126	80	80	5	3A	30W	20 @ 500	3	Audio, high voltage
2N5030	NS	T098	30	12	4	200	320	30 @ 10	400	VHF switch
2N5039	NS	T03	120	75	7	20A	140W	30 @ 2A	60	General purpose audio
2N5086	PS	T092b	50	50	3	50	350	150 @ 1	40	General low frequency
2N5087	PS	T092b	50	50	3	50	350	250 @ 1	40	General low frequency
2N5088	NS	T092b	35	30	3	50	310	300 @ 100µA	–	Audio, low noise
2N5089	NS	T092b	30	25	3	50	310	400 @ 100µA	–	Audio, low noise
2N5102	NS	T060	90	50	4	3.3A	70W	10 @ 500	150	VHF power amplifier
2N5129	NS	T0106	15	12	3	500	300	35 @ 50	150	General purpose audio
2N5135	NS	T0105	30	25	4	200	300	50 @ 10	40	General purpose audio
2N5136	NS	T0105	30	20	3	500	220	20 @ 150	40	General purpose audio
2N5137	NS	T0106	30	20	3	500	300	20 @ 150	40	General purpose audio
2N5138	PS	T0106	30	30	5	100	200	50 @ 100µA	40	Audio, low noise
2N5172	NS	T098	25	25	5	100	200	100 @ 10	–	General purpose audio
2N5179	NS	T072	20	12	2.5	50	200	25 @ 3	900	UHF amplifier
2N5180	NS	T072	30	15	2	50	180	20 @ 2	650	UHF amplifier
2N5189	NS	T039	60	35	5	2A	1W	15 @ 1A	250	General purpose VHF
2N5190	NS	T0126	40	40	5	4A	40W	25 @ 1A5	2	Audio medium power
2N5191	NS	T0126	60	60	4	4A	40W	25 @ 1.5A	2	Audio, high voltage
2N5192	NS	T0126	80	80	4	4A	40W	20 @ 1.5A	2	Audio, high voltage
2N5193	PS	T0126	40	40	5	4A	40W	25 @ 1A5	2	Audio medium power
2N5194	PS	T0126	60	60	4	4A	40W	25 @ 1.5W	2	Audio, high voltage
2N5209	NS	T092b	50	50	4	50	310	150 @ 1	30	General purpose audio
2N5220	NS	T092b	15	15	3	500	310	30 @ 50	100	General purpose audio
2N5222	NS	T092d	20	15	2	50	310	20 @ 4	450	UHF amplifier
2N5223	NS	T092b	25	20	3	100	310	50 @ 2	150	General purpose audio
2N5293	NS	T0Q66	80	75	7	4A	36W	30 @ 500	0.8	Audio, high voltage
2N5294	NS	T0P66	80	75	7	4A	36W	30 @ 500	0.8	Audio, high voltage
2N5295	NS	Y220T	60	50	5	4A	36W	30 @ 1A	800k	Audio driver
2N5296	NS	T0P66	60	50	5	4A	36W	30 @ 1A	0.8	General purpose audio
2N5298	NS	T0P66	80	70	5	4A	36W	20 @ 1.5A	0.8	General purpose audio
2N5301	NS	T03	40	40	5	30A	200W	15 @ 15A	2	General purpose audio
2N5303	NS	T03	80	80	5	20A	200W	15 @ 10A	2	Audio, high voltage
2N5305	NS	T098	25	25	12	300	400	2000 @ 2	60	Darlington, audio
2N5306	NS	T098	25	25	12	300	400	7000 @ 2	60	Darlington, audio
2N5308	NS	T098	40	40	12	300	400	7000 @ 2	60	Darlington, audio
2N5365	PS	X13	40	40	4	500	360	40 @ 50	–	General purpose audio
2N5401	PS	T092b	160	150	5	600	310	60 @ 10	100	RF, extra high voltage
2N5416	PS	T039	350	300	6	1A	10W	30 @ 50	15	RF, extra high voltage
2N5447	PS	X10	40	25	5	200	360	60 @ 50	100	General
2N5448	PS	X10	50	30	5	200	360	30 @ 50	100	General purpose audio
2N5449	NS	X10	50	30	5	800	360	100 @ 50	100	Switching
2N5450	NS	X10	50	30	5	800	360	50 @ 50	100	Switching
2N5451	NS	X10	40	20	5	800	360	30 @ 50	100	General purpose audio
2N5490	NS	T0P66	60	50	5	7A	50W	20 @ 2A	–	General purpose audio
2N5492	NS	T0P66	75	65	5	7A	50W	20 @ 2.5A	–	Audio, high voltage
2N5494	NS	T0P66	60	50	5	7A	50W	20 @ 3A	–	General purpose audio
2N5496	NS	T0P66	90	80	5	7A	50W	20 @ 3.5A	–	Audio, high voltage
2N5551	NS	T092b	160	140	6	600	350	50 @ 1	100	Switching
2N5661	NS	T0P66	400	300	6	1A	20W	25 @ 500	20	Audio, extra high voltage
2N5758	NS	T03	100	100	7	10A	150W	25 @ 3A	1	Audio, high voltage
2N5879	PS	T03	60	60	5	15A	160W	20 @ 6A	4	General purpose audio
2N5884	PS	T03	80	80	5	25A	200W	20 @ 4A	4	Audio power
2N5885	NS	T03	60	60	5	25A	200W	20 @ 10A	4	General purpose RF
2N6082	NS	X27	36	18	4	4A	50W	5 @ 1A	–	Medium power audio
2N6099	NS	T0P66	70	60	8	10A	75W	20 @ 4A	–	Audio, high voltage
2N6109	PS	T0P66	60	50	5	7A	40W	30 @ 2A	0.5	General purpose audio
2N6121	NS	T0P66	45	45	5	4A	40W	25 @ 1.5A	2	General purpose audio
2N6122	NS	T0P66	60	60	5	4A	40W	25 @ 1.5A	2	Audio, high voltage
2N6123	NS	T0P66	80	80	5	4A	40W	20 @ 1.5A	2	Audio, high voltage
2N6124	PS	T0P66	45	45	5	4A	40W	25 @ 1.5A	2	General purpose audio
2N6125	PS	T0P66	60	60	5	4A	40W	25 @ 1.5A	2	Audio, high voltage
2N6126	PS	T0P66	80	80	5	4A	40W	20 @ 1.5A	2	Audio, high voltage
2N6129	NS	T0P66	40	40	5	7A	50W	20 @ 2.5A	2	General purpose audio
2N6130	NS	T0P66	60	60	5	7A	50W	20 @ 2.5A	2	Audio, high voltage
2N6131	NS	T0P66	80	80	5	7A	50W	20 @ 2.5A	2	Audio, high voltage
2N6132	NS	Y220	40	40	5	7A	50W	20 @ 2A5	2.5	Audio power
2N6133	PS	T0P66	60	60	5	7A	50W	20 @ 2.5A	2	Audio, high voltage
2N6134	PS	T0P66	80	80	5	7A	50W	20 @ 2.5A	2	Audio, high voltage
2N6230	PS	T03	120	120	7	10A	150W	20 @ 3A	1	Audio, high voltage
2N6253	NS	T03	55	40	5	15A	115W	20 @ 3A	0.8	General purpose audio
2N6254	NS	T03	100	80	7	15A	150W	20 @ 5	–	Audio power
2N6258	NS	T03	100	80	7	30A	250W	20 @ 15A	0.2	Audio, high voltage
2N6288	NS	T0P66	40	40	5	7A	40W	30 @ 3A	0.5	General purpose audio

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
2N6388	NS	T0P66	80	80	5	10A	40W	1000 @ 5A	20	Darlington, RF
2SC1306	NS	Y220	65	65	4	3A	12W	40 @ 500	300	Medium power audio
2SC2078	NS	Y220	80	75	5	3A	10W	25 @ 500	150	Medium power audio
2SD234	NS	T0P66	60	50	10	3A	25W	40 @ 500	0.5	General purpose audio
40251	NS	T03	50	40	5	15A	117W	15 @ 8A	–	General purpose audio
40254	PG	T03	32	–	5	5A	12W	38 @ 1A	0.15	General purpose audio
40310	NS	T066	–	35	2.5	4A	29W	20 @ 1A	–	General purpose audio
40311	NS	T05	–	30	2.5	700	1W	75 @ 50	50	General purpose audio
40360	NS	T05	–	70	4	700	1W	40 @ 10	100	General purpose
40361	NS	T05	–	70	4	700	1W	70 @ 50	100	General purpose
40362	PS	T05	–	70	4	700	5W	35 @ 50	100	Audio driver
40363	NS	T03	–	70	4	17A	115W	20 @ 4A	700k	Audio power
40406	PS	T05	–	50	4	700	1W	30 @ 0.1	100	General purpose
40407	NS	T05	–	50	4	700	1W	40 @ 1	100	General purpose
40408	NS	T05	–	90	4	700	1W	40 @ 10	100	General purpose
40410	PS	F31	–	90	4	700	3W	50 @ 150	100	Audio driver
40411	NS	T03	–	90	4	30A	150W	35 @ 4A	800k	Audio power
40412	NS	T05	–	250	–	1A	1W	50 @ 30	10	Switching
40871	NS	Y220	–	100	5	7A	40W	50 @ 1A	4	Audio medium power
40872	PS	Y220	–	100	5	7A	40W	50 @ 1A	10	Audio medium power

Note: F31 package=T05 with heat sinks welded on

SOME USEFUL ADDRESSES

SEMICONDUCTOR MANUFACTURER	IC PREFIX *
ANALOGUE DEVICES Central Avenue, East Molesey, Surrey 01-941 0466	AD
FAIRCHILD CAMERA & INSTRUMENT (UK) LTD 230 High Street, Potters Bar, Herts EN6 5BU Potters Bar 51111	µA
FERANTI ELECTRONICS LTD Fields New Road, Chadderton, Oldham OL9 8NP 061-624 0515	ZN
GENERAL INSTRUMENT MICROELECTRONICS LTD 57/61 Mortimer Street, London W1N 7TD 01-636 2022	AY
INTERSIL DATEL (UK) LTD Snamprogetti House, Basingview, Basingstoke RG21 2YS 0256 5731	DG, ICL ICM

SEMICONDUCTOR MANUFACTURER	IC PREFIX*
MOSTEK UK LTD Masons House, 1 Walley Drive, Kingsbury Road, London NW9 01-204 9322	MK
MOTOROLA LTD York House, Empire Way, Wembley Middlesex 01-902 8836	MC
MULLARD LTD (also SIGNETICS) Mullard House, Torrington Place London WC1 7HD 01-580 6633	CA,CD,LM,MC, NE,OM,TAA,TBA, TCA,TDB, µA
NATIONAL SEMICONDUCTOR (UK) LTD 301 Harpur Centre, Horne Lane, Bedford MK40 1TR 0234 47147	AD,ADB,ADC, AH,AN,DAC, DM, DT,LB,LF,LH,LM, MF,TBA,TDA,TP

*** Note that many prefixes are not unique to one manufacturer**

CAPACITORS

MODERN FIXED CAPACITORS can be placed in three general classes according to the characteristics of their dielectric.

(A) Low loss, high stability e.g. mica, low-K ceramic, polystyrene.
(B) Medium loss, medium stability e.g. paper, plastic film, high-K ceramic.
(C) Polarised capacitors e.g. electrolytic, tantalum.

Mica Capacitors

Mica capacitors have low RF losses right through to UHF and very good capacitance stability. They are suitable for use in RF circuits up to 500 MHz and are recommended for use in oscillators and filters where their stability characteristics are almost unrivalled. Mica capacitors of appropriate size can handle large RF currents and high voltages and are often used in transmitting applications.

Moulded Mica or "Postage Stamp" — the most common form is the "Postage stamp" style, so named because of its size and shape. Often cheaper than real postage stamps and taste better when licked! General purpose mica capacitors have good stability and can be obtained with high voltage and high RF current ratings. They are constructed of layers of foil interleaved with mica (referred to as "stacked mica") or layers of metallized mica. Obtainable in values between 10 pF and 0.1 µF. They may be marked 'M.S.' to indicate Stacked Mica.

Silvered Mica — usually labelled with an S.M. marking, not to be confused with Stacked Mica capacitors. These have very high stability and are recommended for use in oscillators, filters and other critical applications requiring highly stable capacitance. Tolerance is also very good, usually specified to ± 5% but in practice often better. Generally obtainable in values from 4.7 pF to 3300 pF.

Metal-Clad Mica — a square or rectangular-shaped capacitor having a metal clamp holding the stack of interleaved plates of foil and mica. This form of construction has low lead inductance and can handle high RF currents. It is used for dc blocking and bypassing in RF circuits.

Button Mica — named after their shape. Very good RF bypasses. Made in standoff and feedthrough styles. They have very low inductance connections and are used for RF bypass, filter, and tuned circuit applications up to UHF. The feedthrough style provides a bypassed connection through a chassis while the standoff style provides a direct bypass or bypassed tie point. Obtainable in values between 5 pF and 10 000 pF.

Dipped Mica — this style is encapsulated by dipping in resinous material below atmospheric pressure. They have improved electrical characteristics and higher reliability than moulded types. Obtainable in values from 10 pF to 0.1 µF.

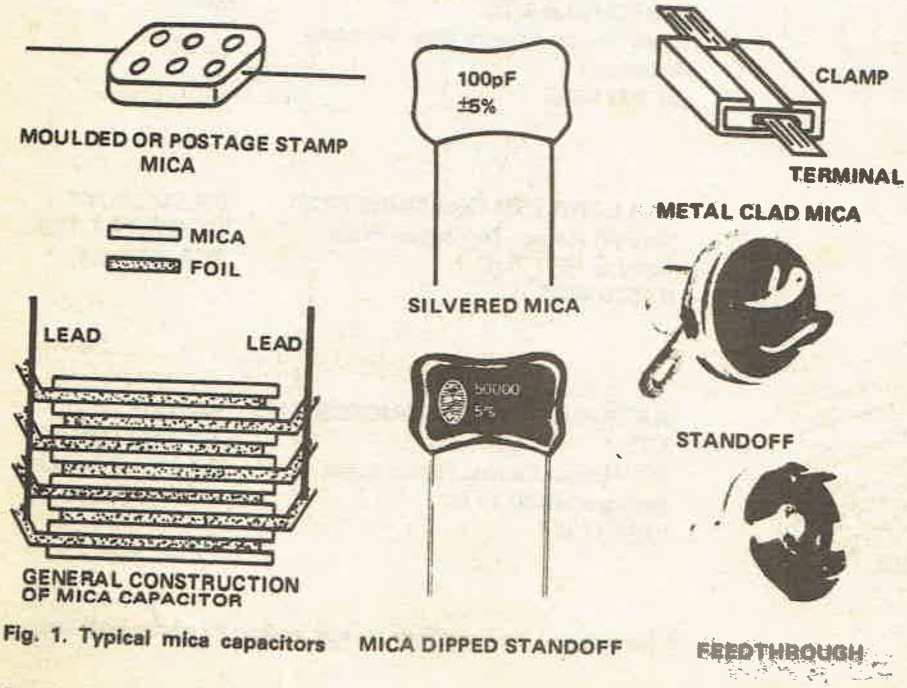


Fig. 1. Typical mica capacitors

Ceramic Capacitors

There are two basic types of ceramic capacitors — low permittivity ("Low-K") and high permittivity ("High-K"). They have widely different characteristics.

Low-K ceramics have low loss and exhibit small, linear changes of capacitance with temperature. They are useful up to 1000 MHz and are made for both low voltage and high voltage applications.

High-K ceramics provide large capacitance values in small space. Their losses are dependent on applied ac and dc fields. They exhibit large, non-linear changes in capacitance against temperature. As a consequence they find application as decoupling and bypass capacitors (discussed later).

Low-K Ceramic Capacitors. Low-K ceramic capacitors are manufactured in a range of temperature characteristics. They are sometimes referred to as "temperature compensating" capacitors as they can be used to compensate for temperature changes in other circuit components. This property is particularly useful in RF oscillators and filters.

The temperature characteristic or coefficient, is quoted in parts per million per °C (ppm/°C), either positive or negative e.g. a capacitor marked 100 pF/P100 will *increase* its capacitance by 100 ppm for each degree centigrade increase in temperature. For a temperature rise of 10°C it will increase its capacitance by 0.1 pF. As a further example, a 1000 pF capacitor

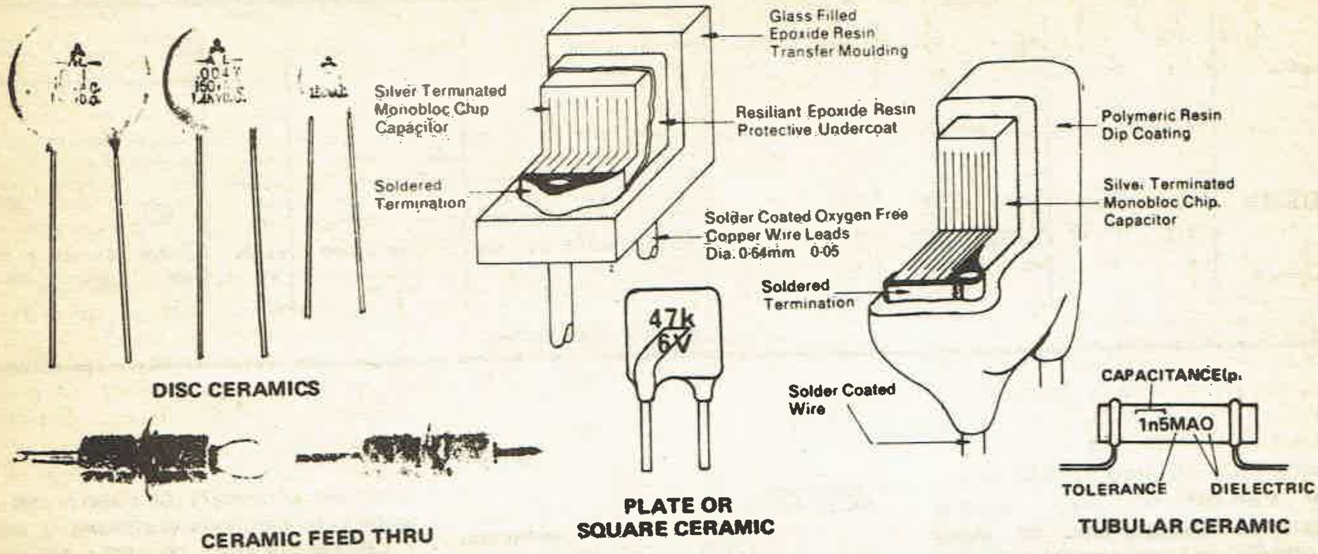


Fig. 2. Ceramic capacitors.

will *decrease* its capacitance by 1500 ppm for each degree centigrade rise in temperature. For a temperature rise of 10°C, its capacitance will drop by 15 pF.

Low-K capacitors are also produced having an extremely small temperature characteristic. These are known as NPO ceramics ("Negative-Positive Zero"). Their stability rivals that of silvered mica capacitors.

The graphs in Fig. 3 indicate the range of standard characteristics manufactured. The nominal value of ceramic capacitors is specified at 25°C. It should be noted that the change in capacitance is not strictly linear, having a small curvature, at low temperatures it becomes more negative. The tolerance on the temperature characteristic ranges from ± 30 ppm for NPO capacitors, to ± 1000 ppm for N5600. Below values of 10 pF stray capacitances begin to have a marked effect on the temperature characteristic and the tolerances are widened.

The temperature coefficient of silvered mica capacitors is usually about +20 ppm/°C but may be as low as +5 ppm/°C which is somewhat better than NPO ceramics.

Low-K ceramic capacitors are made in disc, square and tubular forms. They are obtainable in a range of working voltages from 50 V to 15 kV. They are useful in RF circuits up to three or four hundred megahertz. Above this frequency, leadless unencapsulated "chip" capacitors are used.

Polystyrene Capacitors

Polystrene capacitors are one type of plastic film capacitor. They are constructed usually by interleaving strips of foil and polystyrene film, the alternate strips of foil being staggered to provide connections. The assembly is then rolled up to form a tubular shaped capacitor. See Fig. 4. They exhibit low loss and good stability and are manufactured in a range of working

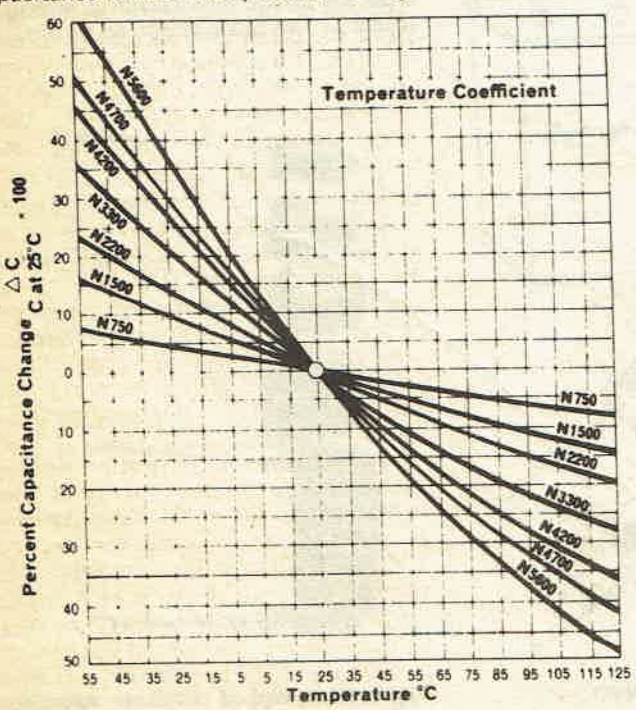
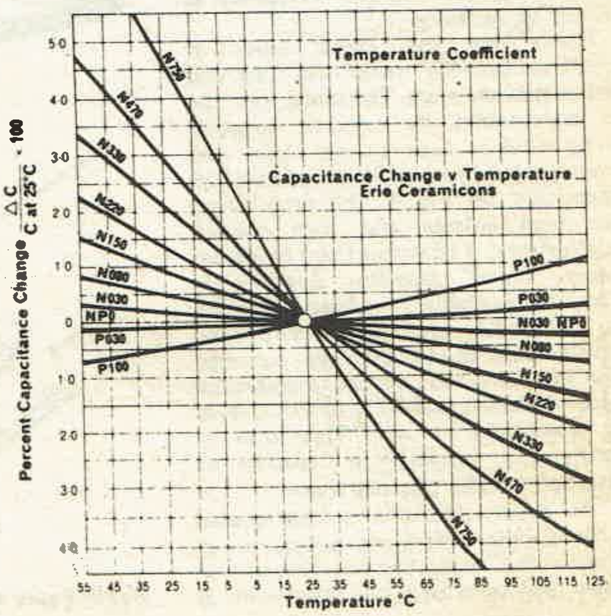


Fig. 3. Characteristics of ceramic capacitors



	Paper		Polyester		Polycarbonate		Polypropylene	
	metalized	film/foil	metalized	film/foil	metalized	film/foil	metalized	film/foil
Insulation resistance (in megohms)	3×10^{1}	2×10^{4}	5×10^{7}	10^{5}	5×10^{4}	10^{5}	10^{5}	5×10^{4}
Tolerance	10	5%	5%	5%	5%	2%	5	2%
Temperature range (°C)	30 to 100	30 to 100	55 to 125	55 to 125	55 to 125	55 to 125	40 to 85	40 to 100
Size per CV*	small	large	small	small	small	small	small	small
Stability	fair	fair	fair	fair	fair	fair	fair	excellent
Capacitance range (µF unless indicated)	0.01 to 100	0.001 to 100	0.001 to 10	100 pF to 0.01 µF	0.001 to 100	5 pF to 0.01 µF	0.001 to 100	100 pF to 0.47 µF
Voltage (ac) (dc)	250-630 500-5000	250-630	63-400 100-1500	90-160 160-400	40-250 63-1000	63-160 100-400	250-440 750-1000	63-500 100-1500
Temperature coefficient PPM/°C	300	300	400	400 (non linear)	150	50 to 100	170	120
Approx resonance MHz	0.1	0.1	0.1	1	0.1	1	0.1	1

	Polystyrene	Ceramic		Mica	Electrolytic		
		disc/tube	monolithic		aluminium foil	foil	tantalum solid & wet
Insulation resistance (in megohms)	10^{6}	10^{3}	10^{4}	10^{5}	← variable	→	
Tolerance	0.625%	10%	20%	0.5%	10	10	5
Temperature range (°C)	40 to 70	-55 to 125	-55 to 125	-55 to 125	-20 to 80	40 to 125	-40 to 150
Size per CV*	large	small	small	small	very small	small	
Stability	excellent	fair	fair	excellent	fair	very good	excellent
Capacitance range (µF unless indicated)	100 pF to 0.6 µF	5 pF to 1µF	0.001 to 10	5 pF to 0.01 µF	typically 1-22 000	1-1000	3500 max
Voltage (ac) (dc)	- 63-1000	63-250 63-10 000	- 63-450	- 63-630	- 6.3-500	- 6.3-300	- 1-50
Temperature coefficient PPM/°C	150	non linear positive to 1000 neg		100	1500	1000 (non linear)	200-1000
Approx resonance MHz	1	10	100	1.0	0.05	0.1	0.1

*CV product of capacitance and voltage

Capacitor Comparison Chart.

voltages from 100 volts to 630 volts. They exhibit a small negative temperature characteristic of about 150 ppm/°C and are sometimes used as temperature compensating capacitors. Their main application is in tuned circuits and as coupling capacitors up to about 100 MHz. The higher values (0.01 µF and above) are sometimes used in bypass and decoupling applications.

Polystyrene capacitors are affected by heat, greases and solvents. Care must be taken when using them to keep them away from heat sources (e.g. power resistors). Exercise care when soldering. Flux solvents and other chemical solvents will dissolve the capacitor, with disastrous effects.

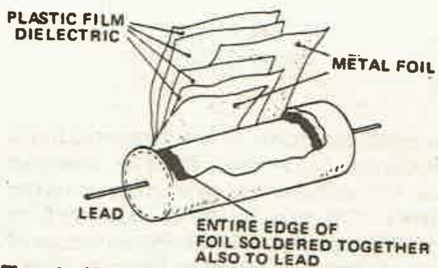


Fig. 4. How polystyrene capacitors are made

Paper Capacitors

Paper capacitors are medium loss, medium stability capacitors that were once widely used. They have been largely replaced by plastic film types for most purposes but are unsurpassed in high voltage dc and low frequency ac power applications.

There are two basic types of construction, the metal foil type and the metallized type. The metal foil type is constructed by winding together interleaved layers of foil and impregnated paper similar to plastic film capacitors, see Fig. 4. This type is best for high voltage and high current applications, a common form being the paper "block" capacitor. See Fig. 5. They are available in voltage ratings up to 4000 V and will withstand considerable charge-discharge currents. The metalized type has the impregnated paper dielectric coated with a thin layer of aluminium or zinc. This form of construction results in a capacitor of relatively smaller physical size.

The paper dielectric is impregnated with another dielectric substance to replace the water content inherent in paper and to prevent the absorption of moisture. A variety of natural oils or waxes, or synthetic chemicals, is used.

Encapsulation of the capacitor assembly is usually by moulding in resin or encasing in hermatically sealed metal cans as is done with block capacitors.

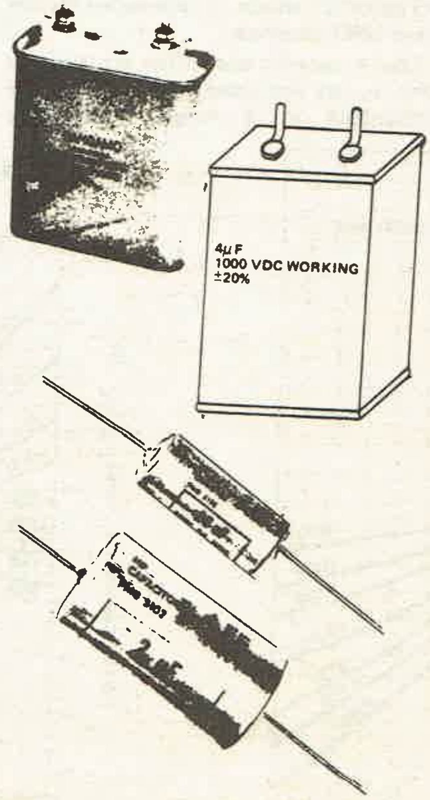


Fig. 5. Paper block capacitors

Plastic Film Capacitors

Plastic films are widely used in capacitor manufacture due to their high reliability and low cost. They have medium loss and medium stability characteristics except for polystyrene capacitors which have already been discussed. Many types of plastic film are used but these fall into three general groups:— polystyrene, polyester and polycarbonate.

The common form of construction uses strips of aluminium foil interleaved with the plastic film dielectric, alternate layers of foil being staggered to provide

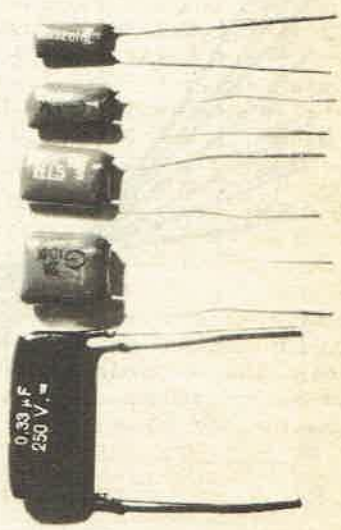


Fig. 6. Resin dipped polyester capacitors.

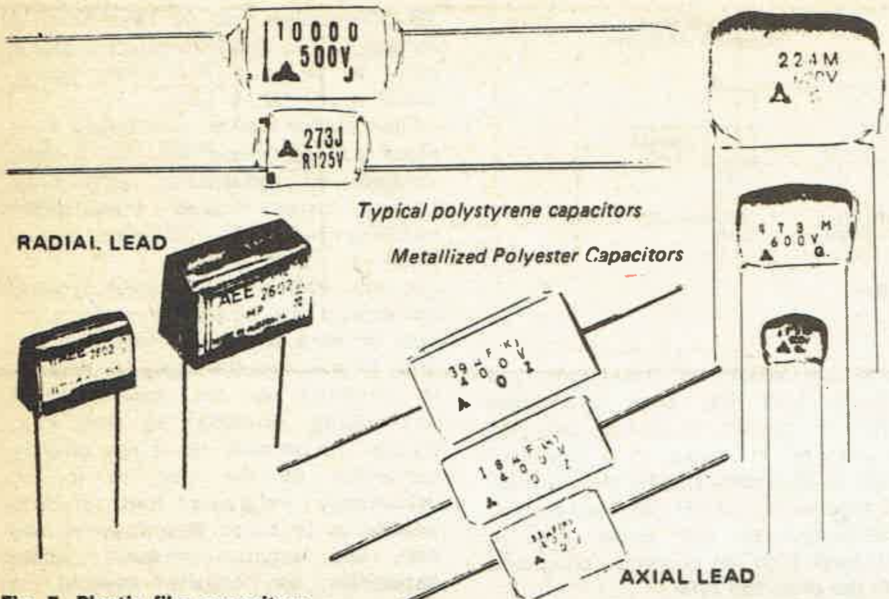


Fig. 7. Plastic film capacitors

lead connections. The assembly is then rolled-up to form a tubular-shaped capacitor. Some types are wound flat to form a flat rectangular-shaped capacitor which enables it to be packed more densely on a printed circuit board. They are referred to as 'flat film' capacitors.

Metallized film construction is also extensively used with plastic film capacitors, resulting in physically small dimensions. These capacitors have largely replaced paper capacitors in most low voltage applications owing to their superior electrical characteristics and considerably smaller size.

Plastic film capacitors are generally encapsulated in a tough, impervious plastic or resin or in a metal case.

The polyester films used are generally of the polyethylene type (Mylar, Melinex etc) or polypropylene, and for most purposes they have similar properties to polycarbonate films. The latter though, has less loss and exhibits less change in capacitance with temperature. Polyester capacitors are available in ratings up to 100 Vdc (or 250 V rms ac), Polycarbonate capacitors are usually only available in ratings up to 400 Vdc.

A small defect, such as a hole, in the dielectric of a capacitor will allow an arc between the electrodes when a sufficiently high voltage is present. In foil capacitors, the arc usually destroys more of the surrounding dielectric, resulting in catastrophic failure — usually a short circuit.

This disadvantage does not occur in metallized capacitors. The heat generated by the arc rapidly vaporizes the electrode section, clearing the short. A very short pulse of current occurs and the voltage across the capacitor drops and then rises again in a few microseconds. Usually, no further damage results. The process is illustrated in Fig. 8.

High-K Ceramic Capacitors

High-K ceramic capacitors provide large values of capacitance in a very

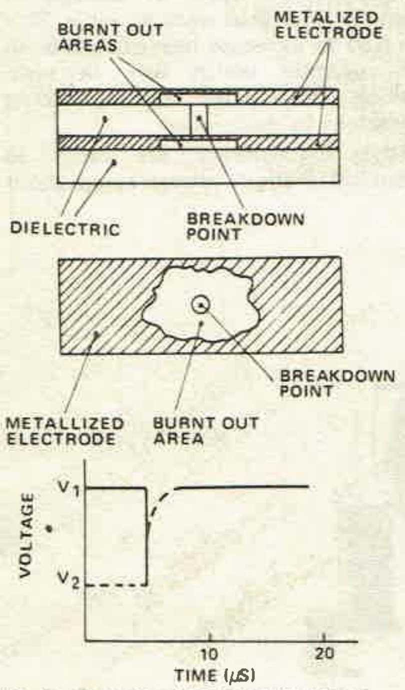


Fig. 8. Process of self healing of a metalized dielectric capacitor. The voltage trace is typical during the process.

small space. Owing to their method of manufacture they have appreciable loss and show large non-linear changes in capacitance with temperature. Primarily for these reasons they largely find application in bypassing and dc blocking. They change capacitance with applied dc and ac voltage, showing a decrease in capacitance with increasing dc voltage which ranges from 14% for the relatively low permittivity high-K ceramics to 80% for the higher permittivity ceramics. Ac voltage effects are the reverse of dc, giving an increase in capacitance with increasing voltage. This may be only 2% for the lower permittivity ceramic or up to 80% with the higher permittivity types.

High-K ceramic capacitors also change capacitance with frequency. The change is primarily dependent on the particular ceramic used, rather than high or low permittivity. They decrease in capacitance with increasing frequency. Most high-K capacitors only show a decrease of 5% between 1 kHz and 10 MHz, but others can drop 20% over the same range. These characteristics are usually of little consequence in most applications. However, care should be exercised in using them as bypass and decoupling capacitors around oscillator circuits. Plastic film capacitors or low-k disc ceramics are to be preferred.

In general, high-K ceramic capacitors have less internal inductance than plastic film or paper capacitors, as well as smaller size and are preferred in bypass applications. Disc or plate style ceramic capacitors are suitable for bypass applications from 10 MHz to 100 MHz. High-K ceramic capacitors are also made in button feedthrough and bypass styles for bypass applications to 1000 MHz. The tubular style is suitable in bypass applications to 50 MHz while the ceramic feedthrough is useful to 500 MHz. See Fig. 2 for illustrations. The large value (1000 pF – 0.47 μF) 'chip' or 'block' style, which has very low lead inductance, is very useful for bypassing in digital circuitry.

Electrolytic Capacitors

Electrolytic capacitors consist basically of two aluminium foils interleaved with an absorbent paper and wound tightly into a cylinder. Contacts are provided by tabs of aluminium attached to the foils. The winding is impregnated with electrolyte and housed in a suitable container, usually an aluminium can, which is hermetically sealed (Fig. 9).

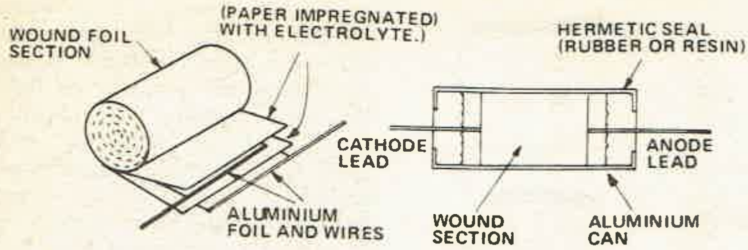


Fig. 9. Construction of typical electrolytic capacitor.

A dielectric layer of aluminium oxide is 'formed' electrolytically on the surface of one aluminium foil which acts as the positive plate, or anode, of the capacitor. The electrolyte serves as the second plate of the capacitor and also to repair any flaws in the oxide film when the electrolyte is polarised. The second foil, usually called the cathode foil, provides contact to the electrolyte. Since this film will have a thin oxide film, due to natural oxidation, it will also possess very high capacitance. The thinness of the oxide films, and their high breakdown potential, is responsible for the very high capictance values per unit volume and high working voltages of electrolytic capacitors.

As a result of their construction, these capacitors are polarised and require the anode terminal to be at a positive potential to the cathode terminal. Most types will only withstand a reverse voltage of 1 V or 2 V for short periods and about 1.5 V peak-to-peak ac without a depolarising voltage.

There are two types of electrolytic capacitor, the plain foil type and the etched foil type. The plain foil construction is described above. The etched foil type is constructed similarly to the plain foil except that the aluminium oxide on the anode and cathode foils has been chemically etched to increase its surface area and permittivity. It results in a capacitor which is physically smaller than a plain foil type of equivalent value but has the disadvantage of not being able to withstand high ac currents, compared with the plain foil type.

Etched foil electrolytics are best used in coupling, dc blocking and bypass applications. Plain foil types are better suited as reservoir capacitors in power supplies.

Tolerances

Electrolytic capacitors are usually manufactured to a tolerance of −20 +100% or −50 +100% (they really are!).

The capacitance value and leakage current both increase with temperature. The leakage current increases with applied dc voltage, this increase becoming more rapid at voltages in excess of the rated working value. This can lead to increased heat dissipation in the capacitor which will, in turn, increase the leakage current, leading ultimately to destruction

Most electrolytics are rated to withstand a short voltage surge about 15–20% greater than the rated working voltage. e.g: a capacitor rated at 450 V may be marked 450 VWdc (volts, working, dc), 525 V surge.

Electrolytics can be used below their rated voltage. There may be a slight increase of capacitance with time. Leakage current is usually considerably reduced, resulting in an increased service life.

In manufacture, the internal negative connection may be taken directly to the case or to a tag on the insulated end disc. In this case the capacitor winding is inserted in the case without surrounding insulation so that, even though the negative tag is not directly connected to the case, it is not deliberately insulated from it and leakage current can flow between the case and negative terminal. These capacitors are usually covered in shrunk-on plastic sleeve to insulate the can.

Electrolytic capacitors are made in a range of voltage ratings from 10 V to 600 V.

Non-Polarised Electrolytics

These capacitors are constructed using several foils in one winding and connected 'back-to-back'. They are usually larger than polarised capacitors of equivalent value. Since double the foil area than is normally required is used they have increased leakage current. Ac voltage without a dc polarising voltage is permissible, the value depending on ripple current ratings and the frequency.

These capacitors are used as speaker coupling and crossover network capacitors. They are obtainable in values from 1 μF to 100 μF.

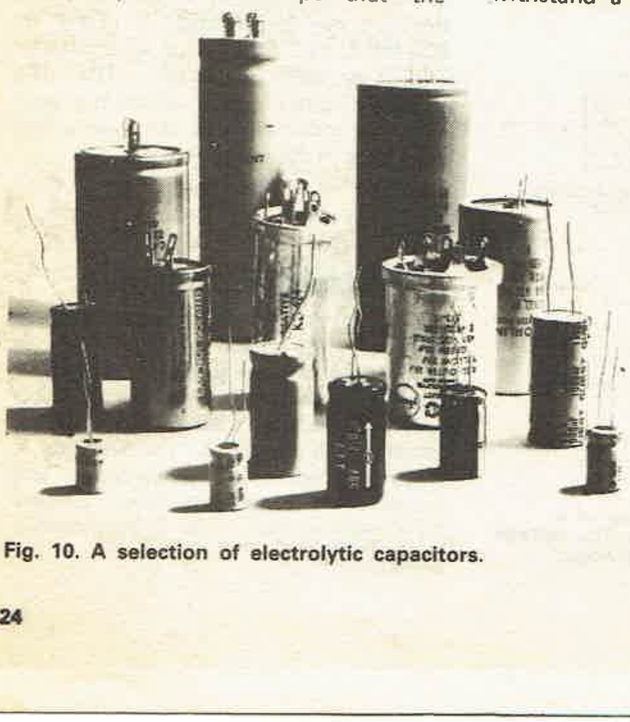


Fig. 10. A selection of electrolytic capacitors.

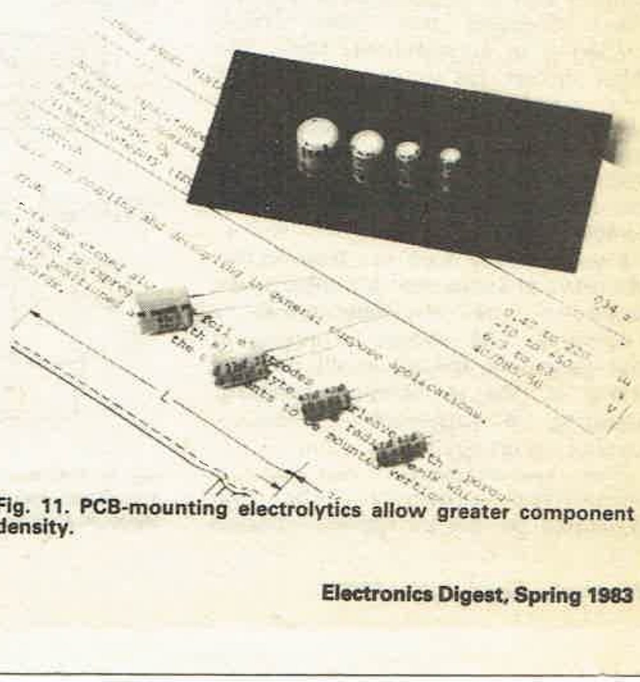


Fig. 11. PCB-mounting electrolytics allow greater component density.

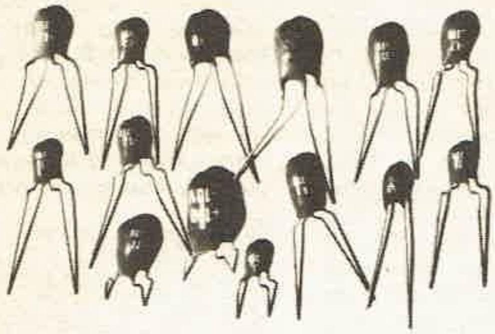


Fig. 12. Miniature tantalum capacitors have a small size and large capacity, but usually have a low working voltage.

Tantalum Capacitors

These capacitors use tantalum oxide as a dielectric. This has a much greater permittivity than aluminium oxide resulting in high value capacitance in relatively small space. Owing to their construction, they are also used as polarised capacitors.

There are three different types of tantalum capacitors, each having different construction. These are the tantalum foil type, the solid tantalum, and the wet-sintered tantalum. The tantalum foil type is similar in construction to electrolytic capacitors but the electrolyte and anode and cathode terminals use different materials.

Solid tantalum capacitors use solid maganese dioxide (which is a semiconductor) as the electrolyte, and a tantalum anode. The cathode connection is formed by coating the electrolyte with graphite and silver. These capacitors may be encapsulated in capacitors may be encapsulated in epoxy resin, polyester sleeve with epoxy seals, or a can with epoxy seals.

Tantalum capacitors are rated at much lower voltages than electrolytic capacitors. Their small size makes them very suitable for use in transistor circuits. Low leakage current and better capacitance stability than electrolytics are two features which make them suitable for timing applications.

Tantalum capacitors are generally available in values between 0.1 µF and 100 µF. Tolerance is usually +50% −20%. Solid tantalum capacitors are available in voltage ratings from 3 V to 100 V. Wet sintered tantalums are available up to 125 V rating and foil tantalums up to 450 V.

Variable Capacitors

Variable capacitors can be divided into two basic groups: continuously variable types, generally called tuning capacitors, and preset types, generally called trimmers.

Tuning capacitors have a set of fixed plates and a set of moving plates that mesh with the fixed plates. The position of the moving plates with respect to the fixed plates determines the capacitance. Capacitance is maximum when the plates are fully meshed. The dielectric may be air, mica or plastic film. Various tuning capacitors are shown in Fig. 1.3. Most tuning capacitors have air as the dielectric. Miniature tuning capacitors such as those used in portable transistor radios, have a plastic film dielectric. As this has a greater permittivity than air, a considerable reduction in size is achieved. Precision tuning capacitors such as those used in instruments and communications receivers have precision ball-race bearings at each end of the shaft and a heavy, rigid frame to provide stability and reset accuracy.

Tuning capacitors are available in various sizes and values for different applications. Those for receiver applications generally have small, closely-spaced plates, several units being "ganged" together in one frame so that several circuits may be tuned simultaneously. Two and three gang capacitors are quite common. The plates are often semi-circular or specially shaped to produce the desired tuning scale or "law". This is done to obtain linear or logarithmic dial calibrations for example.

There are four basic tuning characteristics.

Linear Capacitance For each degree of rotation there is an equal change in capacitance. For example, a capacitor may change by 2 pF for each degree of rotation. This produces a square-law dial scale.

Linear Frequency Each degree of rotation causes an equal change in frequency. This produces a linear dial scale. This characterisation is very useful in tuners and communication receivers.

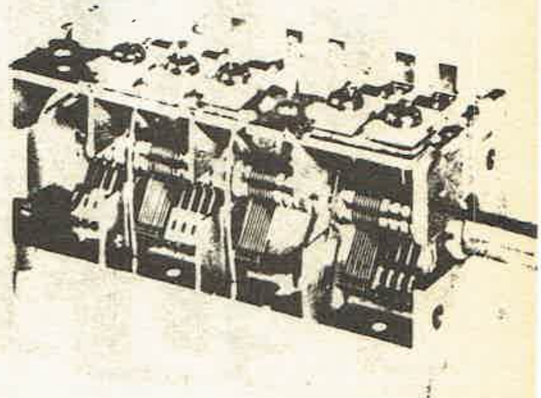
Log Frequency Each degree of rotation produces a constant percentage change in frequency, e.g. a 1% change in frequency for each degree of rotation. This produces a logarithmic dial scale which is sometimes seen on AM tuners and broadcast receivers. It is often used in measuring instruments and signal generators.

Square Law The variation in capacitance is proportional to the square of the angle of rotation. This is also used in measuring instruments. Typical dial calibrations and capacitor tuning law curves are shown in Fig. 15.

Multiple-gang capacitors are commonly used in superhet receivers, particularly AM and FM broadcast receivers, where the RF, mixer and

Fig. 13. Different types of variable capacitor used where the circuit requires continual readjustment.

Low capacitance, single section air dielectric variable capacitor.



Combined tuning gang for AM/FM receiver.

oscillator circuits are ganged to tune a range of frequencies. Usually, each section of a gang covers the same capacitance range and has the same tuning law. As the oscillator circuit covers a different frequency range from the RF and mixer, one section of a gang may have less plates and thus a different capacitance range or a slightly different tuning law. This is done so that the oscillator can correctly "track" the RF and mixer circuit with an almost constant frequency difference (the intermediate frequency).

Maximum and minimum capacitance values used for tuning the AM broadcast band and in general coverage HF receivers are:–

3 – 120 pF
10 – 240 pF
4 – 250 pF
6 – 340 pF
10 – 365 pF
11 – 415 pF

For the 88-108 MHz FM broadcast band, common values are:–

0.9 – 19 pF
1 – 22 pF
2 – 32 pF
7 – 40 pF

Some gangs may have each section fitted with trimmers so that the effect of stray capacitance may be compensated for and to provide alignment for the high frequency end of the tuning range.

Tuning capacitors for use in transmitters usually have large, widely-spaced plates to withstand high voltages, and special connections to reduce inductance and to conduct high RF currents. Semi-circular plates are commonly used. For push-pull tuned circuits, requiring two sets of fixed plates and common moving plates, 'butterfly' capacitors are used. See Fig. 14. The construction permits 90° rotation only. 'Split-Stator' capacitors are also used in this application: these have two sets of semi-circular rotor plates on opposite sides of a common shaft and two sets of stator plates with separate connections. These turn a full 180°.

Trimmers

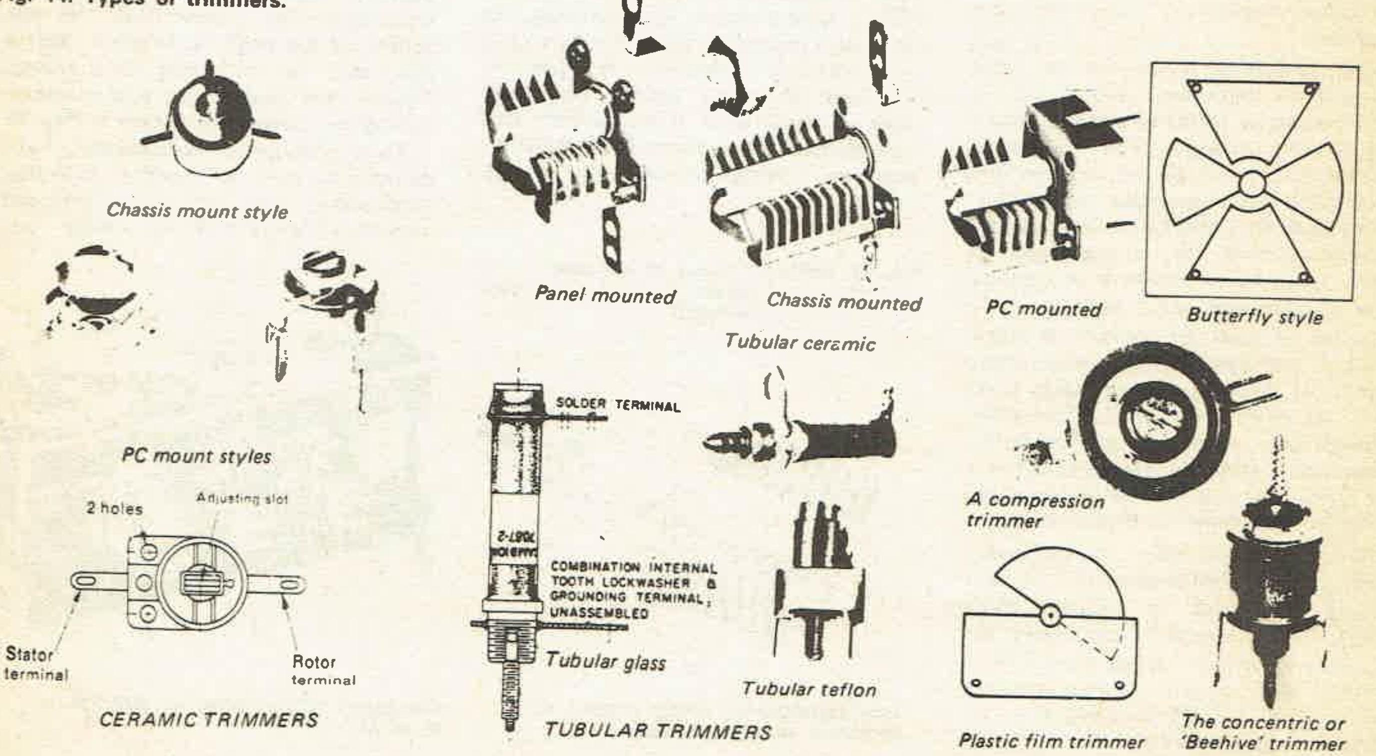
Trimming capacitors are available in a wide variety of constructions and adjustment methods. The most common dielectrics are air, mica and ceramic, although glass and quartz are also used for their superior temperature stability. A representative selection is illustrated in Fig. 14.

Vane Trimmers These trimmers have solid metal plates that may be silver-soldered to a rigid frame or the plates and frame milled from a single piece of specially shaped metal. The latter have better mechanical and electrical stability. The capacitor assembly is usually fixed to a ceramic mounting plate. This type of trimmer is usually more costly than other types but has superior electrical characteristics. Vane trimmers are available in a wide variety of values and sizes, with breakdown voltage ratings from 100 V to 1500 V, depending on the air gap between the fixed and moving plates. Butterfly and split-stator types can also be obtained.

Concentric or 'Beehive' Trimmers The fixed and moving plates of these trimmers are constructed from short sections of different diameter aluminium cylinders, nested inside each other and mounted concentrically around a central shaft. The diameters of the moving plates are such that they mesh between the fixed plates with a small air gap. The central shaft is threaded and a hexagonal boss on top of the moving plates enables capacitance to be adjusted by using a simple plastic tool. These trimmers are cheap and have a wide variety of applications. They are made in several values, the most common being 3-30 pF and 5-60 pF. Their breakdown voltage is usually above 250 V, although it is not *recommended* that they be operated at high voltages. The threaded centre shaft imparts a vernier action which makes adjustment easy and accurate.

Compression Trimmers These consist of several thin plates of springy metal interleaved with a mica or plastic film

Fig. 14. Types of trimmers.



dielectric. An insulated screw is passed through the centre of the plates and threaded into a phenolic, plastic or ceramic mounting compressing the springy plates. The further the screw is turned in, the more compression is applied to the plates, thus increasing the capacitance. Trimmers of this type are usually quite inexpensive. Their stability is not very good but is nevertheless adequate for many applications, but they drift appreciably with time necessitating frequent realignment.

Mica compression trimmers are generally constructed on a ceramic mount. They have the best characteristics of all the compression trimmers and find application in solid state transmitters as they can withstand appreciable RF currents. Some types are manufactured especially for this application. The other styles having a phenolic or plastic mount are used mostly in receiver or non-critical instrument applications.

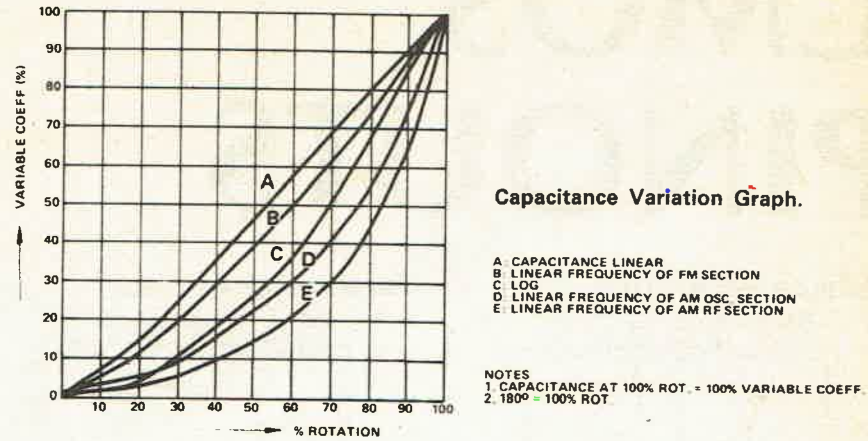
Compression trimmers are capable of quite a wide adjustment range — an advantage over other trimmers, although the adjustment may be coarse and quite non-linear. Typical minimum and maximum values are:—

2 – 25 pF
3 – 30 pF
2.5 – 40 pF
3 – 55 pF
10 – 80 pF
30 – 150 pF
20 – 220 pF

Compression trimmers have a large, and not really predictable temperature co-efficient that varies appreciably over their range. Their breakdown voltage is in the order of 100 V to 300 V.

Plastic Film Trimmers. These are constructed in a way similar to vane trimmers and generally have semi-circular fixed and moving plates with a plastic film dielectric. Consequently they are smaller in size for similar values. These trimmers are relatively inexpensive and are a good alternative to air dielectric trimmers. They generally have a negative temperature coefficient of about 200 ppm/°C (decrease capacitance with increasing temperature). They are generally manufactured for p.c. board mounting although chassis-mounting styles are available. Typical minimum and maximum values are:—

1 – 5 pF
1.8 – 10 pF
2 – 18 pF
1.5 – 20 pF
4 – 40 pF
5 – 60 pF
7 – 100 pF



Capacitance Variation Graph.

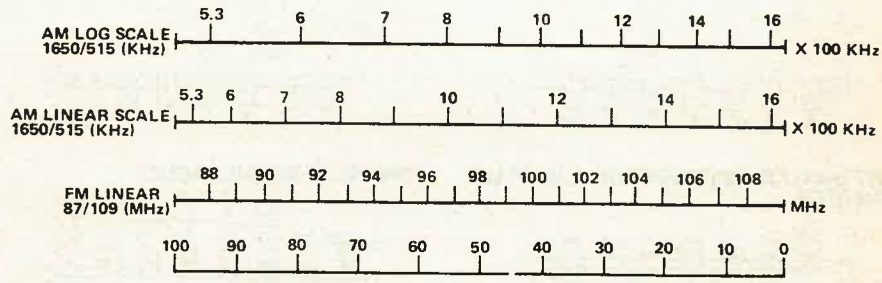


Fig. 15. The standard dial formats.

Film dielectric trimmers generally have a breakdown voltage of 100 V.

Ceramic Trimmers. These consist of a ceramic body with a semi-circular metal film deposited on it as the fixed plate. The moving plate is a ceramic disc with a semi-circular film (the same size as the fixed plate) deposited on it, and pivoted over the fixed plate by a metal screw which is soldered to the metal film. The screw passes through a nut in the ceramic body, the moving plate connection being made to this nut.

Ceramic trimmers are available having a variety of temperature characteristics ranging from P 100 to N 500, the more common values having negative temperature coefficients. Typical maximum and minimum values and temperature coefficients are:—

2 – 4 pF/P100
3 – 9 pF/N033 or N075*
3 – 12 pF/N 470
4 – 20 pF/N 470 or N 750*
7 – 35 pF/N 1500
10 – 60 pF/N 1500

* Characteristic depends on size, the subminiature ones having the smaller coefficient. Ceramic trimmers are obtainable in pc board or chassis mounting styles and may be operated at voltages of at least 200 V or greater.

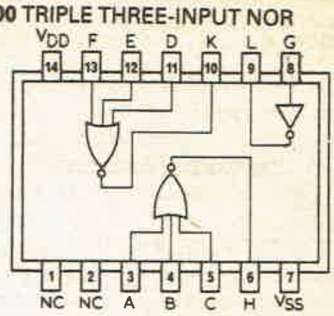
Tubular Trimmers. Tubular trimmers are also known as 'piston' trimmers. They consist of a tube of dielectric material which has a metal band or metal film around one end forming the fixed plate and a threaded metal cap on the other, through which passes a screw; this latter assembly forms the moving plate. The dielectric material may be ceramic, glass, PTFE (Teflon), polypropylene or quartz. Tubular trimmers are very stable but are used only in VHF/UHF receiver applications (i.e. TV tuners, VHF converters as their particular construction limits the maximum capacitance obtainable. However, ceramic, glass and quartz types can withstand considerable RF currents and voltages, so find some applications in transmitters. Typical working voltages are 250 Vdc to 600 Vdc. Tubular trimmers with a plastic dielectric are generally cheapest, the more costly styles being ceramic, glass and quartz. Typical maximum and minimum values are:—

0.25 – 1.5 pF
0.7 – 3 pF
0.8 – 8.5 pF
1.8 – 10 pF
0.8 – 12 pF
0.8 – 23 pF
0.8 – 38 pF
2 – 60 pF

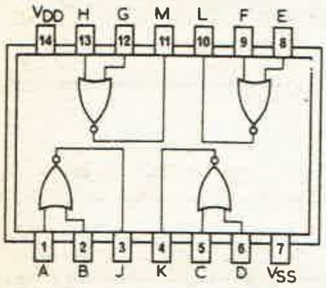
Both printed circuit and chassis mounting styles are available.

CMOS PINOUTS

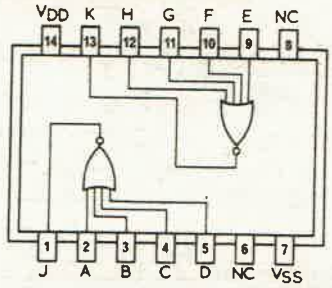
4000 TRIPLE THREE-INPUT NOR



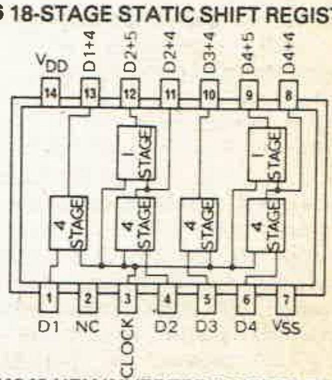
4001 QUAD TWO-INPUT NOR



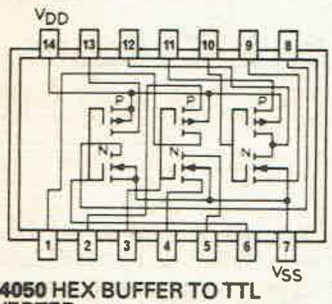
4002 DUAL FOUR-INPUT NOR



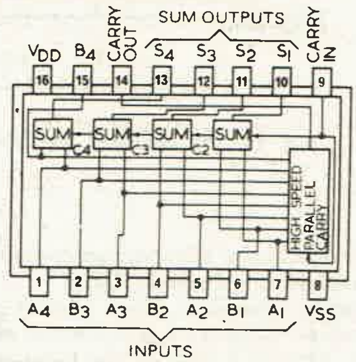
4006 18-STAGE STATIC SHIFT REGISTER



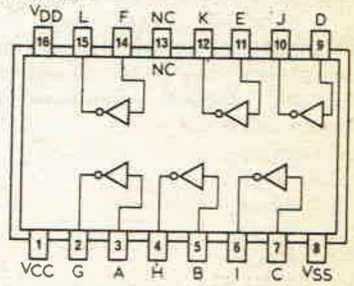
4007 DUAL COMPLEMENTARY PAIR PLUS INVERTER



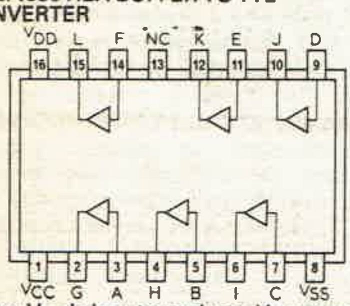
4008 FOUR-BIT FULL ADDER



4009/4049 HEX INVERTER/BUFFER TO TTL CONVERTER

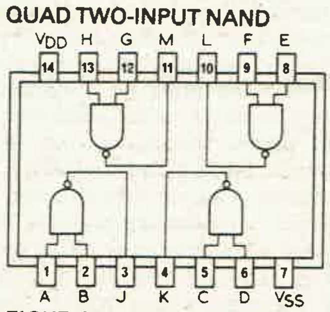


4010/4050 HEX BUFFER TO TTL CONVERTER

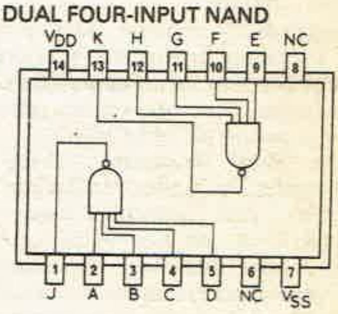


Note: V_{DD} is input supply and is not used on 4049/4050; V_{CC} supplies output circuitry, plus input on 4049/4050

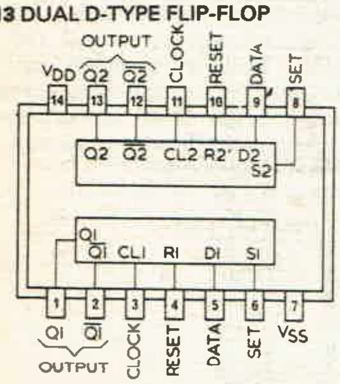
4011 QUAD TWO-INPUT NAND



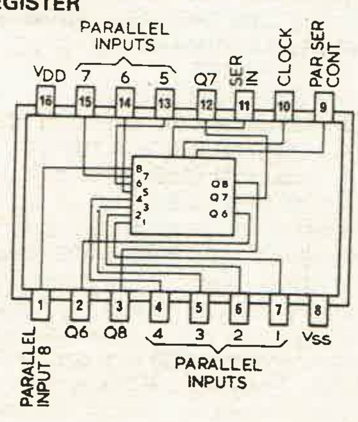
4012 DUAL FOUR-INPUT NAND



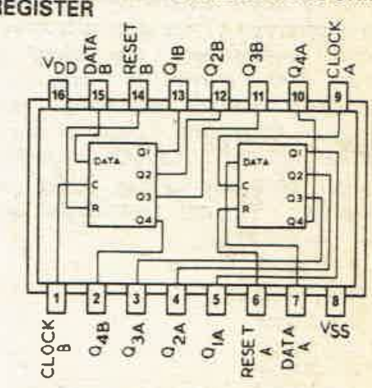
4013 DUAL D-TYPE FLIP-FLOP



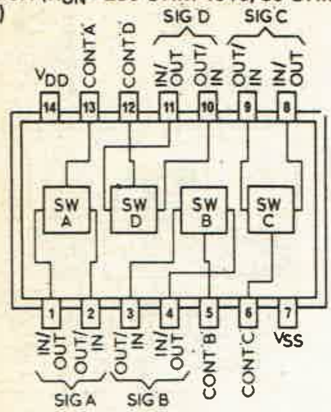
4014 EIGHT-STAGE STATIC SHIFT REGISTER



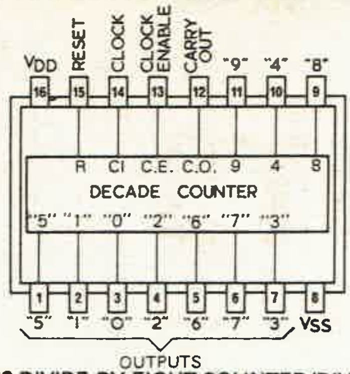
4015 DUAL FOUR-STAGE STATIC SHIFT REGISTER



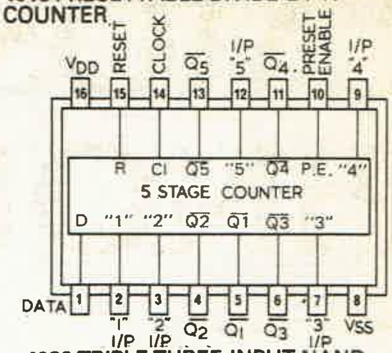
4016/4066 QUAD BILATERAL ANALOGUE SWITCH (R_{ON}=280 OHM 4016, 80 OHM 4066)



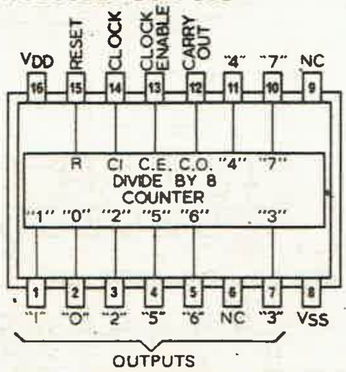
4017 DECADE COUNTER/DIVIDER



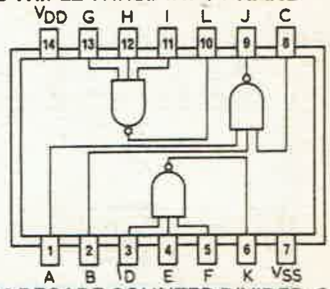
4018 PRESETTABLE DIVIDE-BY-N COUNTER



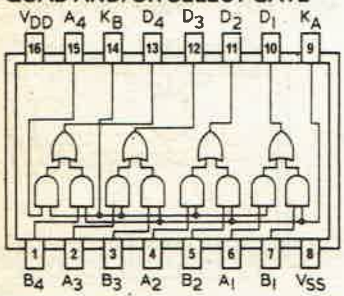
4022 DIVIDE-BY-EIGHT COUNTER/DIVIDER WITH DECODED OUTPUTS



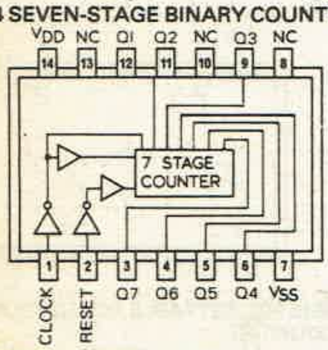
4023 TRIPLE THREE-INPUT NAND



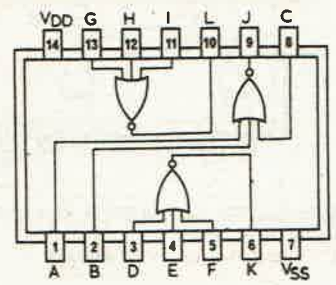
4019 QUAD AND/OR SELECT GATE



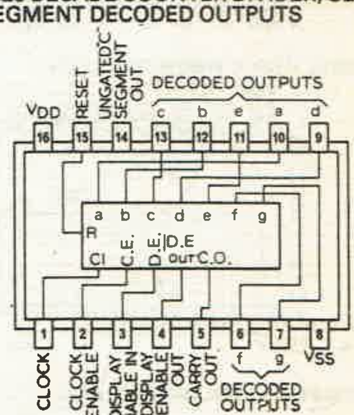
4024 SEVEN-STAGE BINARY COUNTER



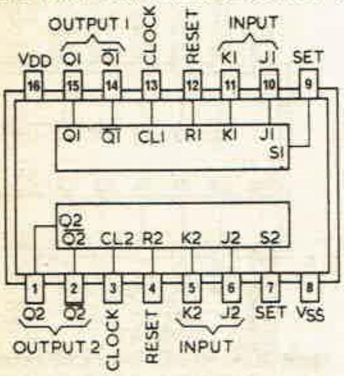
4025 TRIPLE THREE-INPUT NOR



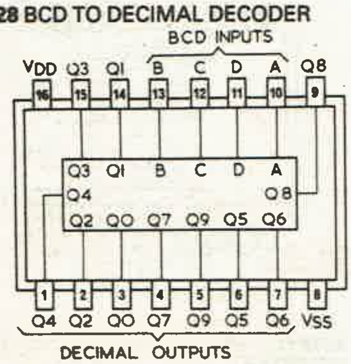
4026 DECADE COUNTER DIVIDER, SEVEN-SEGMENT DECODED OUTPUTS



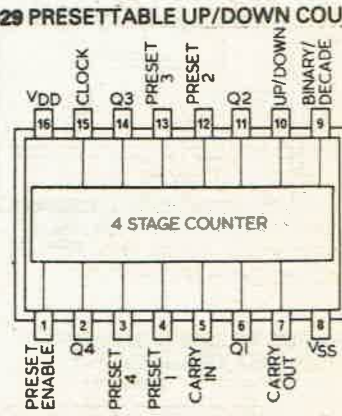
4027 DUAL J-K MASTER-SLAVE FLIP-FLOP



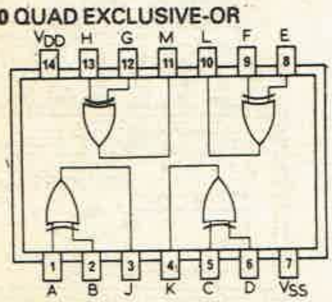
4028 BCD TO DECIMAL DECODER



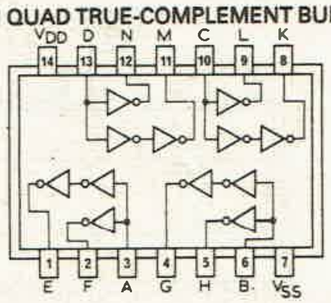
4029 PRESETTABLE UP/DOWN COUNTER



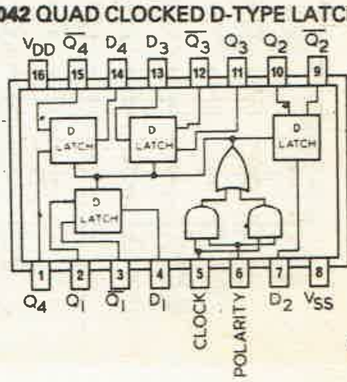
4030 QUAD EXCLUSIVE-OR



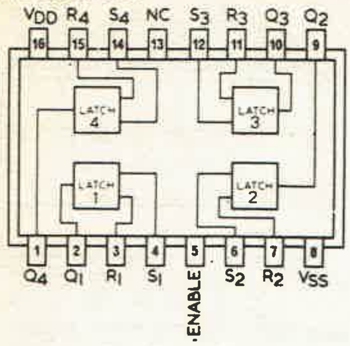
4041 QUAD TRUE-COMPLEMENT BUFFER



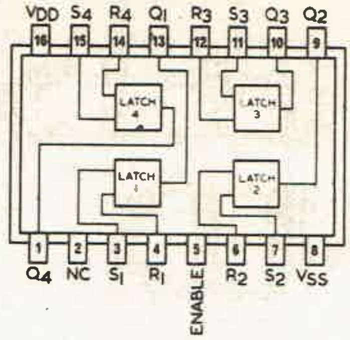
4042 QUAD CLOCKED D-TYPE LATCH



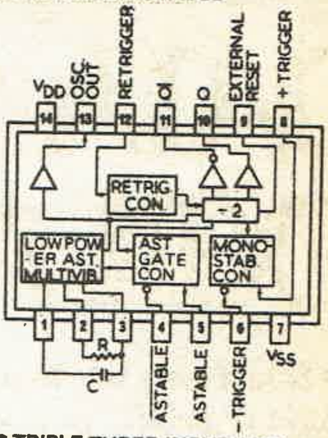
4043 QUAD NOR R/S LATCHES WITH TRI-STATE OUTPUTS



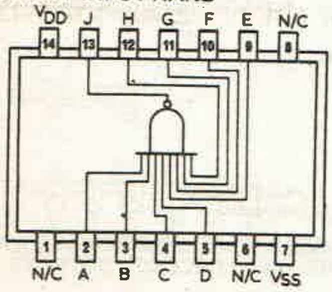
4044 QUAD NAND R/S LATCHES WITH TRI-STATE OUTPUTS



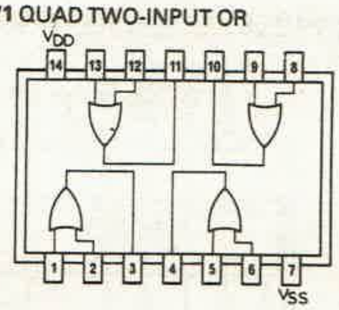
4047 LOW-POWER MONOSTABLE/ASTABLE



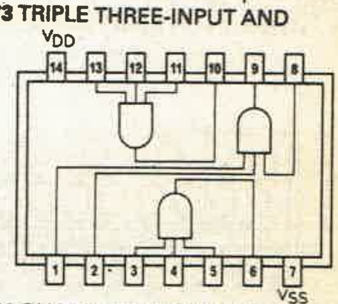
4068 EIGHT-INPUT NAND



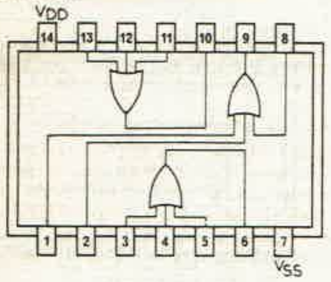
4071 QUAD TWO-INPUT OR



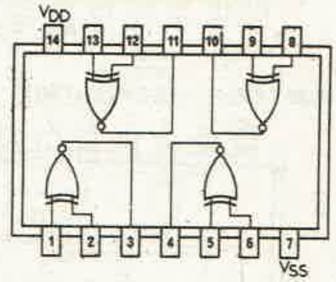
4073 TRIPLE THREE-INPUT AND



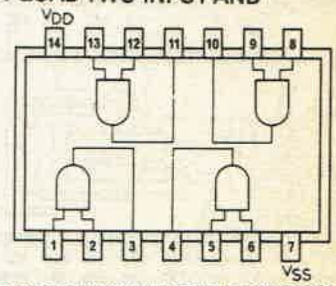
4075 TRIPLE THREE-INPUT OR



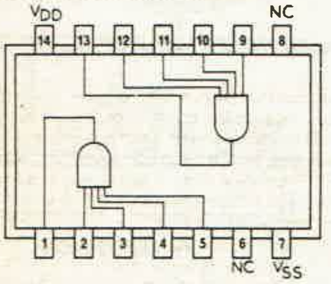
4077 QUAD EXCLUSIVE-NOR



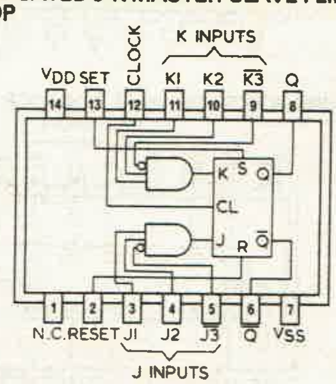
4081 QUAD TWO-INPUT AND



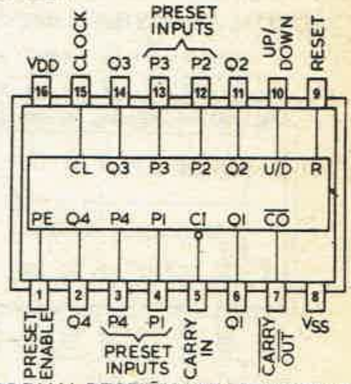
4082 DUAL FOUR-INPUT AND



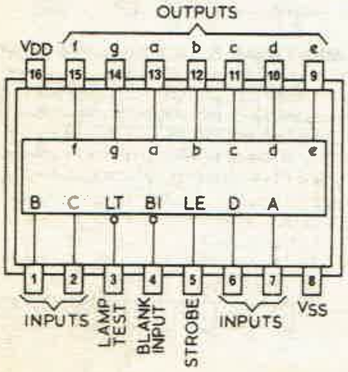
4096 GATED J-K MASTER-SLAVE FLIP-FLOP



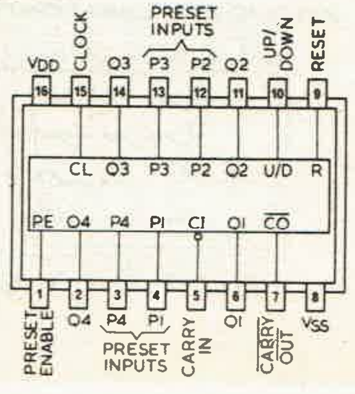
4510 PRE-SETTABLE BCD UP/DOWN COUNTER



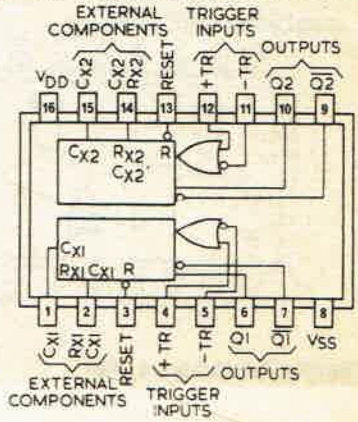
4511 BCD TO SEVEN-SEGMENT LATCH/DECODER/DRIVER



4516 PRE-SETTABLE BINARY UP/DOWN COUNTER



4528 DUAL RESETTABLE MONOSTABLE



DATA SHEETS EXPLAINED

The data sheets which we publish regularly are very popular, but from time to time we receive requests for a fairly simple explanation of the terms and abbreviations which one finds in semiconductor device data sheets, and so here it is!

THE INFORMATION contained in semiconductor device data sheets is often grossly misunderstood. Great care must be taken to ensure that the exact meaning of a term or abbreviation is clear. As an example, we can quote the following conversation which actually occurred between two people who should both have known better.

A representative of a semiconductor distributor was showing data on a new power device to a lecturer. The lecturer said that the device data was wrong, since the maximum collector current was quoted as 12A and the maximum collector-emitter voltage (V_{CEO}) as 80V; this is a power level of 12 × 80 = 960W, but the maximum permissible dissipation quoted in the data sheet is only 90W. The representative could provide no answer!

The data was, of course, perfectly correct. The problem arose because neither of the people concerned had appreciated the exact meaning of V_{CEO} which signifies the collector-emitter voltage *with the base open circuited*. Under these conditions (with zero base current) the collector current will be very small and the power dissipation in the transistor will also be quite small. Thus there is a great deal of difference between V_{CE} (the collector-emitter voltage under any conditions) and V_{CEO} (the collector-emitter voltage with the base open circuited). If still more information is required, one must look into the SOAR (Safe Operating ARea) graph to ascertain the regions of the collector voltage/collector current curve where the device can be safely operated for limited or unlimited times.

This is a very simple example of the pitfalls one can encounter if one does not really understand the *exact* meanings of the terms and abbreviations used in data sheets. Such misunderstandings are very common, but not (we hope!) amongst the devices covered in our data sheets, since it is equally important that our readers understand the exact meanings of abbreviations used in data sheets on relatively simple devices such as ordinary diodes and transistors.

Letter Symbols

Three of the most important symbols used in semi-conductor device data sheets are V, I and P for voltage, current and power respectively. Various subscripts are added to these three letters to indicate the electrode(s) to which the symbol is being applied and possibly certain circuit conditions. Some of the most commonly used subscripts are listed below.

A	anode
AV	average
B	base
BO	breakover
BR	breakdown
C	collector
D	drain or delay
E	emitter
F	forward
G	gate
H	holding
I	input
J	junction
K	cathode
M	peak value of a quantity
O	open circuit or output
R	reverse or repetitive
S	source, short circuit, series or shield
T	in the on state (that is, triggered)
W	working
X	specified circuit
Z	impedance

Order of subscripts

In most cases more than one subscript is needed; the subscripts are usually placed in a definite order governed by the following rules.
The first subscript indicates the electrode at which the current or voltage is measured.
The second subscript denotes the reference terminal or circuit mode. (This subscript is often omitted if it is felt no ambiguity will arise.)

Thus i_E is the instantaneous value of the total emitter current, i_e the instantaneous value of the alternating component of the emitter current, and $I_{E(AV)}$ the average (DC) value of the total emitter current. Other subscripts can be used in a similar way, I_F being the forward DC current with no signal, i_F the instantaneous forward current and I_{FM} the peak forward current.

The letter O may be used as a third subscript to show that the electrode not indicated by any previous subscript is open circuited. Similarly the letter S can be used as a third subscript to show the third electrode is shorted to the reference electrode of the second subscript, whilst the letter R as a third subscript indicates that a specified resistance is connected between the third electrode and the reference electrode.
The supply voltage to a collector is indicated as V_{CC}, the second suffix being a repetition of the first in the case of supply voltages. Similarly, one often meets the symbol V_{DD} for the positive supply to a CMOS (or COS/MOS) device, this being the supply to the drain. The negative supply to CMOS devices is normally represented by the symbol V_{SS}.

It should now be clear why V_{CEO} is the steady collector emitter voltage with the base open circuited. Similarly I_{CER} is the collector cut off current with a specified resistance between the base and emitter. It is current with the base and emitter joined, since either the base or emitter can be used as the reference electrode without any change when they are joined.

The parameters of individual devices vary from one device to another of the same type number. The typical value of a parameter such as transistor current gain is often quoted in data sheets by the abbreviation 'typ' after the quantity, but minimum and maximum values are also often quoted. In economical devices no maximum and minimum values may be quoted. In the case of breakdown voltages the minimum value applicable to any device of that type number is usually quoted so that the circuit designer knows that he can apply that value of voltage without danger of the device junction breaking down.

The above discussion gives the general principles of the way in which the symbols for various parameters are chosen. It is not complete, since we have not yet covered such items as current gain of a transistor or thermal characteristics of a device. However, these and other quantities will be covered in the following tables.

Thermal characteristics

The symbols used for the following thermal quantities apply to all types of semiconductor device.

- P_{tot} total power dissipated within the device
- T_{amb} ambient temperature
- T_c temperature of the case of the device
- T_j temperature of the junction in the semiconductor material
- T_{mb} temperature of the mounting base of the device ($=T_c$)

- T_{stg} storage temperature
- θ_h thermal resistance of heat sink. (Units. C/W)
- θ_i contact thermal resistance between the case of the device and the heat sink
- θ_{j-amb} junction to ambient thermal resistance
- θ_{j-c} junction to case thermal resistance

Symbols used mainly with diodes

- C_d diode capacitance with reverse bias
- C_f diode capacitance with forward bias
- C_j capacitance of the junction itself
- C_{min} minimum capacitance (which occurs at the rated breakdown voltage)
- C_o diode capacitance at zero bias
- f_{co} cut off frequency of a varactor diode
- I_F total dc forward current
- i_F instantaneous forward current
- $I_{F(AV)}$ average forward current
- I_{FM} peak forward current
- I_{FRM} repetitive peak forward current
- I_{FSM} non-repetitive peak forward current occurring under surge conditions
- I_R continuous reverse leakage current
- i_R instantaneous reverse leakage current
- I_{RRM} repetitive peak reverse current
- I_{RSM} non-repetitive peak reverse current
- I_Z zener diode continuous operating current
- I_{ZM} zener diode peak current
- t_{on} turn on time
- t_{off} turn off time
- t_r rise time
- t_{rr} reverse recovery time
- t_s storage time
- V_F steady forward voltage
- v_F instantaneous forward voltage
- V_R steady reverse voltage
- v_R instantaneous value of the reverse voltage
- V_{RM} peak reverse voltage
- V_{RRM} repetitive peak reverse voltage
- V_{RSM} non-repetitive peak reverse voltage (on surges)
- V_Z zener diode working voltage

Symbols used mainly with transistors

- C_{ob} transistor output capacitance in the grounded base circuit
- C_{oe} transistor output capacitance in the grounded emitter circuit
- f_T transition frequency or gain-bandwidth product in common emitter circuit
- h_{FE} (h_{FB}, h_{FC}) current gain in the grounded emitter circuit (or in the grounded base or grounded collector circuit)
- h_{fe} the increase in collector current divided by the small increase in the base current which produces it. (Small signal current gain.)
- I_B, I_C or I_E the steady base, collector or emitter current
- $I_{B(AV)}$, $I_{C(AV)}$ or $I_{E(AV)}$ the average value of the base, collector or emitter current
- I_{CEX} collector cut-off current in a specified circuit
- I_{CM}, I_{BM} or I_{EM} peak value of collector, base or emitter current
- I_b, I_c or I_e rms value of the alternating component of the current
- I_{bm}, I_{cm} or I_{em} peak value of the alternating component of the current
- i_C, i_B or i_E instantaneous value of the total current
- i_c, i_b or i_e instantaneous value of the alternating component of the current
- I_{CBO} collector cut off current with the emitter open circuited
- I_{CBS} or I_{CES} collector cut off current with emitter shorted to the base
- I_{CEO} collector cut off current with the base open circuited
- I_{CER} collector cut off current with a specified value of resistance between the base and the emitter
- I_{EBO} emitter cut off current with the collector open circuited
- $V_{BE(SAT)}$ base-emitter saturation voltage
- $V_{(BR)}$ breakdown voltage
- $V_{(BR)CBO}$ collector to base breakdown voltage with emitter open circuited
- $V_{(BR)CEO}$ collector to emitter breakdown voltage with base open circuited
- V_{CB} collector-base voltage
- V_{CBO} collector to base voltage with emitter open circuited
- V_{CC} collector supply voltage
- V_{CE} collector to emitter voltage
- V_{CEO} collector to emitter voltage with base open circuited
- V_{ce} collector to emitter rms voltage
- $V_{CE(SAT)}$ collector to emitter saturation voltage
- V_{EB} emitter-base voltage
- V_{EBO} emitter-base voltage with collector open circuited
- V_{eb} emitter-base rms voltage

Symbols used mainly with FETS

- I_D steady value of the drain current
- I_{DSS} steady value of the drain current with the gate connected to the source
- I_m peak drain current
- I_G steady gate current
- I_S steady source current
- r_{DS} drain to source (or channel) resistance
- V_{DS} steady drain to source voltage
- V_{GS} steady gate to source voltage

Symbols used mainly with thyristors

- I_{FRM} repetitive peak forward current
- I_{FSM} non-repetitive peak (surge) current
- I_{GD} gate current which does not trigger the device
- I_{GT} gate trigger current
- I_{GO} gate turn off current
- I_H holding current required to maintain conduction
- I_R steady reverse leakage current
- I_{RG} reverse gate current
- I_{RRM} repetitive peak reverse current
- I_{RSM} non-repetitive peak reverse current (in surge conditions)
- I_T steady anode-cathode 'ON' state current
- P_G gate power
- t_{gt} gate controlled turn-on time
- t_{gq} gate controlled turn-off time
- $V_{(BO)}$ breakover voltage
- V_D continuous off state voltage
- V_{FG} forward gate voltage
- V_{GT} gate trigger voltage
- V_R steady reverse voltage

Operational amplifier terms

Bandwidth, Δf. The frequency at which the gain falls by a factor of 0.7 relative to the gain at low frequencies

Common mode rejection ratio, CMMR. The gain when a signal is applied to one of the inputs of the amplifier divided by the gain when the signal is applied to both the inverting and non-inverting inputs. It is usually expressed in dB.

Frequency compensation. An operational amplifier requires a capacitor to enable it to be used in circuits which are stable over a wide frequency range. Internally compensated operational amplifiers have this capacitor fabricated on the silicon chip, but an external capacitor must be used with other types of operational amplifier which do not contain an internal capacitor.
Input bias current, I_{BIAS}. The mean value of the currents at the two inputs of an operational amplifier.
Input offset current, I_{OS}. The difference in the two currents to the inputs of an operational amplifier. Normally much smaller than the input bias current.
Input offset voltage, V_{OS}. The voltage which must be applied between the two input terminals to obtain zero voltage at the output.
Open loop voltage gain, A_{VOL}. The amplifier gain with no feedback applied.
Output resistance, R_O. The small signal resistance seen at the output when the output voltage is near zero.

Voltage regulator terms

Dropout voltage, V_{DO}. When the difference between the input and output voltages falls down below the dropout voltage, the device ceases to provide regulation.
Foldback current limiting. In regulators with foldback current limiting, the current will 'fold back' to a fairly small value when the output is shorted.
Line regulation. The change in the output voltage for a specified change in the input voltage.
Load regulation. The change in output voltage for a change in the load current at a constant chip temperature.
Quiescent current, I_Q. The current taken by the regulator device when it is not delivering any output current.
Ripple rejection. The ratio of the peak-to-peak ripple at the input of the regulator to that at the output. Normally expressed in dB.

Monolithic timer terms

Comparator input current. The mean current flowing in the comparator input connection during a timing cycle.
Timing capacitor, C_t. This capacitor is normally connected between the comparator input and ground. The time taken for it to charge controls the delay time.
Timing resistor, R_t. This is the resistor through which the timing capacitor charges.
Trigger current. The current flowing in the trigger input connection, at the specified trigger voltage.
Trigger voltage. The voltage required at the trigger pin to initiate a timing cycle.

Conclusions

Data sheets must be used intelligently and with much thought. Information on the conditions under which an entry in the data sheet is applicable is often stated in small print, but is of great importance. Data should always be thoroughly studied before a device is used for the first time, only then will you be able to fully understand the potential applications of the device.

DIODES

Types Note that we have generally stuck to general purpose, switching, and rectifier diodes, though a few of other types have been included.

Mat Material: G = germanium, S = silicon; other materials can be used for diodes as well.

PIV Peak inverse volts.

I_m Maximun mean current through the diode for a sustained period.

I_p Maximum peak current through the diode for a transient period, normally specified as one cycle for rectifiers.

C Diode capacitance, normally specified at zero volts.

I_r Maximum reverse current, specified at a particular reverse voltage, often PIV; specified at 25 deg. C or, when indicated by an asterisk, higher.

Use/ Additional data Very rough indication of usage; additional data are recovery time for switching diodes, maximum voltage drop at specified current for rectifiers.

Type	Mat	PIV (V)	I_m (A)	I_p (A)	C (pF)	I_r@ V uA @ V	Use/Additional data (see notes)
1N34	G	60	50 m	500 m	-	30 @ 10	General purpose
1N34A	G	60	50 m	500 m	-	30 @ 10	General purpose
1N821	S	-	-	-	-	-	6V2 Zenner
1N823	S	-	-	-	-	-	6V2 Zenner
1N914	S	75	75 m	-	4	5 @ 20	Switching/ 4 nS
1N916	S	75	75 m	-	2	5 @ 20	Switching/ 4 nS
1N1190	S	600	35	500	-	10 m @ 600*	Rectifier/ 1V7 @ 35 A
1N4001	S	50	1	30	-	10 @ 50	Rectifier/ 1V6 @ 1 A
1N4002	S	100	1	30	-	10 @ 100	Rectifier/ 1V6 @ 1 A
1N4003	S	200	1	30	-	10 @ 200	Rectifier/ 1V6 @ 1 A
1N4004	S	400	1	30	-	10 @ 400	Rectifier/ 1V6 @ 1 A
1N4005	S	600	1	30	-	10 @ 600	Rectifier/ 1V6 @ 1 A
1N4006	S	800	1	30	-	10 @ 800	Rectifier/ 1V6 @ 1 A
1N4007	S	1k	1	30	-	10 @ 1k	Rectifier/ 1V6 @ 1 A
1N4008	G	12	100 m	-	1	25 @ 12	Switching/ 70 nS
1N4009	S	25	-	-	4	100n @ 25	Switching/ 4 nS
1N4148	S	75	75 m	-	4	25n @ 20	Switching/ 4 nS
1N4150	S	50	-	-	2.5	100n @ 50	Switching/ 6nS
1N4448	S	75	-	-	4	25n @ 20	Switching/ 4 nS
1N4517	S	200	2	150	-	100 @ 200	Rectifier/ 1V2 @ 2 A
1N5172	S	100	2	200	-	10 @ 100	Rectifier/ 1V3 @ 3 A
1N5176	S	600	2	200	-	25 @ 600	Rectifier/ 1V2 @ 2 A
1N5400	S	50	3	200	-	500 @ 50*	Rectifier/ 1V2 @ 3 A
1N5401	S	100	3	200	-	500 @ 100*	Rectifier/ 1V2 @ 3 A
1N5402	S	200	3	200	-	500 @ 200*	Rectifier/ 1V2 @ 3 A
1N5403	S	300	3	200	-	500 @ 300*	Rectifier/ 1V2 @ 3 A
1N5404	S	400	3	200	-	500 @ 400*	Rectifier/ 1V2 @ 3 A
1N5406	S	600	3	200	-	600 @ 500*	Rectifier/ 1V2 @ 3 A
1N5407	S	800	3	200	-	500 @ 800*	Rectifier/ 1V2 @ 3 A
1N5408	S	1k	3	200	-	500 @ 1k*	Rectifier/ 1V2 @ 3 A
1N5624	S	200	3	125	-	300 @ 200	General purpose
1N5625	S	400	3	125	-	300 @ 400*	General purpose
1N5626	S	600	3	125	-	200 @ 600*	General purpose
1N5627	S	800	3	125	-	200 @ 800*	General purpose
1S44	S	40	75 m	-	6	50 @ 10	Switching/ 6 nS
BA102	S	20	-	-	-	-	Varicap, typ 20 p to 45 p range
BA133	S	1k	50 m	-	-	1 @ 1k	Rectifier/ 1V1 @ 100 mA
BA138	S	30	-	-	-	-	Varicap, typ 3p8 to 5p5 range
BA145	S	300	300 m	1	4	2 @ 300	General purpose
BA157	S	400	-	-	-	5 @ 400	Switching/ 500 nS
BA158	S	600	-	-	-	5 @ 600	Switching/ 300 nS
BA159	S	1k	-	-	-	5 @ 1k	Switching/ 500nS
BA182	S	35	-	-	-	100 @ 20	General purpose
BA201	S	50	150 m	-	4	100 @ 30	Switching/ 4 nS
BA202	S	75	150 m	-	4	100 @ 50	Switching/ 4 nS

Type	Mat	PIV (V)	I_m (A)	I_p (A)	C (pF)	I_r @ V (uA @ V)	Use/Additional data (see notes)
BA243	S	20	100 m	-	-	100 @ 15	VHF Switching/
BA316	S	10	100 m	-	3	200 @ 10	Switching/ 4 nS
BA317	S	30	10 m	-	3	200 @ 30	Switching/ 4nS
BA318	S	50	10 m	-	3	200 @ 50	Switching/ 4 nS
BAV10	S	60	400 m	-	2.5	100 @ 60	Switching/ 6 nS
BAV19	S	120	250 m	-	1.5	100 @ 125	Switching/ 50 nS
BAV20	S	200	250 m	-	1.5	100 @ 200	Switching/ 50 nS
BAV49	S	35	50 m	-	2	50 p @20	Switching/ 30 nS
BAX13	S	50	75 m	-	3	25 @ 10	Switching/ 4 nS
BAX16	S	150	200 m	-	10	100 @ 150	Switching/ 70 nS
BY126	S	650	1	150	-	10 @ 650*	Rectifier/ 1V5 @ 5 A
BY127	S	800	1	40	-	10 @ 1k2	Rectifier/ 1V5 @ 5A
BY134	S	600	1	50	-	5 @ 650	Rectifier/ 1V3 @ 2 A
BY188	S	25	1.2	40	-	-	Rectifier/ 1V5 @ 5 A
BY188A	S	50	1.2	-	-	-	Rectifier/ 1V5 @ 5 A
BY206	S	300	400 m	-	4	2 @ 300	Switching/ 1 uS
BY207	S	500	400 m	-	4	2 @ 500	Switching/ 1 uS
BY223	S	1k5	10	-	-	600 @ 1k5*	Switching/ 20 uS
BY297	S	200	2	70	-	10 @ 200	Rectifier/ 1V3 @ 3 A
BY299	S	800	2	70	-	10 @ 800	Rectifier/ 1V3 @ 3 A
HSCH1001	S	60	-	-	2.2	200 n @ 50	100 GHz switching
MZ2361	S	-	-	-	-	-	1V35 Zener
OA47	G	25	110 m	-	3.5	100 @ 25	Switching/ 70 nS
OA90	G	30	10 m	200 m	10	1m1 @ 30	General purpose
OA91	G	115	50 m	0.5	-	275 @ 100	General purpose
OA95	G	115	50 m	0.5	-	250 @ 100	Genreal purpose
OA200	S	50	160 m	-	10	0.1 @ 50	Switching/ 3.5 uS
OA202	S	150	160 m	-	10	0.1 @ 150	Switching/ 3.5 uS
ZS120	S	50	250 m	5	12	5 @ 50	General purpose

FETs, Unijunctions and PUTs

UNIPOLAR TRANSISTORS are also known as Field Effect Transistors (FETs); they have a channel through which carriers flow, from the **source** to the **drain**, and a **gate** that controls the flow of carriers. The channel can be either N-type semiconductor, in which case the carriers are electrons, or P-type semiconductors, in which case the carriers are holes. carriers are holes.

In junction field effect transistors, JFETs, the gate is made of semiconductor of opposite polarity to the junction, so the two are separated by a PN junction. For an N-channel JFET, the gate is a piece of P-type semiconductor, and must always be negative with respect to the channel or a high current will flow from the gate to the source or drain. Taking the gate negative drives carriers from the channel, hence the device is said to operate in the depletion mode. The voltage at which just too few carriers are present to support conduction is known as the pinch-off voltage, V_p.

For a P-channel JFET, the gate is N-channel semiconductor, so the pinch-off voltage is a positive voltage.

MOSFETs

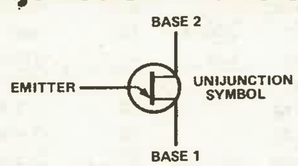
Another way of forming an FET is to make a channel, then deposit an insulating layer (normally a layer of silicon dioxide), then a metal electrode which forms the gate: hence the acronym MOSFET, metal oxide silicon field effect transistor. Because there is no PN junction there is no reason why MOSFETs should not be designed to act in the enhancement mode, ie with a positive pinch-off voltage for an N-channel device, or negative pinch-off for a P-channel device.

Thus the difference between an enhancement type and a depletion type is that a voltage is required to turn off a depletion type, but to turn on an enhancement type, Note that data tables do not usually tell you the sign of the voltage required but leave it up to you to work this out from the channel polarity and the mode. However, the majority of discrete FETs in use are of the junction type, and where it is not specifically stated, it is safest to assume that the FET should be operated in the depletion mode.

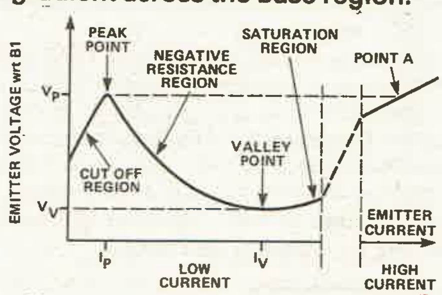
VMOS FETs are MOS types that have a special construction that allows them to dissipate more power than an equivalent ordinary MOSFET.

All types of FET are voltage-controlled devices, so the current flowing through them is controlled by the voltage at the gate. Thus the gain is a mutual conductance with the dimension amps per volt, or mhos (the inverse of ohms). More usually, the mutual conductance (symbol g_m) is expressed in milli-mhos (mmho) or mA per volt.

Unijunction Transistors

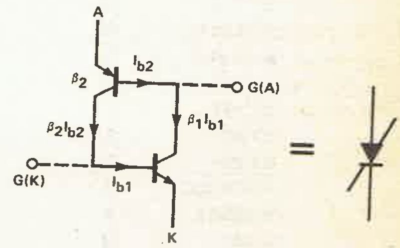


Unijunction transistors consist of a base region of N-type silicon with two connections, and a tiny area of P-type silicon, called the emitter with its own connection. The two connections to the base are used to set up a potential gradient across the base region.



Suppose you apply a gradually increasing voltage to the emitter; the current will increase only very slowly (and will remain very small anyway) until you reach the **peak voltage, V_p,** which is equal to the voltage across the base multiplied by the **intrinsic stand-off ratio, n.** Exactly what happens next depends on what you're using to supply the current. If you're using a voltage source that doesn't notice the current burden, the current will flip over to a very high value (point A on the diagram). If, however, your source has a relatively high output resistance, then the current will flip over to a relatively low value that may be before or after the valley point. (If you were using a current source, you would trace out the curve in the diagram). Above the valley point the emitter voltage vs current curve is more or less linear.

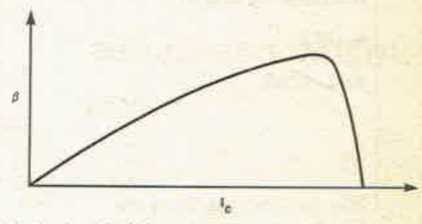
PUTs, SCSs, SCRs



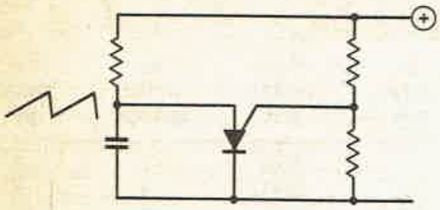
PUTs (programmable unijunction transistors), SCSs (silicon controlled switches) and SCRs (silicon controlled rectifiers) all have basically the same structure. The difference lies in which gates are made available to the user (see diagram). In the case of PUTs and SCRs, only one terminal is made available; whereas with SCSs both gates are made available and both may be used to trigger the device. Once triggered, the load current must be removed to reset any of the devices. The following notes on the two transistor model may be useful.

Two Transistor Model of PUT/SCS/SCR

Typically these devices are produced so that the gains of the transistors are fairly low. The product of their gains – $\beta_1 \times \beta_2$ – is usually much less than unity up to a value known as the holding current. Above this value $\beta_1 \times \beta_2$ is greater than unity and conduction can sustain itself. Below this value

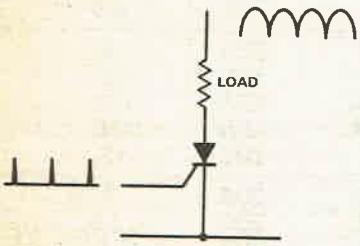


Typical gain (β) variation of a transistor with increasing collector current.



of current the gain drops quickly and the device turns off. These devices are typically used as switches and oscillators.

For sustained conduction
$\beta_2 I_{B2} > I_{B1}$ ($I_{B2} = \beta_1 I_{B1}$)
$\beta_2 \beta_1 I_{B1} > I_{B1}$
Therefore $\beta_2 \beta_1 > 1$



FET Case And Pin-out Codes

The last two letters of the case/pinpoint code given in the table indicate the lead code; the first section of the composite code indicates the case body.

Lead Code	Lead No. 1	2	3	4
DA	s	g	d	–
DB	s	d	g	–
DC	d	g	s	–
DD	d	s	g	–
DE	g	s	d	–
DF	g	d	s	–
DH	s	d	g	case
DW	d	g	s	sub, case
DX	d	g2	g1	s, sub
QV	s1	g1	d1	NC
QV (cont)	5:d2	6:g2	7:s2	8:NC

Unijunction Codes

Lead Code	Lead No. 1	2	3
XA	e	b2	b1
XB	b2	e	b1
XC	b1	E	b2

The only PUT presently available to the hobbyist is the BRY39; it has all four terminals available to the user and so can be used in three modes.

1. By using the G_A gate only: this is the usual PUT mode. The appropriate characteristics are then:

V_{GaA} (max	Anode gate to anode voltage:	70V
I_A (max)	Anode current d.c:	250mA
I_P	Peak point current (V_S = 10V, R_G = 10kΩ):	<5μA
I_V	Valley point current (V_S = 10V, R_G = 10kΩ):	>50μA
I_{ARM} (max)	Repetitive peak anode current:	2.5A
I_{GaAO} (max)	Anode gate to anode leakage current @ V_{GaA} = 70V:	10nA
I_{GaKS} (max)	Anode gate to cathode leakage current @ V_{GaK} = 70V:	10nA

2. By using both terminals; the device is a silicon controlled switch (SCS). The appropriate characteristics are:

	PNP transistor	NPN transistor
V_{CEO} (max)	−70V	—
V_{CBO} (max)	−70V	70V*
V_{EBO} (max)	−70V*	5V*
I_E (max)	D.C. Emitter current:	175mA
I_{ERM}	Max repetitive peak emitter current:	2.5A
P_{TOT}	Max total dissipation:	275mW
V_{AK}	Forward on-state voltage:	<1.4V
I_H	Holding current:	<1mA
t_{on}	Turn on time:	<0.25μs
t_q	Turn off time:	<5μs
h_{fe}		>0.25 @ I_E = 1mA; >50 @ I_C = 10mA
f_T		300MHz (typ)
V_{AK}	Forward on-state voltage:	<1.4V
I_H	Holding current:	<1mA
t_{on}	Turnon time:	<0.25μs
t_q	Turn off time:	<5μs
h_{fe}		>0.25 @ i_E = 1mA; >50 @ I_C = 10mA
f_T		300MHz (typ)

3. By using the G_K gate only. The device is now a thyristor, and the appropriate characteristics are:

Max d.c. on-state current:	250mA
On-state voltage:	1.4V
Peak reverse current @ V_R = 70V:	1nA (typ); 100nA (max)
Holding current (max)	250μA

	Cathode gate to cathode		Anode gate to anode	
Voltage that will trigger all devices (v_D = 6V):	V_{GkT}	0.5V (min)	V_{GaT}:	1V)Min)
Reverse peak voltage:	V_{GkM}	5V (max)	V_{GaM}:	70V (max)
Current that will trigger all devices (V_D = 6V):	I_{GkT}	1μA (min)	I_{GaT}:	100μA (min)
Forward peak current:	I_{GkM}	100mA (max)	I_{GaM}:	100mA (max)

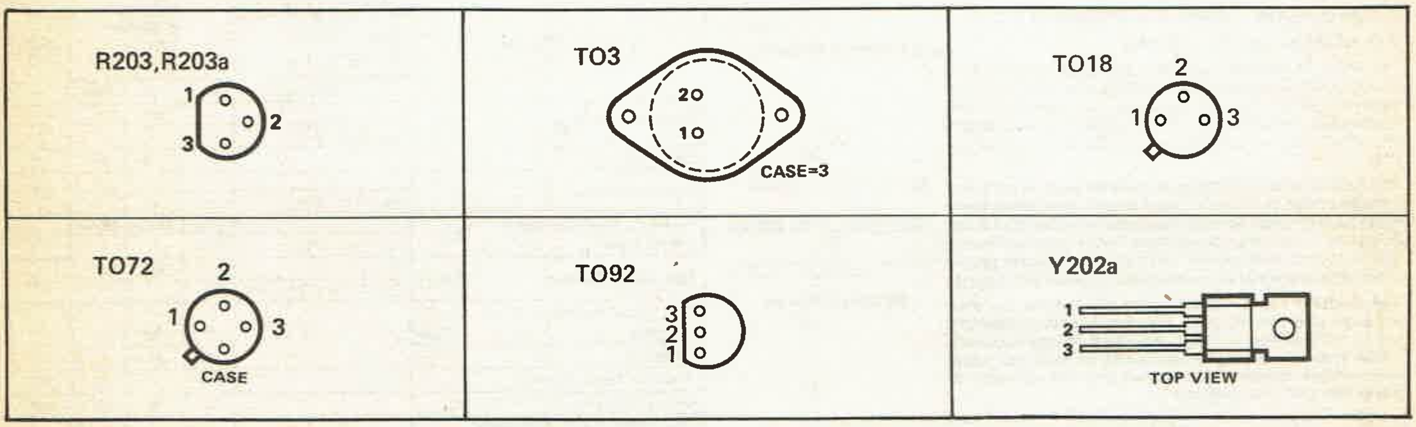
FIELD EFFECT TRANSISTORS

Type	Pol/Mode Structure	Case	V_{DS} (max) V	V_{GS} (max) V	V_p (max) V	I_D (max) mA	P_{TOT} (max) mA	g_M (min) mmhos	C_{IS} (max) pF
BF244	ND	R203	30	30	5	–	360	3	4
BF244A	ND	T092DC	30	30	8	25	300	3	4
BF244B	ND	T092DC	30	30	8	25	300	3	4
BF245A	ND	R203cDD	30	30	8	25	300	3	4
BF245B	ND	R203cDD	30	30	8	25	300	3	4
BF246	ND	R203	25	25	14	–	250	8	11
BF246A	ND	T092DA	25	25	14	–	250	8	11
BF246B	ND	T092DA	25	25	14	–	250	8	11
BF247A	N(PE)	R203cDD	25	25	14	–	250	8m	11
BF247B	N(PE)	R203cDD	25	25	14	–	250	8m	11
BF256A	ND	R203cDD	30	30	7.5	–	300	4.5	–
BF256B	ND	R203cDD	30	30	7.5	–	300	4.5	–
BF256C	ND	R203cDD	30	30	7.5	–	300	4.5	–
E430	N–	T0105QV	–	25	4	–	350	10	5
J300	N–	T092DE	–	25	6	–	350	4.5	5.5
J310	N–	T092DD	–	25	6.5	–	350	8	5
U430	N–	T099QV	–	25	4	–	500	10	5
VN46AF	ND	Y202aDA	40	15	2	2A	12W	170	–
VN66AF	ND	Y202aDA	60	15	2	2A	12W	170	–
MPF102	N	T092DD	25	25	8	–	200	2	7
MPF103	N	T092DD	25	25	6	16	200	1	7
MPF104	N	T092DD	25	25	7	16	200	1.5	7
MPF105	N	T092DD	25	25	8	16	200	2	7
MPF106	N	T072DH	25	25	4	30	200	2.5	5
MPF107	N	T072DH	25	25	6	30	200	4	5
MPF112	N	T092DD	25	25	10	–	200	1	8
2N3819	ND	T092DA	25	25	8	–	360	2	8
2N3820	PD	T092DA	20	20	8	–	360	0.8	32
2N3821	ND	T072DA	50	50	4	–	330	1.5	6
2N3822	ND	T072DH	50	50	6	–	330	1.5	6
2N3823	ND	T072DH	30	30	15	–	300	3.5	6
2N3824	ND	T072DH	50	50	–	–	300	–	6
2N5245	N	R203DD	–	30	6	–	360	4.5	4.5
2N5246	N	R203DD	–	30	4	–	360	3	4.5
2N5247	N	R203DD	–	30	8	–	360	4.5	4.5
2N5248	N	T092DA	–	30	8	–	360	3.5	6
2N5266	P	T072DH	60	60	3	20	200	1	7
2N5457	N	T092DD	–	25	6	–	310	1	7
2N5458	N	T092DD	–	25	7	–	310	1.5	7
2N5459	N	T092DD	–	25	8	–	310	2	7
2N5460	P	T092DB	–	40	6	–	310	1	7
2N5543	N	T039DB	–	75	15	–	500	0.75	10
2SJ49	PMOS	T03DF	140	14	1.5	7A	100W	600	900
2SJ50	PMOS	T03DF	160	14	1.5	7A	100W	600	900
3N128	ND	T072DW	20	20	8	50	330	5	7
3N138	ND	T072DW	35	10	–	50	150	–	5
3N139	ND	T072DW	35	10	6	50	150	–	7
3N140	ND	T072DX	20	4	4	50	400	6	7
3N143	ND	T072DW	20	20	8	50	330	5	7
3N152	ND	T072DW	20	8	8	50	330	5	–
3N154	ND	T072DW	20	8	8	50	330	5	–
3N200	ND	T072DX	20	6	3	50	330	10	–
3N201	ND	T072DX	25	30	5	50	360	8	–
40673	ND	T072DX	20	1	4	50	330	12	6
40822	ND	T072DX	18	9	4	50	330	12	9.5

UNIJUNCTION TRANSISTORS

Type	Case	P_{TOT} (max) mW	V_{EB2} (max) V	I_E (max) A	I_{EB2} (max)	Ip (max) μA	I_V (mA)	n	R_{B-B} Ω	V_{B-B} (max) V
TIS43	T092XA	300	30	1.5	10nA	5		0.55 to 0.82	4k to 9k1	35
2N2646	T018XB	300	30	2	12μA	5	4	0.56 to 0.75		35
2N2647	T018XB	300	30	2	200nA	2	8	0.68 to 0.82	–	35
2N4870	T092XC	300	–	–	–	–	2	max 0.75	–	35
2N4871	T092XC	300	30	1	1μA	5	4	0.7 to 0.85	4k to 9k1	35

PINOUT DIAGRAMS



MORE USEFUL ADDRESSES

SEMICONDUCTOR MANUFACTURER	IC PREFIX*
PLESSEY SEMICONDUCTORS Cheney Manor, Swindon, Wiltshire SN2 2QW 0793 6251	SAA,SBA,SL,SP
RAYTHEON SEMICONDUCTOR UK Howard Chase, Pipps Hill Industrial Estate, Basildon, Essex SS14 3DD 0268 288562	R
RETICON Seymour House, The Courtyard, Denmark Street, Workingham, Berkshire RG11 2DR 0734 788666	RC
RCA LIMIITED	CA,CD
RCA LIMITED Sunbury-on-Thames, Middlesex, TWW16 7HW 093 27 85511	CA,CD
SGS-ATES (UK) LTD Planar House, Walton Street, Aylesbury, Bucks 0296 5977	L,LM,LS,M,MC TAA,TBA,TCA, TDA
SIEMENS Great West House, Great West Road, Brentford TW8 9DG 01-586 9133	P,S,SAS,TAA,TBA, TBB,TBC,TBE,TCA, TDB,TDC,UAA
TEXAS INSTRUMENTS Manton Lane, Bedford 0256 29155	TL,SN72,SN76

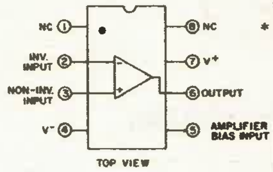
*** Note that many prefixes are not unique to one manufacturer**

CA3080

CA3080A, CA3080AE, CA3080AS
CA3080, CA3080E, CA3080S
Operational Transconductance Amplifiers (OTA's)

Features:

- Slew rate (unity gain, compensated): 50 V/µs
- Adjustable power consumption: 10µW to 30 mW
- Flexible supply voltage range: ±2 V to ±15 V
- Fully adjustable gain: 0 to g_mR_L limit
- Tight g_m spread: CA3080 (2:1), CA3080A (1.6:1)
- Extended g_m linearity: 3 decades

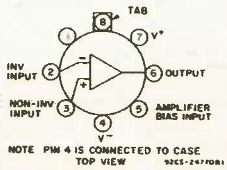


Plastic Package (E Suffix)

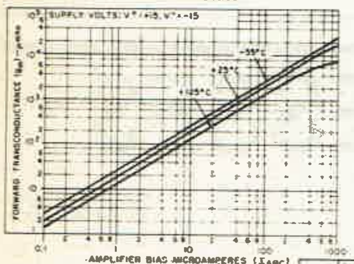
The RCA-CA3080 and CA3080A types are Gatable-Gain Blocks which utilize the unique operational-transconductance-amplifier (OTA) concept described in Application Note ICAN-6668, "Applications of the CA3080 and CA3080A High-Performance Operational Transconductance Amplifiers".

The CA3080 and CA3080A types have differential input and a single-ended, push-pull, class A output. In addition, these types have an amplifier bias input which may be used either for gating or for linear gain control. These types also have a high output impedance and their transconductance (g_m) is directly proportional to the amplifier bias current (I_{ABC}).

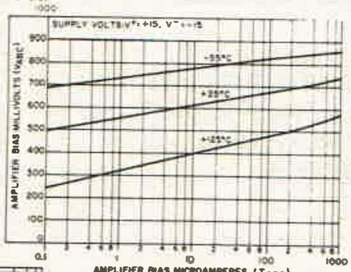
The CA3080 and CA3080A types are notable for their excellent slew rate (50 V/µs), which makes them especially useful for multiplex and fast unity-gain voltage followers. These types are especially applicable for multiplex applications because power is consumed only when the devices are in the "ON" channel state.



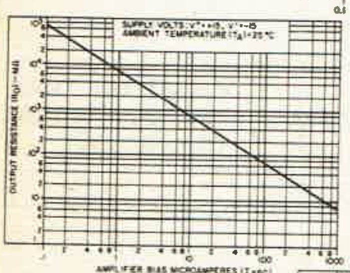
TO-5 Style Package



Transconductance as a function of amplifier bias current.



Amplifier bias voltage as a function of amplifier bias current.



Output resistance as a function of amplifier bias current.

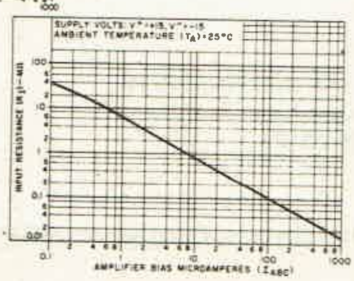


Fig. 15 — Input resistance as a function of amplifier bias current.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

DC SUPPLY VOLTAGE (Between V⁺ and V⁻ terminals)	36 V
DIFFERENTIAL INPUT VOLTAGE	±5 V
DC INPUT VOLTAGE	V⁺ to V⁻
INPUT SIGNAL CURRENT	1 mA
AMPLIFIER BIAS CURRENT	2 mA
OUTPUT SHORT-CIRCUIT DURATION*	Indefinite
DEVICE DISSIPATION	125 mW
TEMPERATURE RANGE:	
Operating	
CA3080, CA3080E, CA3080S	0 to +70 °C
CA3080A, CA3080AE, CA3080AS	−55 to +125 °C
Storage	−65 to +150 °C
LEAD TEMPERATURE (During Soldering): At distance 1/16 ± 1/32 in. (1.59 ± 0.79 mm) from case for 10 s max.	+265 °C

* Short circuit may be applied to ground or to either supply.

ELECTRICAL CHARACTERISTICS
For Equipment Design

CHARACTERISTIC		TEST CONDITIONS V⁺ = 15 V, V⁻ = −15 V, I_{ABC} = 500 µA, T_A = 25°C (unless indicated otherwise)	CA3080 CA3080E CA3080S LIMITS Min.	Typ.	Max.	UNITS
Input Offset Voltage	V_{IO}		–	0.4	5	mV
		T_A = 0 to 70°C	–	–	6	
Input Offset Current	I_{IO}		–	0.12	0.6	µA
Input Bias Current	I_I		–	2	5	µA
		T_A = 0 to 70°C	–	–	7	
Forward Transconductance (large signal)	g_m		6700	9600	13000	µmho
		T_A = 0 to 70°C	5400	–	–	
Peak Output Current	$\|I_{OM}\|$	R_L = 0	350	500	650	µA
		R_L = 0, T_A = 0 to 70°C	300	–	–	
Peak Output Voltage: Positive	V^+_{OM}	$R_L = \infty$	12	13.5	–	V
Negative	V^-_{OM}		−12	−14.4	–	
Amplifier Supply Current	I_A		0.8	1	1.2	mA
Device Dissipation	P_D		24	30	36	mW
Input Offset Voltage Sensitivity: Positive	$\Delta V_{IO}/\Delta V^+$		–	–	150	µV/V
Negative	$\Delta V_{IO}/\Delta V^-$		–	–	150	
Common-Mode Rejection Ratio	CMRR		80	110	–	dB
Common-Mode Input-Voltage Range	V_{ICR}		12 to −12	13.6 to −14.6	–	V
Input Resistance	R_I		10	26	–	kΩ

CHARACTERISTIC		TEST CONDITIONS V⁺ = 15 V, V⁻ = −15 V, I_{ABC} = 500 µA, T_A = 25°C (unless indicated otherwise)	CA3080A CA3080AE CA3080AS LIMITS Min.	Typ.	Max.	UNITS
Input Offset Voltage	V_{IO}	I_{ABC} = 5 µA	–	0.3	2	mV
			–	0.4	2	
		T_A = −55 to +125°C	–	–	5	
Input Offset Voltage Change	$\|\Delta V_{IO}\|$	I_{ABC} = 500 µA to I_{ABC} = 5 µA	–	0.1	3	mV
Input Offset Current	I_{IO}		–	0.12	0.6	µA
Input Bias Current	I_I		–	2	5	µA
		T_A = −55 to +125°C	–	–	8	
Forward Transconductance (large signal)	g_m		7700	9600	12000	µmho
		T_A = −55 to +125°C	4000	–	–	
Peak Output Current	$\|I_{OM}\|$	I_{ABC} = 5 µA, R_L = 0	3	5	7	µA
		R_L = 0	350	500	650	
		R_L = 0, T_A = −55 to +125°C	300	–	–	
Peak Output Voltage: Positive	V^+_{OM}	I_{ABC} = 5 µA, $R_L = \infty$	12	13.8	–	V
Negative	V^-_{OM}		−12	−14.5	–	
Positive	V^+_{OM}	$R_L = \infty$	12	13.5	–	
Negative	V^-_{OM}		−12	−14.4	–	
Amplifier Supply Current	I_A		0.8	1	1.2	mA
Device Dissipation	P_D		24	30	36	mW
Input Offset Voltage Sensitivity: Positive	$\Delta V_{IO}/\Delta V^+$		–	–	150	µV/V
Negative	$\Delta V_{IO}/\Delta V^-$		–	–	150	
Magnitude of Leakage Current		I_{ABC} = 0, V_{TP} = 0	–	0.08	5	nA
		I_{ABC} = 0, V_{TP} = 36 V	–	0.3	5	
Differential Input Current		I_{ABC} = 0, V_{DIFF} = 4 V	–	0.008	5	nA
Common-Mode Rejection Ratio	CMRR		80	110	–	dB
Common-Mode Input-Voltage Range	V_{ICR}		12 to −12	13.6 to −14.6	–	V
Input Resistance	R_I		10	26	–	kΩ

CA3130

CA3130B, CA3130A, CA3130

FEATURES:

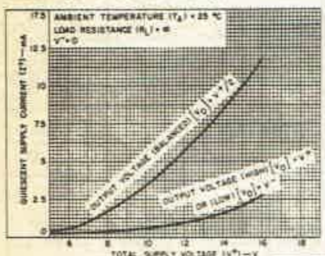
- *MOS/FET input stage provides:*
  very high Z = 1.5 TΩ (1.5 × 10^{12}Ω) typ.
  very low I_I = 5 pA typ. at 15-V operation
  2 pA typ. at 5-V operation
- *Common-mode input-voltage range includes negative supply rail; input terminals can be swung 0.5 V below negative supply rail* — *Ideal for single-supply applications*
- *COS/MOS output stage permits signal swing to either (or both) supply rails*
- *Low V_{IO}: 2 mV max. (CA3130B)*
- *Wide BW: 15 MHz typ. (unity-gain crossover)*
- *High SR: 10 V/µs typ. (unity-gain follower)*
- *High output current (I_O): 20 mA typ.*
- *High A_{OL}: 320,000 (110 dB) typ.*
- *Compensation with single external capacitor*

RCA-CA3130T, CA3130E, CA3130S, CA-3130AT, CA 3130AS, CA3130AE, CA3130BT, and CA3130BS are integrated-circuit operational amplifiers that combine the advantages of both COS/MOS and bipolar transistors on a monolithic chip.

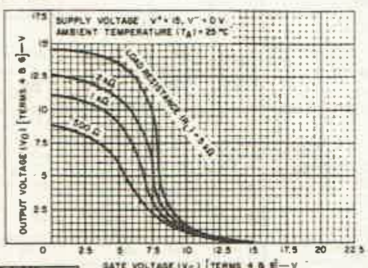
Gate-protected p-channel MOS/FET (PMOS) transistors are used in the input circuit to provide very-high-input impedance, very-low-input current, and exceptional speed performance. The use of PMOS field-effect transistors in the input stage results in common-mode input-voltage capability down to 0.5 volt below the negative-supply terminal, an important attribute in single-supply applications.

A complementary-symmetry MOS (COS/MOS) transistor-pair, capable of swinging the output voltage to within 10 millivolts of either supply-voltage terminal (at very high values of load impedance), is employed as the output circuit.

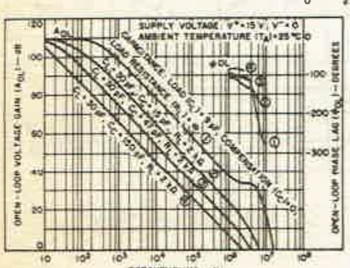
The CA3130 Series circuits operate at supply voltages ranging from 5 to 16 volts, or ±2.5 to ±8 volts when using split supplies. They can be phase compensated with a single external capacitor, and have terminals for adjustment of offset voltage for applications requiring offset-null capability. Terminal provisions are also made to permit strobing of the output stage.



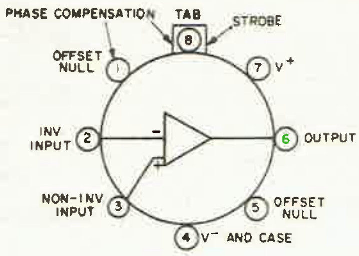
Quiescent supply current vs. supply voltage.



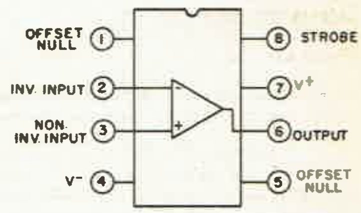
Voltage transfer characteristics of COS/MOS output stage.



Open-loop voltage gain and phase shift vs. frequency for various values of C_L, C_C and R_L.



S and T Suffixes



E Suffix

MAXIMUM RATINGS, *Absolute-Maximum Values*

DC SUPPLY VOLTAGE (Between V+ and V− Terminals) .... 16 V
DIFFERENTIAL-MODE INPUT VOLTAGE .... ±8 V
COMMON-MODE DC INPUT VOLTAGE ... (V+ +8 V) to (V− −0.5 V)
INPUT-TERMINAL CURRENT .... 1 mA
DEVICE DISSIPATION
WITHOUT HEAT SINK –
UP TO 55°C .... 630 mW
ABOVE 55°C .... Derate linearly 6.67 mW/°C
WITH HEAT SINK –
UP TO 90°C .... 1 W
ABOVE 90°C ... Derate linearly 16.7 mW/°C

TEMPERATURE RANGE:
OPERATING (all types) ..... −55 to + 125°C
STORAGE (all types) .... −65 to + 150°C
OUTPUT SHORT-CIRCUIT DURATION* .... INDEFINITE
LEAD TEMPERATURE (DURING SOLDERING):
AT DISTANCE 1/16 ± 1/32 INCH (1.59 ± 0.79 mm) FROM CASE FOR 10 SECONDS MAX. .... +265°C

*Short circuit may be applied to ground or to either supply.

ELECTRICAL CHARACTERISTICS at T_A=25°C, V+=15 V, V− = 0 V (Unless otherwise specified)

CHARACTERISTIC	LIMITS									Units
	CA3130B (T,S)			CA3130A (T,S,E)			CA3130 (T,S,E)			
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage, $\lvert V_{IO}\rvert$, V±=±7.5 V	–	0.8	2	–	2	5	–	8	15	mV
Input Offset Current, $\lvert I_{IO}\rvert$, V±=±7.5 V	–	0.5	10	–	0.5	20	–	0.5	30	pA
Input Current, I_I V±=±7.5 V	–	5	20	–	5	30	–	5	50	pA
Large-Signal Voltage Gain, A_{OL}	100 k	320 k	–	50 k	320 k	–	50 k	320 k	–	V/V
V_O=10 V_{p-p}, R_L=2 kΩ	100	110	–	94	110	–	94	110	–	dB
Common-Mode Rejection Ratio, CMRR	86	100	–	80	90	–	70	90	–	dB
Common-Mode Input-Voltage Range, V_{ICR}	0	−0.5 to 12	10	0	−0.5 to 12	10	0	−0.5 to 12	10	V
Power-Supply Rejection Ratio, $\Delta V_{IO}/\Delta V^{\pm}$ V±=±7.5 V	–	32	100	–	32	150	–	32	320	µV/V
Maximum Output Voltage: At R_L=2 kΩ V_{OM}^+	12	13.3	–	12	13.3	–	12	13.3	–	V
At R_L=2 kΩ V_{OM}^-	–	0.002	0.01	–	0.002	0.01	–	0.002	0.01	V
At R_L= ∞ V_{OM}^+	14.99	15	–	14.99	15	–	14.99	15	–	V
At R_L= ∞ V_{OM}^-	–	0	0.01	–	0	0.01	–	0	0.01	V
Maximum Output Current: I_{OM}^+ (Source) @ V_O = 0 V	12	22	45	12	22	45	12	22	45	mA
I_{OM}^- (Sink) @ V_O = 15 V	12	20	45	12	20	45	12	20	45	mA
Supply Current, I^+: V_O=7.5 V, R_L = ∞	–	10	15	–	10	15	–	10	15	mA
V_O = 0 V, R_L = ∞	–	2	3	–	2	3	–	2	3	mA
Input Offset Voltage Temp. Drift, $\Delta V_{IO}/\Delta T$*	–	5	–	–	10	–	–	10	–	µV/°C

CA3140

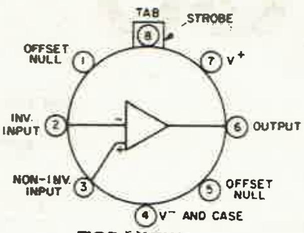
CA3140B, CA3140A, CA3140
BiMOS Operational Amplifiers

FEATURES:

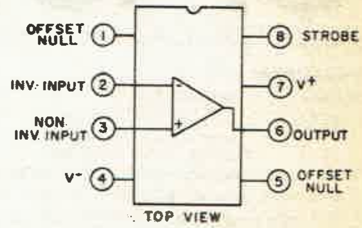
- *MOS/FET Input Stage*
  - *(a) Very high input impedance (Z_{IN}) — 1.5 TΩ typ.*
  - *(b) Very low input current (I_I) — 10 pA typ. at ± 15 V*
  - *(c) Low input-offset voltage (V_{IO}) — to 2 mV max.*
  - *(d) Wide common-mode input-voltage range (V_{ICR})— can be swung 0.5 volt below negative supply-voltage rail*
  - *(e) Output swing complements input common-mode range*
  - *(f) Rugged input stage — bipolar diode protected*
- *Directly replaces industry type 741 in most applications*
- *Includes numerous industry operational amplifier categories such as general-purpose, FET input, wideband (high slew rate)*
- *Operation from 4-to-44 volts Single or Dual supplies*
- *Internally compensated*
- *Characterized for ± 15-volt operation and for TTL supply systems with operation down to 4 volts*
- *Wide bandwidth — 4.5 MHz unity gain at ± 15 V or 30 V; 3.7 MHz at 5 V*
- *High voltage-follower slew rate — 9 V/μs*
- *Fast setting time — 1.4 μs typ. to 10 mV with a 10-V_{p-p} signal*
- *Output swings to within 0.2 volt of negative supply*
- *Strobable output stage*

The CA3140B, CA3140A, and CA3140 are integrated-circuit operational amplifiers that combine the advantages of high-voltage PMOS transistors with high-voltage bipolar transistors on a single monolithic chip. Because of this unique combination of technologies, this device can now provide designers, for the first time, with the special performance features of the CA3130 COS/MOS operational amplifiers and the versatility of the 741 series of industry-standard operational amplifiers.

The CA3140, CA3140A, and CA3140 BiMOS operational amplifiers feature gate-protected MOS/FET (PMOS) transistors in the input circuit to provide very-high-input impedance, very-low-input current, and high-speed performance. The CA3140B operates at supply voltages from 4 to 44 volts; the CA3140A and CA3140 from 4 to 36 volts (either single or dual supply). These operational amplifiers are internally phase-compensated to achieve stable operation in unity-gain follower operation, and, additionally, have access terminals for a supplementary external capacitor if additional frequency roll-off is desired. Terminals are also provided for use in applications requiring input offset-voltage nulling. The use of PMOS field-effect transistors in the input stage results in common-mode input-voltage capability down to 0.5 volt below the negative-supply terminal, an important attribute for single-supply applications. The output stage uses bipolar transistors and includes built-in protection against damage from load-terminal short-circuiting to either supply-rail or to ground.



TOP VIEW
S and T Suffixes



E Suffix

MAXIMUM RATINGS, *Absolute-Maximum Values:*

	CA3140, CA3140A	CA3140B
DC SUPPLY VOLTAGE (BETWEEN V⁺ AND V⁻ TERMINALS)	36 V	44 V
DIFFERENTIAL-MODE INPUT VOLTAGE	±8 V	±8 V
COMMON-MODE DC INPUT VOLTAGE	(V⁺ +8 V) to (V⁻ −0.5 V)	
INPUT-TERMINAL CURRENT	1 mA	
DEVICE DISSIPATION:		
WITHOUT HEAT SINK —		
UP TO 55°C	630 mW	
ABOVE 55°C	Derate linearly 6.67 mW/°C	
WITH HEAT SINK —		
Up to 55°C	1 W	
Above 55°C	Derate linearly 16.7 mW/°C	
TEMPERATURE RANGE:		
OPERATING (ALL TYPES)	−55 to +125°C	
STORAGE (ALL TYPES)	−65 to +150°C	
OUTPUT SHORT-CIRCUIT DURATION*	INDEFINITE	
LEAD TEMPERATURE (DURING SOLDERING): AT DISTANCE 1/16 ± 1/32 INCH (1.59 ± 0.79 MM) FROM CASE FOR 10 SECONDS MAX.	+265°C	

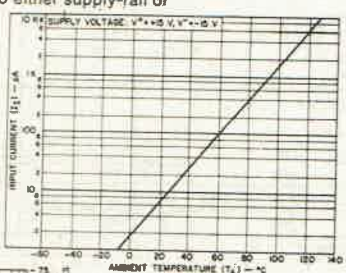
* Short circuit may be applied to ground or to either supply.

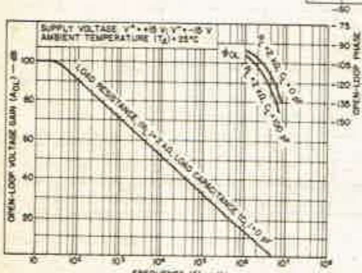
ELECTRICAL CHARACTERISTICS FOR EQUIPMENT DESIGN
At V⁺ = 15 V, V⁻ = 15 V, T_A = 25°C Unless Otherwise Specified

CHARACTERISTIC		LIMITS									UNITS
		CA3140B			CA3140A			CA3140			
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage, $\|V_{IO}\|$		–	0.8	2	–	2	5	–	5	15	mV
Input Offset Current, $\|I_{IO}\|$		–	0.5	10	–	0.5	20	–	0.5	30	pA
Input Current, I_I		–	10	30	–	10	40	–	10	50	pA
Large-Signal Voltage Gain, A_{OL}● (See Figs. 4,18)		50 k	100 k	–	20 k	100 k	–	20 k	100 k	–	V/V
		94	100	–	86	100	–	86	100	–	dB
Common-Mode Rejection Ratio, CMRR (See Fig.9)		–	20	50	–	32	320	–	32	320	μV/V
		86	94	–	70	90	–	70	90	–	dB
Common-Mode Input-Voltage Range, V_{ICR} (See Fig.20)		−15	−15.5 to +12.5	12	−15	−15.5 to +12.5	12	−15	−15.5 to +12.5	11	V
Power-Supply Rejection Ratio, PSRR (See Fig.11)	$\Delta V_{IO}/\Delta V$	–	32	100	–	100	150	–	100	150	μV/V
		80	90	–	76	80	–	76	80	–	dB
Max. Output Voltage■ (See Figs.13,20)	V_{OM}^+	+12	13	–	+12	13	–	+12	13	–	V
	V_{OM}^-	−14	−14.4	–	−14	−14.4	–	−14	−14.4	–	V
Supply Current, I⁺ (See Fig.7)		–	4	6	–	4	6	–	4	6	mA
Device Dissipation, P_D		–	120	180	–	120	180	–	120	180	mW
Input Offset Voltage Temp. Drift, $\Delta V_{IO}/\Delta T$		–	5	–	–	6	–	–	8	–	μV/°C
Max. Output Voltage.*	V_{OM}^+	+19	+19.5	–	–	–	–	–	–	–	V
	V_{OM}^-	−21	−21.4	–	–	–	–	–	–	–	V
Large-Signal Voltage Gain, A_{OL}♦*		20 k	50 k	–	–	–	–	–	–	–	V/V
		86	94	–	–	–	–	–	–	–	dB

● At V_O = 26V_{p-p}, +12V, −14V and R_L = 2 kΩ.
■ At R_L = 2 kΩ.
♦ At V_O = +19 V, −21 V, and R_L = 2 kΩ.
* At V⁺ = 22 V, V⁻ = 22 V.

Input current vs ambient temperature.





Open-loop voltage gain and phase lag vs frequency.

CA3240

CA3240A, CA3240 Types Dual BiMOS Operational Amplifiers

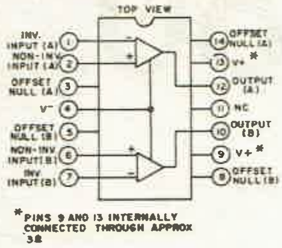
With MOS/FET Input, Bipolar Output

Features:

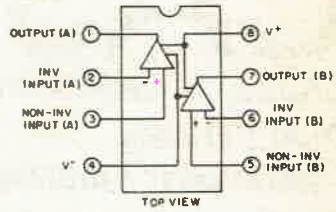
- Dual version of CA3140
- Internally compensated
- MOS/FET input stage
  - (a) Very high input impedance (Z_{IN}) – 1.5 TΩ typ.
  - (b) Very low input current (I_I) – 10 pA typ. at ± 15 V
  - (c) Wide common-mode input-voltage range (V_{ICR}) – can be swung 0.5 volt below negative supply-voltage rail
  - (d) Rugged input stage – bipolar diode protected
- Directly replaces industry types 747 and 1458 in most applications
- Operation from 4-to-36 volts single or dual supplies
- Characterized for ± 15-volt operation and for TTL supply systems with operation down to 4 volts
- Wide bandwidth – 4.5 MHz unity gain at ± 15 V or 30 V
- High voltage-follower slew rate – 9 V/μs
- Output swings to within 0.5 volt of negative supply at $V^+ = 5$ V, $V^- = 0$

The RCA-CA3240A and CA3240 are dual versions of the popular CA3140-series integrated circuit operational amplifiers. They combine the advantages of MOS and bipolar transistors on the same monolithic chip. The gate-protected MOS/FET (PMOS) input transistors provide high input impedance and a wide common-mode input voltage range (typically to 0.5 V below the negative supply rail). The bipolar output transistors allow a wide output voltage swing and provide a high output current capability.

The CA3240A and CA3240 are supplied in the 8-lead dual-in-line plastic package (Mini-DIP, E suffix), and in the 14-lead dual-in-line plastic package (E1 suffix). They are pin-compatible with the industry standard 747 and 1458 operational amplifiers in similar packages. The CA3240A and CA3240 have an operating-temperature range of –40 to +85°C. The offset null feature is available only when these types are supplied in the 14-lead dual-in-line plastic package (E1 suffix).



E1 Suffix
Pin compatible with the industry-standard 747



E Suffix
Pin compatible with the industry-standard 1458

MAXIMUM RATINGS, *Absolute-Maximum Values:*

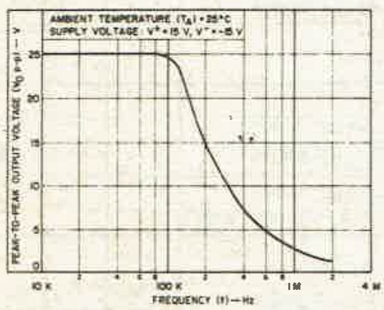
DC SUPPLY VOLTAGE
(BETWEEN V^+ AND V^- TERMINALS) . . . . . 36 V
OPERATING VOLTAGE RANGE . . . . . 4 to 36 V or ±2 to ±18 V
DIFFERENTIAL-MODE INPUT VOLTAGE . . . . . ±8 V
COMMON-MODE DC INPUT VOLTAGE . . . . . (V^+ +8 V) to (V^- –0.5 V)
INPUT-TERMINAL CURRENT . . . . . 1 mA
DEVICE DISSIPATION:
UP TO 55°C . . . . . 630 mW
ABOVE 55°C . . . . . Derate linearly 6.67 mW/°C
TEMPERATURE RANGE:
OPERATING . . . . . –40 to +85°C
STORAGE . . . . . –65 to +150°C
OUTPUT SHORT-CIRCUIT DURATION● . . . . . UNLIMITED
LEAD TEMPERATURE (DURING SOLDERING):
AT DISTANCE 1/16 ± 1/32 INCH (1.59 ± 0.79 MM)
FROM CASE FOR 10 SECONDS MAX. . . . . . +265°C

● Short circuit may be applied to ground or to either supply. Temperatures and/or supply voltages must be limited to keep dissipation within maximum rating.

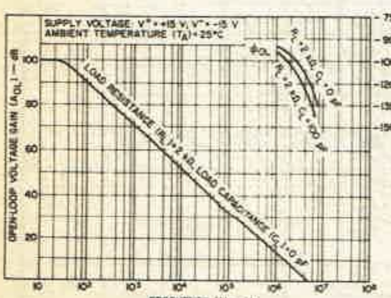
ELECTRICAL CHARACTERISTICS FOR EQUIPMENT DESIGN
At $V^+ = 15$ V, $V^- = 15$ V, $T_A = 25$°C Unless Otherwise Specified

CHARACTERISTIC	LIMITS						UNITS
	CA3240A			CA3240			
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage, $\lvert V_{IO} \rvert$	–	2	5	–	5	15	mV
Input Offset Current, $\lvert I_{IO} \rvert$	–	0.5	20	–	0.5	30	pA
Input Current, I_I	–	10	40	–	10	50	pA
Large-Signal Voltage Gain, A_{OL}● (See Figs. 4, 19)	20 k	100 k	–	20 k	100 k	–	V/V
	86	100	–	86	100	–	dB
Common-Mode Rejection Ratio, CMRR (See Fig. 9)	–	32	320	–	32	320	μV/V
	70	90	–	70	90	–	dB
Common-Mode Input-Voltage Range, V_{ICR} (See Fig. 16)	–15	–15.5 to +12.5	12	–15	–15.5 to +12.5	11	V
Power-Supply Rejection Ratio, $\Delta V_{IO}/\Delta V$ PSRR (See Fig. 11)	–	100	150	–	100	150	μV/V
	76	80	–	76	80	–	dB
Maximum Output Voltage,■ V_{OM}^+ (See Figs. 22, 16)	+12	13	–	+12	13	–	V
V_{OM}^-	–14	–14.4	–	–14	–14.4	–	V
Maximum Output Voltage,† V_{OM}^-	0.4	0.13	–	0.4	0.13	–	V
Supply Current, I^+ (See Fig. 7) For Both Amps.	–	8	12	–	8	12	mA
Total Device Dissipation, P_D	–	240	360	–	240	360	mW

● At $V_O = 26\ V_{p-p}$, +12 V, –14 V and $R_L = 2$ kΩ.
■ At $R_L = 2$ kΩ.
† At $V^+ = 5$ V, V^- = GND, $I_{Sink} = 200$ μA.



Maximum output voltage swing as a function of frequency.



Open-loop voltage gain and phase lag as a function of frequency.

CA3280

CA3280G, CA3280AG

Dual Variable Operational Amplifiers

"G" Suffix Type-Hermetic Gold-CHIP in Dual-In-Line Plastic Package

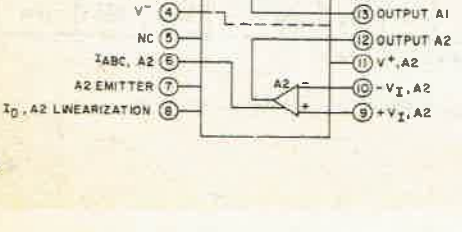
Features:

- **Low initial input-offset voltage: 500 μV max. (CA3280A)**
- **Low offset-voltage change versus I_{ABC}: < 500 μV typ. for all types**
- **Low offset-voltage drift: 5 μV/C max. (CA3280A)**
- **Excellent matching of the two amplifiers for all characteristics**
- **Internal current-driven linearizing diodes reduce the external input current to an offset component**
- **Differential amplifier emitters brought out for use in emitter-coupled dual-differential amplifier applications**
- **Low noise: 8 nV/√Hz @ 1 kHz typ.**
- **Low distortion: 0.4% THD typ.**
- **Two modes of gain control**
- **Hermetic Gold-CHIP in a plastic package**

The RCA-CA3280 and CA3280A types types consist of two variable operational amplifiers that are designed to substantially reduce the initial input offset voltage and the offset-voltage variation with respect to changes in programming current. This design results in reduced "AGC thump," an objectionable characteristic of many AGC systems. Interdigitation, or crosscoupling, of critical portions of the circuit reduces the amplifier dependence upon thermal and processing variables.

The CA3280 has all the generic characteristics of an operational voltage amplifier except that the forward transfer characteristic is best described by transconductance rather than voltage gain, and the output is current, not voltage. The magnitude of the output current is equal to the product of transconductance and the input voltage. This type of operational transconductance amplifier was first introduced by RCA in 1969*, and it has since gained wide acceptance as a gateable, gain-controlled building block for instrumentation and audio applications, such as linearization of transducer outputs, standardization of widely changing signals for data processing, multiplexing, instrumentation amplifiers operating from the nanopower range to high current and high-speed comparators.

* "OTA Obsoletes Op Amp," by C.F. Wheatley and H.A. Wittlinger, NEC Proceedings, December, 1969.



MAXIMUM RATINGS, *Absolute-Maximum Values:*

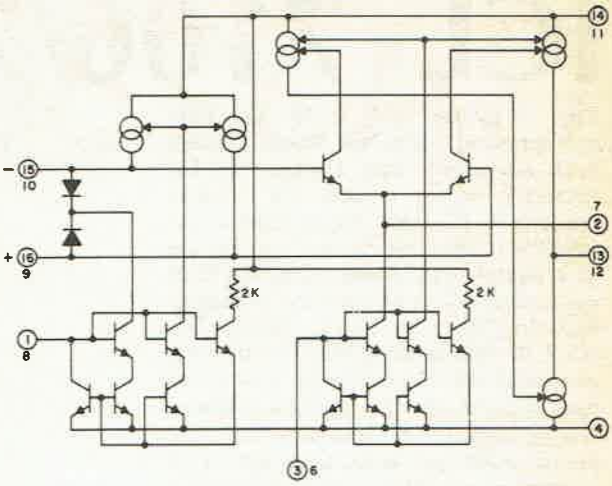
DC SUPPLY VOLTAGE (BETWEEN V⁺ AND V⁻ TERMINALS) . . . 36 V
DIFFERENTIAL INPUT VOLTAGE . . . ±5 V
DC INPUT VOLTAGE RANGE . . . V⁺ to V⁻
INPUT SIGNAL CURRENT AT I_D = 0 . . . 100 μA
AMPLIFIER BIAS CURRENT . . . 10 mA
OUTPUT SHORT CIRCUIT DURATION* . . . Indefinite
LINEARIZING DIODE BIAS CURRENT, I_D . . . 5 mA
PEAK INPUT CURRENT WITH LINEARIZING DIODE . . . $\pm I_D$
POWER DISSIPATION, P_D:
Either Amplifier . . . 600 mW
Total Package . . . 750 mW
Above 55°C . . . Derate linearly at 6.67 mW/°C
AMBIENT TEMPERATURE RANGE, T_A:
Operating:
CA3280 . . . 0 to +70°C
CA3280A . . . −55 to +125°C
Storage, All Types . . . −65 to +150°C
LEAD TEMPERATURE (DURING SOLDERING):
At distance 1/16 ±1/32 in. (1.59 ±0.79 mm) from case for 10 sec. max. . . . +265°C

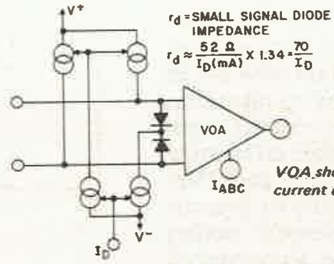
ELECTRICAL CHARACTERISTICS at T_A = 25°C, V± = 15 V (Unless Otherwise Stated) For Equipment Design

CHARACTERISTIC	TEST CONDITIONS	LIMITS						UNITS
		CA3280G			CA3280AG			
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage, V_{IO}	I_{ABC}=1 mA	–	–	3	–	–	0.5	mV
	I_{ABC}=100μA	–	0.7	3	–	0.25	0.5	
	I_{ABC}=10μA	–	–	3	–	–	0.5	
	I_{ABC}=1mA to 10μA, T_A=full temp. range	–	0.8	4	–	0.8	1.5	
Input Offset Voltage Change, $\|\Delta V_{IO}\|$	I_{ABC}=1μA to 1mA	–	0.5	1	–	0.5	1	mV
	I_{ABC}=100μA, T_A=full temp. range	–	5	–	–	3	5	μV/°C
Amplifier Bias Voltage, V_{ABC}	I_{ABC}=100μA	–	1.2	–	–	1.2	–	V
Peak Output Voltage: Positive VOM^+	I_{ABC}=500μA	12	13.7	–	12.5	13.7	–	V
Negative VOM^-		12	−14.3	–	−13.3	−14.3	–	
Positive VOM^+	I_{ABC}=5μA	12	13.9	–	12.5	13.9	–	
Negative VOM^-		12	−14.5	–	−13.5	−14.5	–	
Common-Mode Input Voltage Range, V_{ICR}	I_{ABC}=100μA	−13	–	13	−13	–	13	V
Noise Voltage, e_N: 10 Hz	I_{ABC}=500μA	–	20	–	–	20	–	nV/√Hz
1 kHz		–	8	–	–	8	–	μV/√Hz
10 kHz		–	7	–	–	7	–	nV/√Hz
Input Offset Current, I_{IO}	I_{ABC}=500μA	–	0.3	0.7	–	0.3	0.7	μA
Input Bias Current, I_{IB}	I_{ABC}=500μA	–	1.8	5	–	1.8	5	μA
	I_{ABC}=500μA, T_A=full temp. range	–	3	8	–	3	8	
Peak Output Current: Source IOM^+	I_{ABC}=500μA	350	410	650	350	410	650	μA
Sink IOM^-		−350	−410	−650	−350	−410	−650	
Source IOM^+	I_{ABC}=5μA	3	4.1	7	3	4.1	7	
Sink IOM^-		−3	−4.1	−7	−3	−4.1	−7	
Sink and Source, IOM^-, IOM^+	I_{ABC}=500μA, T_A=full temp. range	350	450	550	350	450	550	
Linearization Diodes: Dynamic Impedance	I_D = 100μA	–	700	–	–	700	–	Ω
Offset Current	I_D =100μA	–	10	–	–	10	–	μA
	I_D=10μA	–	0.5	1	–	0.5	1	

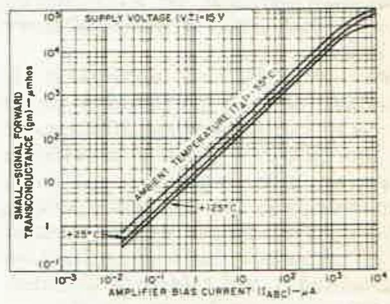
ELECTRICAL CHARACTERISTICS (Cont'd)

CHARAC-TERISTIC	TEST CONDITIONS	LIMITS CA3280 Min.	Typ.	Max.	CA3280A Min.	Typ.	Max.	UNITS
Diode Network Supply Current	I_{ABC}=100μA	250	400	800	250	400	800	μA
Amplifier Supply Current (Per amplifier)	I_{ABC}=500μA	–	2	2.4	–	2	2.4	mA
Amplifier Output Leakage Current, I_{OL}	I_{ABC}=0, V_O=0V	–	0.015	0.1	–	0.015	0.1	nA
	I_{ABC}=0, V_O=30V	–	0.15	1	–	0.15	1	nA
Common-Mode Rejection Ratio, CMRR	I_{ABC}=100μA	80	100	–	94	100	–	dB
Power-Supply Rejection Ratio, PSRR	I_{ABC}=100μA	86	105	–	94	105	–	dB
Open-Loop Voltage Gain, A_{OL}	I_{ABC}=100μA, R_L=∞,	94	100	–	94	100	–	dB
	V_O=20 Vp-p	50K	100K	–	50K	100K	–	V/V
Forward Transconductance: Large Signal, Gm	I_{ABC}=50μA	–	0.8	1.2	–	0.8	1.2	mmho
Small Signal, gm	I_{ABC}=1mA	–	16	22	–	16	22	
Input Resistance, R_I	I_{ABC}=10μA	0.5	–	–	0.5	–	–	MΩ
Channel Separation	f=1 kHz	–	94	–	–	94	–	dB
Open-Loop Total Harmonic Distortion	f=1 kHz, I_{ABC}=1.5 mA, R_L=15kΩ, V_O=20 Vp-p	–	0.4	–	–	0.4	–	%
Bandwidth	I_{ABC}=1mA, R_L=100Ω	–	9	–	–	9	–	MHz
Slew Rate, SR: Open Loop	I_{ABC}=1mA	–	125	–	–	125	–	V/μs
Capacitance: Input, C_I	I_{ABC}=100μA	–	4.5	–	–	4.5	–	pF
Output, C_O		–	7.5	–	–	7.5	–	pF
Output Resistance, R_O	I_{ABC}=100μA	–	63	–	–	63	–	MΩ

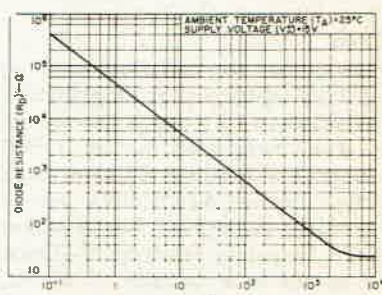




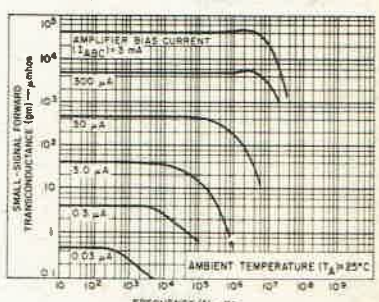
VOA showing linearization diodes and current drive.



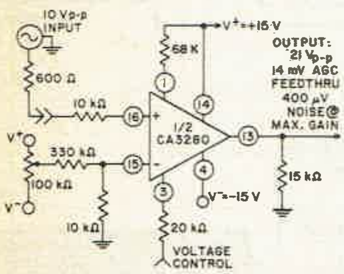
Amplifier gain as a function of amplifier bias current.



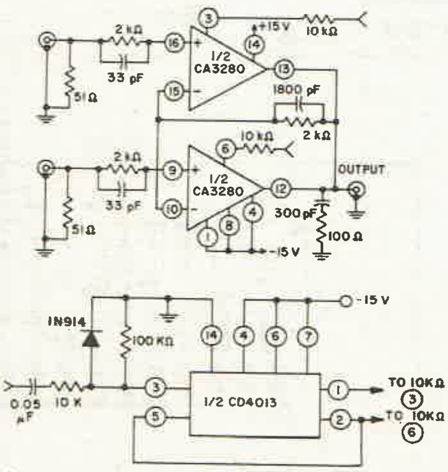
Diode resistance as a function of diode current.



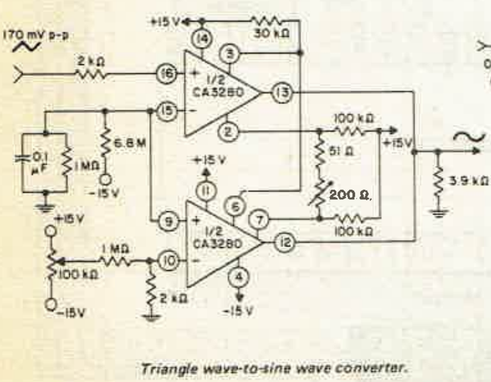
Amplifier gain as a function of frequency.



Typical gain control circuit.



Two-channel linear multiplexer.



Triangle wave-to-sine wave converter.

The CA3280 and CA3280A are supplied in the 16-lead dual-in-line Gold-CHIP plastic package (G suffix). The operating-temperature ranges are −55 to +125°C for the CA3280A, and 0 to +70°C for the CA3280. The CA3280 is also supplied as a hermetic Gold-CHIP (HG suffix).

ICL 7106/7107

THE ICL7106 and 7107 are high performance, low power, CMOS 3½ digit A/D converters that contain all the necessary active devices on a single monolithic IC. Each has parallel seven-segment outputs which are ideal for use in a digital panel meter. The ICL7106 will directly drive a liquid crystal display including the backplane drive. The ICL7107 will directly drive instrument size LEDs without buffering. With seven passive components, display and power supply, the system forms a complete digital voltmeter with automatic zero connection and polarity. (see figs. 1 and 3).

Both ICs use the time-proven dual slope integration technique with all its advantages, i.e. non-critical components, high noise rejection, non-critical clock frequency and almost perfect differential linearity. Both the ICL7106 and 7107 can be used not only with its internal reference, but true ratiometric reading applications may also be accomplished over a full scale input range of 199.9 mV to 1.999 V.

The accuracy of conversion is guaranteed to plus or minus 1 count over the entire plus or minus 2000 counts and the auto-zero facility provides a guaranteed zero reading for 0 volts input. However, the chip does provide a true polarity output at low voltages for null detection. Both chips have an on-board clock and reference circuitry, as well as overrange detection.

The Clock

The chip carries the active parts of an RC oscillator which runs at about 48 kHz and is divided by 4 for use as the system clock. The integration period (1000 clock pulses) is therefore 83.3 ms. Each conversion requires 4,000 clock pulses, i.e. 3 readings per second. For optimum 50 Hz line frequency rejection, the clock should be set to a multiple of 50 Hz, e.g. 50 kHz.

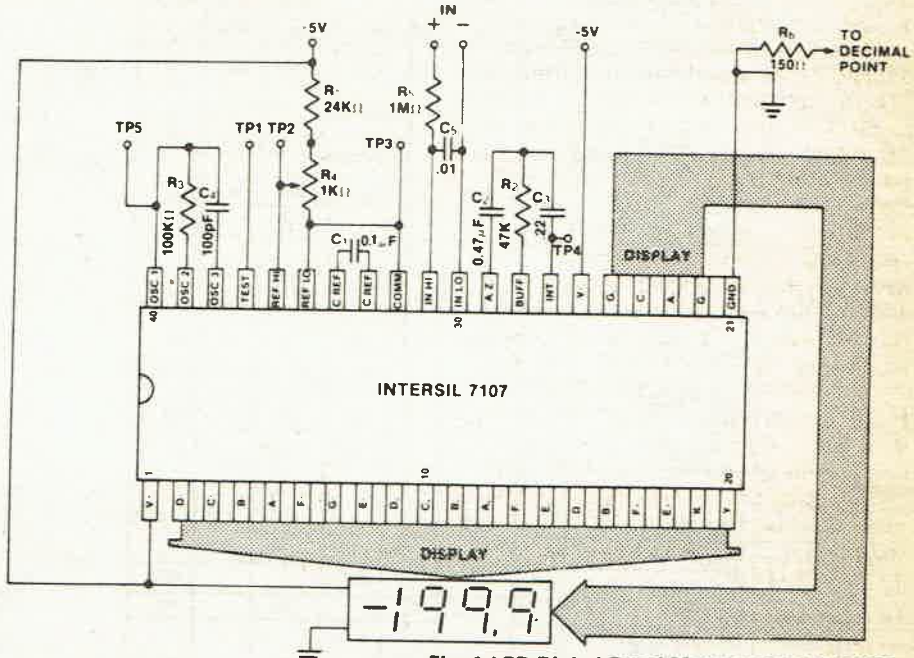


Fig. 1 LED Digital Panel Meter using ICL 7107

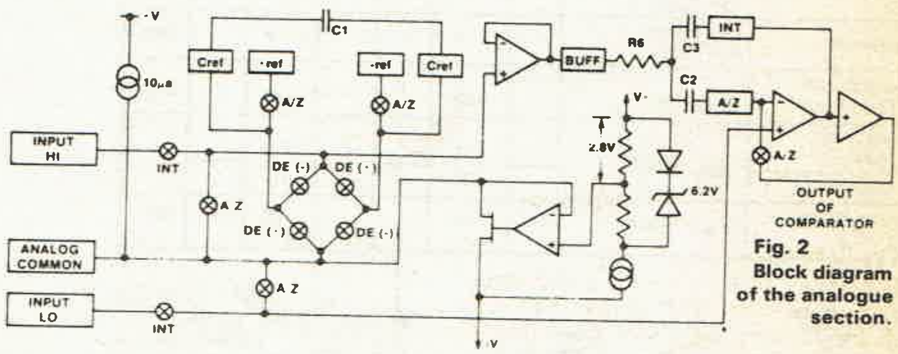


Fig. 2 Block diagram of the analogue section.

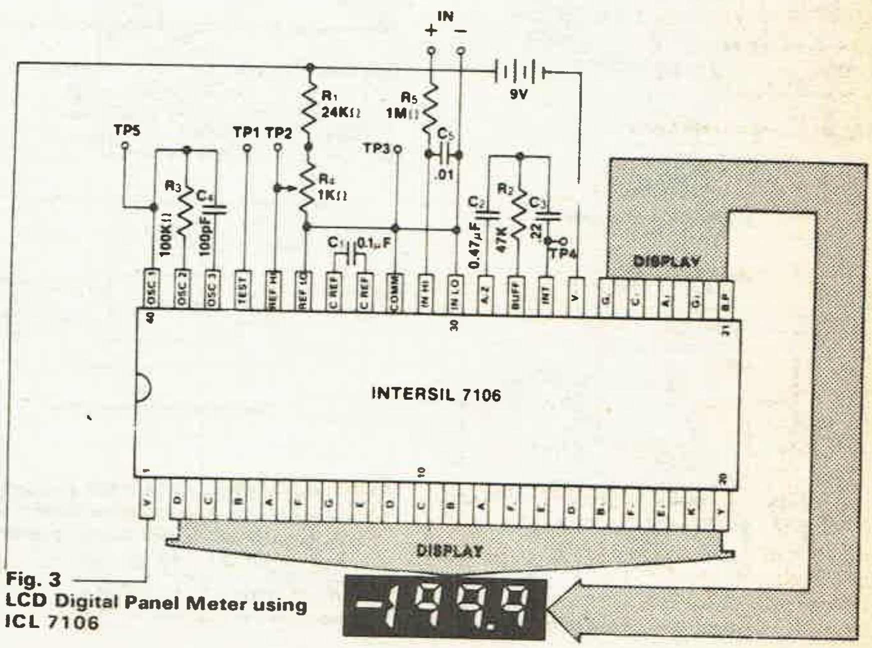
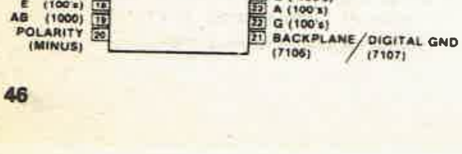


Fig. 3 LCD Digital Panel Meter using ICL 7106

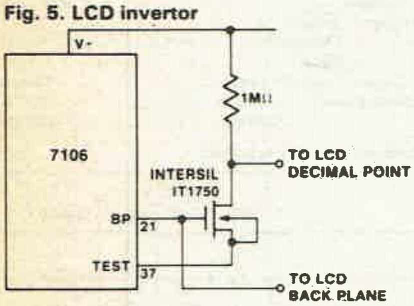
Fig. 4. Pinouts



Displays and DPs

The additional components required to build a DPM are a display (either LCD or LED), 4 resistors, 4 capacitors, and an input filter if required. Liquid crystal displays become polarised and damaged if a DC voltage is continuously applied to them, so they must be driven with an AC signal. To turn on a segment, a waveform 180 degrees out of phase with the backplane drive (but of equal amplitude) is applied to that segment. The 7106 generates the segment drive waveform for all digits internally, but does not generate segment drive for the decimal point. This must be done using an inverter or exclusive-OR logic (see fig. 5 below). For use with LED displays the 7107 pull-down FETs will sink about 8 mA per segment, which produces a bright display suitable for almost any indoor application. A fixed decimal point can be turned on by tying the appropriate cathode to ground through a 150 ohm resistor.

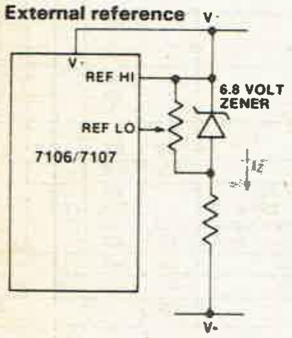
Fig. 5. LCD invertor



The Reference

For 200.0 mV full scale, the voltage applied between REF Hi and REF Lo should be set at 100.0 mV. For 2.000 V full scale, this should be 1.000 V. The reference inputs are floating, and the only restriction on the applied voltage is that it should lie in the range V— to V+.

Fig. 6. External reference



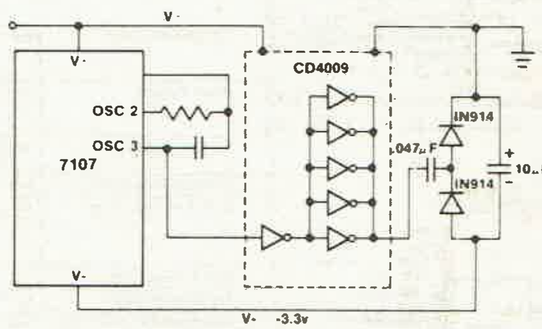
(a)

For many applications, the internal reference of 2.8 V between V+ and COMMON is adequate, but power dissipation in the 7107 LED version can wreck this. However, an external reference can be added as shown in Fig.6.

Electrical Specifications @ +25 C unless otherwise specified

Full Scale Voltage Range	±200mv (5.0V min V+ to V—) ±2.0V (6.0V min V+ to V—)
Full Scale Digital Range	±2000 Counts
Common Mode Voltage Range	V+ minus 0.5V to V—, plus 1V
Accuracy 10 C to 50 C with external reference	<1/2 Count
Noise referred to Input	15μV typical
Zero width	0—1 transition at 7 to 9 counts
Turnover	< 1 Count
Input circuit	Differential
Input Bias Current	2pA
Input Impedance	> 10 ohm
Polarity	Automatic with neg sign displayed.
Reference (Internal)	Internal 2.8V, referenced to V+ Temperature Coefficient 100ppm/ C typical.
Reference (External)	External reference must be in the range V+ to V—
Recommended External Components	
200mV Full Scale	2V Full Scale
C = Int Cap 220n	C = Int Cap 220n
C = AZ Cap 470n	C + AZ Cap 47n
C = Ref Cap 100n	C = Ref Cap 100n
C = Clock Cap 100p	C = Clock Cap 100p
R = Int Res 47k	R = Int Res 470k
R = Clock Res 100k	R = Clock Res 100k
R = Short	R = Short
Clock Frequency	48kHz divided by 4 An internal divide by 4 counter is provided to count external oscillators down to 12kHz, the internal dual slope clock.
Display Outputs (LED ICL7107)	22 Current limited segment drives plus one current limited neg sign drive plus LED common Note The 2 die in the 1k bit are in parallel
Display Outputs (LCD ICL7106)	22 segment drives plus one neg sign drive plus LCD back plane drive
LED (7107) current @ +5.0V	5.5 to 8.0ma
Power Requirements	LCD Ima @ 4.5 — 6V LED 1ma @ 4.5 — 6V, plus LED current
Power supply configuration (7107)	Dual +4.5 to +6V and —3 to —6V @ 1ma Note for inputs that remain within the CM voltage range only a single supply is required
Digital input Signals (7106)	Test Single 5 to 12V A high on the test input turns on all segments and the minus sign
Read Rate	3 Readings per second with 12kHz internal clock (48kHz external clock) Accurate from 1 to 15 reading per second.

Fig. 7. Deriving a negative supply



Power Supplies

The 7106 will run from a single 5 to 12 V supply. If INPUT Lo is shorted to COMMON, this will cause V+ to sit 2.8 V positive with respect to INPUT Lo, and V— at 6.2 V negative with respect to INPUT Lo.

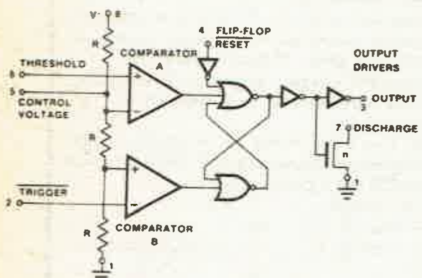
The 7107 requires dual supplies, +4.5 to +6 V and —3 to —6 V at 1 mA. A negative supply may be derived from +5 V using the circuit given in Fig 7.

ICM7555/7556

ICM7555/7556 CMOS General Purpose Timers

FEATURES

- Exact equivalent in most cases for SE/NE555/556 or the 355.
- Low Supply Current — 80μA Typ. (ICM7555) 160μA Typ. (ICM7556)
- Extremely low trigger, threshold and reset currents - 20pA Typical
- High speed operation - 500 kHz guaranteed
- Wide operation supply voltage range guaranteed 2 to 18 volts
- Normal Reset function - No crowbarring of supply during output transition.
- Can be used with higher impedance timing elements than regular 555/6 for longer RC time constants.
- Timing from microseconds through hours
- Operates in both astable and monostable modes
- Adjustable duty cycle
- High output source/sink driver can drive TTL/CMOS
- Typical temperature stability of 0.005% per °C at 25°C
- Outputs have very low offsets, HI and LO



This block diagram reduces the circuitry down to its simplest equivalent components.

NOTE: $\overline{\text{RESET}}$ will dominate all other inputs. $\overline{\text{TRIGGER}}$ will dominate over THRESHOLD.

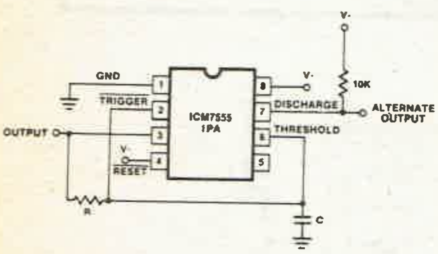


Figure 3: Astable Operation

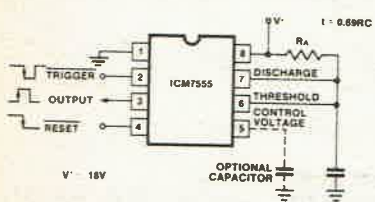


Figure 4: Monostable Operation

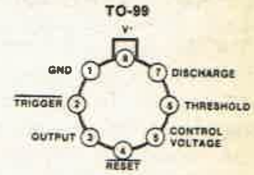
GENERAL DESCRIPTION

The ICM7555/6 are CMOS RC timers providing significantly improved performance over the standard SE/NE555/6 and 355 timers, while at the same time being direct replacements for those devices in most applications. Improved parameters include low supply current, wide operating supply voltage range, low THRESHOLD, $\overline{\text{TRIGGER}}$ and $\overline{\text{RESET}}$ currents, no crowbarring of the supply current during output transitions, higher frequency performance and no requirement to decouple CONTROL VOLTAGE for stable operation.

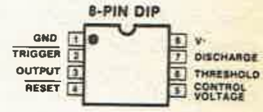
Specifically, the ICM7555/6 are stable controllers capable of producing accurate time delays or frequencies. The ICM7556 is a dual ICM7555, with the two timers operating independently of each other, sharing only V^+ and GND. In the one shot mode, the pulse width of each circuit is precisely controlled by one external resistor and capacitor. For astable operation as an oscillator, the free running frequency and the duty cycle are both accurately controlled by two external resistors and one capacitor. Unlike the regular bipolar 555/6 devices, the CONTROL VOLTAGE terminal need not be decoupled with a capacitor. The circuits are triggered and reset on falling (negative) waveforms, and the output inverter can source or sink currents large enough to drive TTL loads, or provide minimal offsets to drive CMOS loads.

ICM7555

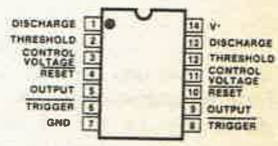
TO-99



8-PIN DIP



ICM7556



TRUTH TABLE

THRESHOLD VOLTAGE	TRIGGER VOLTAGE	$\overline{\text{RESET}}$	OUTPUT	DISCHARGE SWITCH
DON'T CARE	DON'T CARE	LOW	LOW	ON
>2/3(V+)	>1/3(V+)	HIGH	LOW	ON
1/3<V_{TH}<2/3	1/3<V_{TH}<2/3	HIGH	STABLE	STABLE
DON'T CARE	<1/3(V+)	HIGH	HIGH	OFF

ABSOLUTE MAXIMUM RATINGS (NOTE 1)

Supply Voltage .... +18 Volts

Input Voltage: Trigger, Threshold, Reset ..... ≤ V^+ + 0.3V to ≥ V^- − 0.3V

Output Current Control Voltage 100mA

Power Dissipation[2] ICM7556 .... 300mW

ICM7555 .... 200mW

OPERATING CHARACTERISTICS (T_A = 25°C, V^+ = +2 to +15 Volts unless other specified)

PARAMETER	SYMBOL	TEST CONDITIONS	VALUE MIN	VALUE TYP	VALUE MAX	UNITS
Supply Voltage	V^+	−20°C ≤ T_A ≤ +70°C −55°C ≤ T_A ≤ +125°C	2 3		18 16	V V
Supply Current[3]	I^+	ICM7555 V^+ = 2V V^+ = 18V		60 120	200 300	μA μA
		ICM7556 V^+ = 2V V^+ = 18V		120 240	400 600	μA μA
Timing Error Initial Accuracy Drift with Temperature Drift with Supply Voltage		R_A, R_B = 1k to 100k, C = 0.1μF, 5V ≤ V^+ ≤ 15V Note 4 Note 4 V^+ = 5V V^+ = 10V V^+ = 15V V^+ = 5V		2.0 50 1.0	5.0 200 300 600 3.0	% ppm/°C %/V
Threshold Voltage	V_{TH}		0.63	0.66	0.67	V^+
Trigger Voltage	V_{TRIG}		0.29	0.33	0.34	V^+
Trigger Current	I_{TRIG}	V^+ = 18V V^+ = 5V V^+ = 2V		50 10 1		pA pA pA
Threshold Current	I_{TH}	V^+ = 18V V^+ = 5V V^+ = 2V		50 10 1		pA pA pA
Reset Current	I_{RST}	V_{RESET} = Ground V^+ = 18V V^+ = 5V V^+ = 2V		100 20 2		pA pA pA
Reset Voltage	V_{RST}	V^+ = 18V V^+ = 2V	0.4 0.4	0.7 0.7	1.0 1.0	V V
Control Voltage Lead	V_{CV}		0.62	0.66	0.67	V^+
Output Voltage Drop	V_O	Output Lo V^+ = 18V I_{SINK} = 3.2mA V^+ = 5V I_{SINK} = 3.2mA Output Hi V^+ = 18V I_{SOURCE} = 1.0mA V^+ = 5V I_{SOURCE} = 1.0mA	 17.25 4.0	0.1 0.15 17.8 4.5	0.4 0.4	V V V V
Rise Time of Output	t_r	R_L = 10MΩ C_L = 10pF V^+ = 5V	35	40	75	ns
Fall Time of Output	t_f	R_L = 10MΩ C_L = 10pF V^+ = 5V	35	40	75	ns
Guaranteed Max Osc Freq	f_{max}	Astable Operation	500			kHz

NOTES:

1. Due to the SCR structure inherent in the CMOS process used to fabricate these devices, connecting any terminal to a voltage greater than V^+ +0.3V or less than V^- −0.3V may cause destructive latchup. For this reason it is recommended that no inputs from external sources not operating from the same power supply be applied to the device before its power supply is established. In multiple systems, the supply of the ICM7555/6 must be turned on first.
2. Junction temperatures should not exceed 135°C and the power dissipation must be limited to 20mW at 125°C. Below 125°C power dissipation may be increased to 300mW at 25°C. Derating factor is approximately 3mW/°C (7556) or 2mW/°C (7555).
3. The supply current value is essentially independent of the $\overline{\text{TRIGGER}}$, THRESHOLD and $\overline{\text{RESET}}$ voltages.
4. Parameter is not 100% tested. Majority of all units meet this specification.

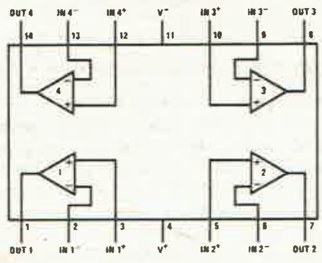
LF347

LF347 Wide Bandwidth Quad JFET Input Operational Amplifiers

Features

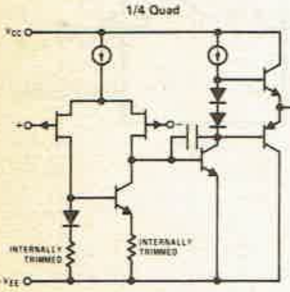
- Internally trimmed offset voltage — 2 mV
- Low input bias current — 50 pA
- Low input noise voltage — 16 nV/$\sqrt{Hz}$
- Low input noise current — 0.01 pA/$\sqrt{Hz}$
- Wide gain bandwidth — 4 MHz
- High slew rate — 13 V/μs
- Low supply current — 7.2 mA
- High input impedance — $10^{12}\Omega$
- Low total harmonic distortion A_V = 10, R_L = 10k, V_O = 20 Vp-p, BW = 20 Hz–20 kHz — <0.02%
- Low 1/f noise corner — 50 Hz
- Fast settling time to 0.01% — 2 μs

Dual-In-Line Package



TOP VIEW

1/4 Quad



General Description

The LF347 is a low cost, high speed quad JFET input operational amplifier with an internally trimmed input offset voltage (BI-FET II™ technology). The device requires a low supply current and yet maintains a large gain bandwidth product and a fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. The LF347 is pin compatible with the standard LM348. This feature allows designers to immediately upgrade the overall performance of existing LF348 and LM324 designs.

The LF347 may be used in applications such as high speed integrators, fast D/A converters, sample-and-hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The device

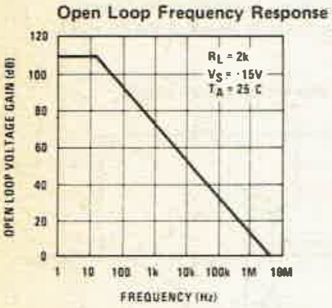
Absolute Maximum Ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Operating Temperature Range	0°C to +70°C
$T_{j(MAX)}$	115°C
Differential Input Voltage	±30V
Input Voltage Range (Note 2)	±15V
Output Short Circuit Duration (Note 3)	Continuous
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

DC Electrical Characteristics (Note 4)

SYMBOL	PARAMETER	CONDITIONS	LF347A			LF347B			LF347			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	R_S = 10 kΩ, T_A = 25°C		1	2		3	5		5	10	mV
		Over Temperature			4			7			13	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	R_S = 10 kΩ		10			10			10		μV/°C
I_{OS}	Input Offset Current	T_j = 25°C, (Notes 4, 5)		25	50		25	100		25	100	pA
		$T_j \leq 70°C$			2			4			4	nA
I_B	Input Bias Current	T_j = 25°C, (Notes 4, 5)		50	100		50	200		50	200	pA
		$T_j \leq 70°C$			4			8			8	nA
R_{IN}	Input Resistance	T_j = 25°C		10^{12}			10^{12}			10^{12}		Ω
A_{VOL}	Large Signal Voltage Gain	V_S = ±15V, T_A = 25°C, V_O = ±10V, R_L = 2 kΩ	50	100		50	100		25	100		V/mV
		Over Temperature	25			25			15			V/mV
V_O	Output Voltage Swing	V_S = ±15V, R_L = 10 kΩ	±12	±13.5		±12	±13.5		±12	±13.5		V
V_{CM}	Input Common-Mode Voltage Range	V_S = ±15V	±11	+15		±11	+15		±11	+15		V
				−12			12			−12		V
CMRR	Common-Mode Rejection Ratio	$R_S \leq$ 10 kΩ	80	100		80	100		70	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 6)	80	100		80	100		70	100		dB
I_S	Supply Current			7.2	11		7.2	11		7.2	11	mA

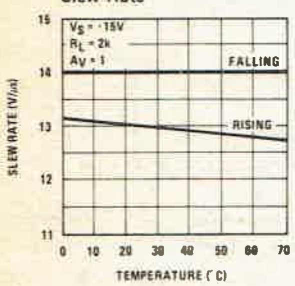
Open Loop Frequency Response



AC Electrical Characteristics (Note 4)

SYMBOL	PARAMETER	CONDITIONS	LF347A			LF347B			LF347			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
	Amplifier to Amplifier Coupling	T_A = 25°C, f = 1 Hz–20 kHz (Input Referred)		−120			−120			−120		dB
SR	Slew Rate	V_S = ±15V, T_A = 25°C		13			13			13		V/μs
GBW	Gain-Bandwidth Product	V_S = ±15V, T_A = 25°C		4			4			4		MHz
e_n	Equivalent Input Noise Voltage	T_A = 25°C, R_S = 100Ω, f = 1000 Hz		16			16			16		nV/$\sqrt{Hz}$
i_n	Equivalent Input Noise Current	T_j = 25°C, f = 1000 Hz		0.01			0.01			0.01		pA/$\sqrt{Hz}$

Slew Rate



Note 1: For operating at elevated temperature, the device must be derated based on a thermal resistance of 125°C/W junction to ambient or 95°C/W junction to case.

Note 2: Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

Note 3: P_D max rating cannot be exceeded.

Note 4: These specifications apply for V_S = ±15V and $0°C \leq T_A \leq +70°C$. V_{OS}, I_B and I_{OS} are measured at V_{CM} = 0.

Note 5: The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature, T_j. Due to limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation, P_D. $T_j = T_A + \Theta_{jA} P_D$ where Θ_{jA} is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

Note 6: Supply voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with common practice.

LF13741

LF13741 monolithic JFET input operational amplifier

features

- Low input bias current 50 pA
- Input common-mode range to positive supply voltage
- Low input noise current 0.01 pA/$\sqrt{Hz}$
- High input impedance $5 \times 10^{11}\Omega$
- Familiar operating characteristics

advantages

- FET inputs — 741 operating characteristics
- Low cost
- Ease of use
- Standard supplies
- Standard pin outs
- Non-rectifying input for RF environment
- Rapid "design time"

applications

- Smoke detectors
- I to V converters
- High impedance buffers
- Low drift sample and hold circuits
- High input impedance, slow comparators
- Long time timers
- Low drift peak detectors
- Supply current monitors
- Low error budget systems

general description

The LF13741 is a 741 with BI-FET input followers on the same die. Familiar operating characteristics — those of a 741 — with the added advantage of low input bias current make the LF13741 easy to use. Monolithic fabrication makes this "drop-in-replacement" operational amplifier very economical.

Applications in which the LF13741 excels are those which require low bias current, moderate speed and low cost. A few examples include high impedance transducer amplifiers, photocell amplifiers, buffers for high impedance, slow to moderate speed sources and buffers in sample-and-hold type systems where leakage from the hold capacitor node must be kept to a minimum.

Systems designers can take full advantage of their knowledge of the 741 when designing with the LF13741 to achieve extremely rapid "design times." The LF13741 can also be used in existing sockets to make the "error budget" for input bias and/or offset currents negligible and in many cases eliminate trimming. For higher speed and lower noise use the LF155, LF156, LF157 series of BI-FET operational amplifiers.

application hints

GENERAL CHARACTERISTICS

The LF13741 makes the job of converting from a bipolar to a FET input op amp easy. As a systems designer you are probably very familiar with the operating characteristics of a 741 op amp. In fact, many of you have used 741s with FET input followers—that's just what the LF13741 is, but it's all on a single die.

When you need a low cost, reliable, well known op amp with low input currents and moderate speed, use an LF13741.

DIFFERENTIAL INPUTS

You don't have to use clamps across the inputs for differential input voltages of less than 40V. The input JFET's of the LF13741, in addition to being well matched, have large reverse breakdown voltages from gate to source and drain.

POSITIVE INPUT COMMON-MODE VOLTAGE LIMIT

With the LF13741 (unlike the normal 741) you can take both inputs above the positive supply voltage by more than 0.1V before the amplifier ceases to function. This feature enables you to use the LF13741 to monitor and/or limit the current from the same supply used to power it (see typical applications).

If you exceed the positive common-mode voltage limit on only one input the output phase will remain correct. When you exceed the limit on both inputs, the output phase is unpredictable.

NEGATIVE INPUT COMMON-MODE VOLTAGE LIMIT

There are two negative input voltage ranges of interest:

1. The range between the negative common-mode voltage limit and the negative supply voltage.
2. Voltages which are more negative than the negative supply voltage.

If you take only one of the inputs of the LF13741 into the first range, the output phase will remain correct. When you take both inputs into this range the output will go toward the positive supply voltage.

If you force either or both of the inputs into the second range, an internal diode will be turned "ON." Unless you externally limit the diode current to about 1 mA, the device will be destroyed. In either case, limited or unlimited input current, you cannot predict the output.

HANDLING

You do not have to take any special precautions in handling the LF13741. It has JFET, as opposed to fragile MOSFET, inputs.

APPLYING POWER

You should never: reverse the power supplies to the LF13741; plug a part in backwards in a powered socket or board; make the negative supply voltage more positive than an input voltage.

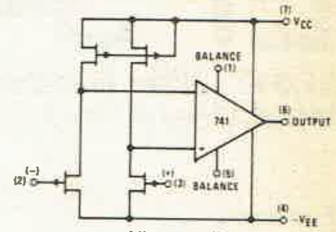
Any one of these supply conditions will forward bias an internal diode. If you have not externally limited the resulting current, the device will be destroyed.

LAYOUT

To ensure stability of response you should take care with lead dress, component placement and power supply decoupling. For example, the body of feedback resistors (from output to input pins) should be placed close to the inverting input pin. Noise "pickup" and capacitance to ground from the input pin will be minimized—effects which are usually desirable.

Because of the very low input bias currents of the LF13741, special care should be taken in printed circuit board layouts to prevent unnecessary leakage from the input nodes.

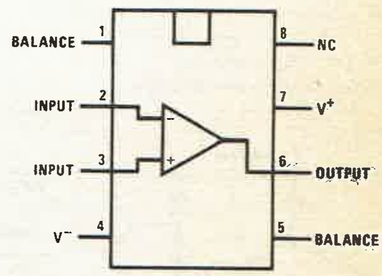
simplified schematic



All on one die.

connection diagrams

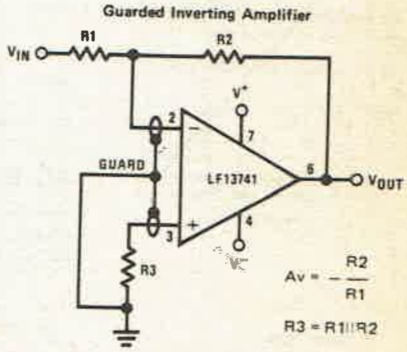
Dual-In-Line Package



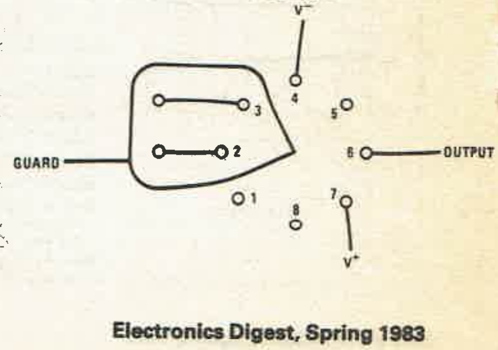
TOP VIEW

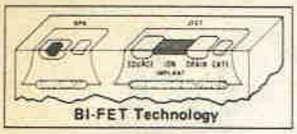
Circuits Using Guard Rings to Prevent Leakage Currents Between Inputs and V⁻

Guarded Inverting Amplifier



PC Layout





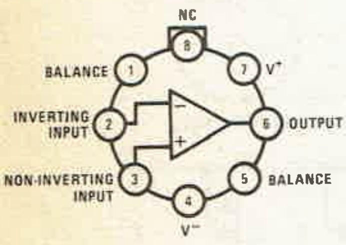
absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Operating Temperature Range	0°C to +70°C
$T_{j(MAX)}$	100°C
Differential Input Voltage	±30V
Input Voltage Range (Note 2)	±16V
Output Short Circuit Duration	Continuous
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

dc electrical characteristics (Note 3)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	R_S = 10 kΩ, T_A = 25°C		5	15	mV
		Over Temperature			20	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	R_S = 10 kΩ		10		μV/°C
I_{OS}	Input Offset Current	T_j = 25°C, (Notes 3, 4)		10	50	pA
		$T_j \leq 70°C$			2	nA
I_B	Input Bias Current	T_j = 25°C, (Notes 3, 4)		50	200	pA
		$T_j \leq 70°C$		1.6	8	nA
R_{IN}	Input Resistance	T_j = 25°C		5×10^{11}		Ω
A_{VOL}	Large Signal Voltage Gain	V_S = ±15V, T_A = 25°C V_O = ±10V, R_L = 2 kΩ	25	100		V/mV
		Over Temperature	15			V/mV
V_O	Output Voltage Swing	V_S = ±15V, R_L = 10 kΩ	±12	±13		V
V_{CM}	Input Common-Mode Voltage Range	V_S = ±15V	±11	+15.1		V
				−12		V
CMRR	Common-Mode Rejection Ratio	$R_S \leq$ 10 kΩ	70	90		dB
PSRR	Supply Voltage Rejection Ratio	(Note 5)	77	96		dB
I_S	Supply Current			2	4	mA

TO-99 Metal Can Package



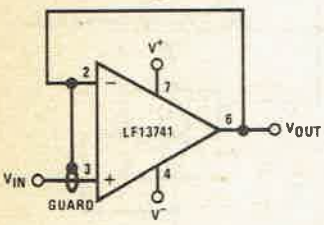
TOP VIEW

Note: Pin 4 connected to case.

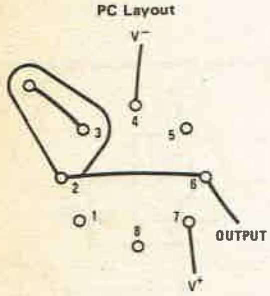
ac electrical characteristics (Note 3)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
SR	Slew Rate	V_S = ±15V, T_A = 25°C		0.5		V/μs
GBW	Gain-Bandwidth Product	V_S = ±15V, T_A = 25°C		1.0		MHz
e_n	Equivalent Input Noise Voltage	T_A = 25°C, R_S = 100 Ω				
		f = 100 Hz		50		$nV/\sqrt{Hz}$
		f = 1000 Hz		37		$nV/\sqrt{Hz}$
i_n	Equivalent Input Noise Current	T_j = 25°C				
		f = 100 Hz		0.01		$pA/\sqrt{Hz}$
		f = 1000 Hz		0.01		$pA/\sqrt{Hz}$

Guarded Voltage Follower



PC Layout



Note 1: For operating at elevated temperature, the device must be derated based on a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case.

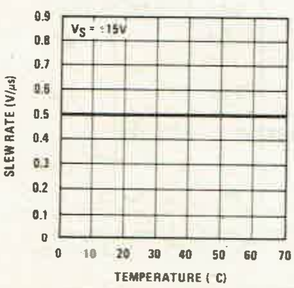
Note 2: Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

Note 3: These specifications apply for V_S = ±15V and $0°C \leq T_A \leq +70°C$. V_{OS}, I_B, and I_{OS} are measured at V_{CM} = 0.

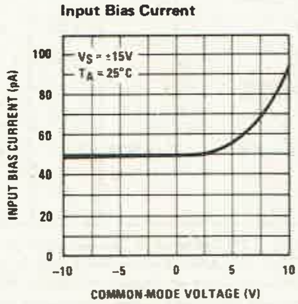
Note 4: The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature, T_j. Due to limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation, P_D. $T_j = T_A + \Theta_{jA} P_D$ where Θ_{jA} is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

Note 5: Supply Voltage Rejection Ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with common practice.

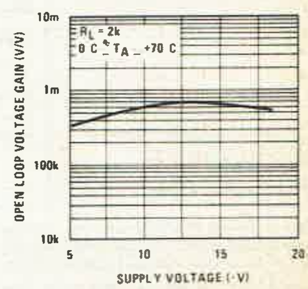
Slew Rate



Input Bias Current



Open Loop Voltage Gain (V/V)



LM134/234/334

LM134/LM234/LM334 3-Terminal Adjustable Current Sources

Features

- Operates from 1V to 40V
- 0.02%/V current regulation
- Programmable from 1 µA to 10 mA
- True 2-terminal operation
- Available as fully specified temperature sensor
- ±3% initial accuracy

General Description

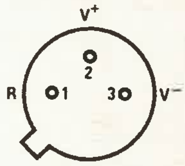
The LM134/LM234/LM334 are 3-terminal adjustable current sources featuring 10,000:1 range in operating current, excellent current regulation and a wide dynamic voltage range of 1V to 40V. Current is established with one external resistor and no other parts are required. Initial current accuracy is ±3%. The LM134/LM234/LM334 are true floating current sources with no separate power supply connections. In addition, reverse applied voltages of up to 20V will draw only a few microamperes of current, allowing the devices to act as both a rectifier and current source in AC applications.

The sense voltage used to establish operating current in the LM134 is 64 mV at 25°C and is directly proportional to absolute temperature (°K). The simplest one external resistor connection, then, generates a current with ≈+0.33%/°C temperature dependence. Zero drift operation can be obtained by adding one extra resistor and a diode.

Applications for the new current sources include bias networks, surge protection, low power reference, ramp generation LED driver, and temperature sensing The LM134-3/LM234-3 and LM134-6/LM234-6 are specified as true temperature sensors with guaranteed initial accuracy of ±3°C and ±6°C, respectively. These devices are ideal in remote sense applications because series resistance in long wire runs does not affect accuracy. In addition, only 2 wires are required.

The LM134 is guaranteed over a temperature range of −55°C to +125°C, the LM234 from −25°C to +100°C and the LM334 from 0°C to +70°C. These devices are available in TO-46 hermetic and TO-92 plastic packages.

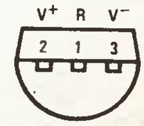
Metal Can Package



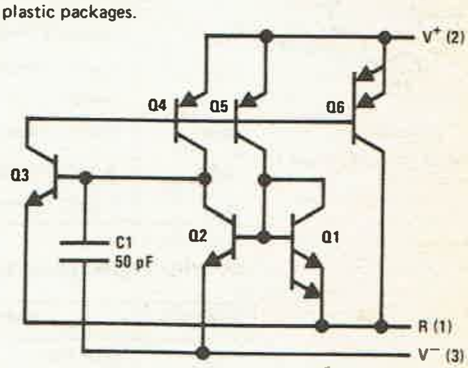
BOTTOM VIEW

Pin 3 is electrically connected to case

Plastic Package



BOTTOM VIEW



Absolute Maximum Ratings

V+ to V− Forward Voltage	
LM134/LM234	40V
LM334/LM134-3/LM134-6/LM234-3/LM234-6	30V
V+ to V− Reverse Voltage	20V
R Pin to V− Voltage	5V
Set Current	10 mA
Power Dissipation	200 mW
Operating Temperature Range	
LM134/LM134-3/LM134-6	−55°C to +125°C
LM234/LM234-3/LM234-6	−25°C to +100°C
LM334	0°C to +70°C
Lead Temperature (Soldering, 10 seconds)	300°C

Electrical Characteristics (Note 1)

PARAMETER	CONDITIONS	LM134/LM234			LM334			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Set Current Error, V+ = 2.5V, (Note 2)	10 µA ≤ ISET ≤ 1 mA			3			6	%
	1 mA < ISET ≤ 5 mA			5			8	%
	2 µA ≤ ISET < 10 µA			5			8	%
Ratio of Set Current to V− Current	10 µA ≤ ISET ≤ 1 mA	14	18	23	14	18	26	
	1 mA ≤ ISET ≤ 5 mA		14			14		
	2 µA ≤ ISET ≤ 10 µA	14	18	23	14	18	26	
Minimum Operating Voltage	2 µA ≤ ISET ≤ 100 µA		0.8			0.8		V
	100 µA < ISET ≤ 1 mA		0.9			0.9		V
	1 mA < ISET ≤ 5 mA		1.0			1.0		V
Average Change in Set Current with Input Voltage	1.5 ≤ V+ ≤ 5V 2 µA ≤ ISET ≤ 1 mA		0.02	0.05		0.02	0.1	%/V
	5V ≤ V+ ≤ 40V		0.01	0.03		0.01	0.05	%/V
	1.5V ≤ V ≤ 5V 1 mA < ISET ≤ 5 mA		0.03			0.03		%/V
	5V ≤ V ≤ 40V		0.02			0.02		%/V
Temperature Dependence of Set Current (Note 3)	25 µA ≤ ISET ≤ 1 mA	0.96T	T	1.04T	0.96T	T	1.04T	
Effective Shunt Capacitance			15			15		pF

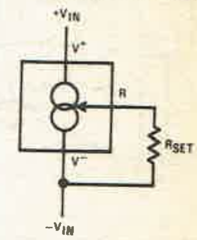
Note 1: Unless otherwise specified, tests are performed at T_j = 25°C with pulse testing so that junction temperature does not change during test.

Note 2: Set current is the current flowing into the V+ pin. It is determined by the following formula: I_{SET} = 67.7 mV/R_{SET} (@ 25°C). Set current error is expressed as a percent deviation from this amount. I_{SET} increases at 0.336%/°C @ T_j = 25°C.

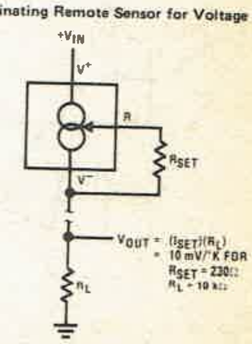
Note 3: I_{SET} is directly proportional to absolute temperature (°K). I_{SET} at any temperature can be calculated from: $I_{SET} = I_o (T/T_o)$ where I_o is I_{SET} measured at T_o (°K).

Typical Applications

Basic 2-Terminal Current Source

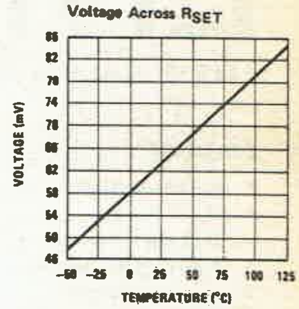


Terminating Remote Sensor for Voltage Output



Electrical Characteristics (Continued) (Note 1)

PARAMETER	CONDITIONS	LM134-3, LM234-3			LM134-6, LM234-6			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Set Current Error, $V^+ = 2.5V$, (Note 2)	$100\ \mu A \le I_{SET} \le 1\ mA$, $T_j = 25°C$			±1			±2	%
Equivalent Temperature Error				±3			±6	°C
Ratio of Set Current to V^- Current	$100\ \mu A \le I_{SET} \le 1\ mA$	14	18	26	14	18	26	
Minimum Operating Voltage	$100\ \mu A\ I_{SET} \le 1\ mA$		0.9			0.9		V
Average Change in Set Current with Input Voltage	$1.5 \le V^+ \le 5V$, $100\ \mu A \le I_{SET} \le 1\ mA$		0.02	0.05		0.02	0.1	%/V
	$5V \le V^+ \le 30V$		0.01	0.03		0.01	0.05	%/V
Temperature Dependence of Set Current (Note 3) and	$100\ \mu A \le I_{SET} \le 1\ mA$	0.98T	T	1.02T	0.97T	T	1.03T	
Equivalent Slope Error				±2			±3	%
Effective Shunt Capacitance			15			15		pF

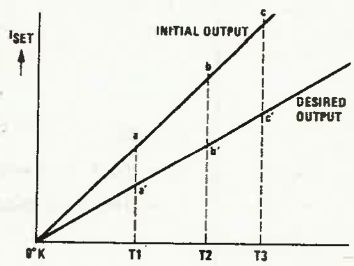


SENSING TEMPERATURE

The LM134 makes an ideal remote temperature sensor because its current mode operation does not lose accuracy over long wire runs. Output current is directly proportional to absolute temperature in degrees Kelvin, according to the following formula:

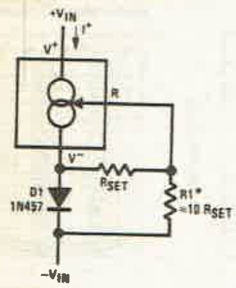
$$I_{SET} = \frac{(227\ \mu V/°K)(T)}{R_{SET}}$$

Calibration of the LM134 is greatly simplified because of the fact that most of the initial inaccuracy is due to a gain term (slope error) and not an offset. This means that a calibration consisting of a gain adjustment only will trim both slope and zero at the same time. In addition, gain adjustment is a one point trim because the output of the LM134 extrapolates to zero at 0°K, independent of R_{SET} or any initial inaccuracy.



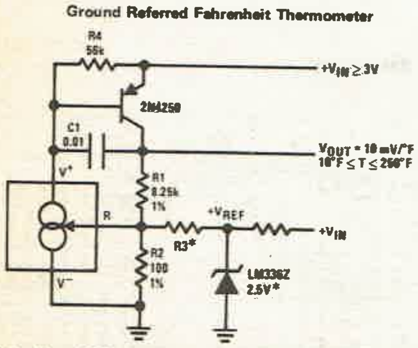
This property of the LM134 is illustrated in the accompanying graph. Line abc is the sensor current before trimming. Line a'b'c' is the desired output. A gain trim done at T2 will move the output from b to b' and will simultaneously correct the slope so that the output at T1 and T3 will be correct. This gain trim can be done on R_{SET} or on the load resistor used to terminate the LM134. Slope error after trim will normally be less than ±1%. To maintain this accuracy, however, a low temperature coefficient resistor must be used for R_{SET}. A 33 ppm/°C drift of R_{SET} will give a 1% slope error because the resistor will normally see about the same temperature variations as the LM134. Separating R_{SET} from the LM134 requires 3 wires and has lead resistance problems, so is not normally recommended. Metal film resistors with less than 20 ppm/°C drift are readily available. Wire wound resistors may also be used where best stability is required.

Zero Temperature Coefficient Current Source



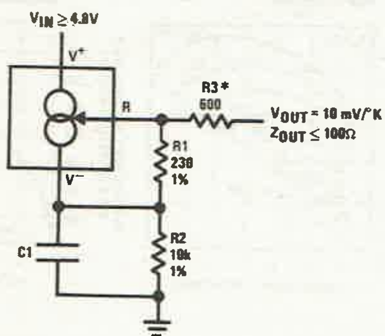
*Select ratio of R1 to R_{SET} to obtain zero drift. $I^+ \approx 2\ I_{SET}$

Ground Referred Fahrenheit Thermometer



*Select R3 = V_{REF}/583 µA. V_{REF} may be any stable positive voltage ≥ 2V
Trim R3 to calibrate

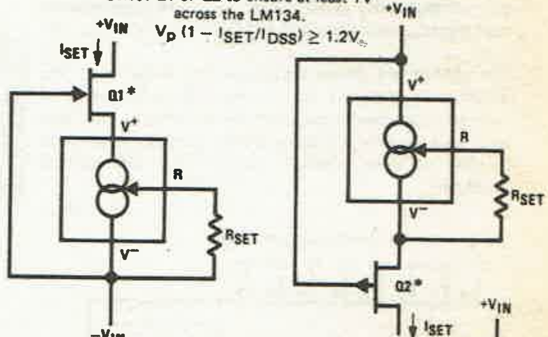
Low Output Impedance Thermometer



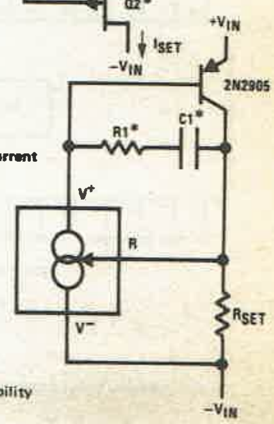
*Output impedance of the LM134 at the "R" pin is approximately $-R_o/16\Omega$, where R_o is the equivalent external resistance connected to the V^- pin. This negative resistance can be reduced by a factor of 5 or more by inserting an equivalent resistor in series with the output.

FET Cascoding for Low Capacitance and/or Ultra High Output Impedance

*Select Q1 or Q2 to ensure at least 1V across the LM134.
$V_p(1 - I_{SET}/I_{DSS}) \ge 1.2V$.



Higher Output Current



*Select R1 and C1 for optimum stability

LM379

LM379 dual 6 watt audio amplifier

absolute maximum ratings

Supply Voltage	35V
Input Voltage	0V – V_{SUPPLY}
Operating Temperatúre	0°C to +70°C
Storage Temperature	−65°C to +150°C
Junction Temperature	150°C
Lead Temperature (Soldering, 10 seconds)	300°C

features

- A_{VO} typical 90 dB
- 6W per channel
- 70 dB ripple rejection
- 75 dB channel separation
- Internal stabilization
- Self centered biasing
- 3 MΩ input impedance
- Internal current limiting
- Internal thermal protection

electrical characteristics

V_S = 28V, T_{TAB} = 25°C, R_L = 8Ω, A_V = 50 (34 dB), unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Total Supply Current	P_{OUT} = 0W		15	65	mA
	P_{OUT} = 1.5W/Channel		430		mA
DC Output Level			14		V
Supply Voltage		10			V
Output Power	T.H.D. = 5%		6		W
	T.H.D. = 10%	6	7		W
T.H.D.	P_{OUT} = 1W/Channel, f = 1 kHz		0.07	1	%
	P_{OUT} = 4W/Channel, f = 1 kHz		0.2		%
Offset Voltage			15		mV
Input Bias Current			100		nA
Input Impedance		3			MΩ
Open Loop Gain	R_S = 0Ω	66	90		dB
Channel Separation	C_F = 250μF, f = 1 kHz	50	70		dB
Ripple Rejection	f = 120 Hz, C_F = 250μF		70		dB
Current Limit			1.5		A
Slew Rate			1.4		V/μs
Equivalent Input Noise Voltage	R_S = 600Ω, 100 Hz – 10 kHz		3		μVrms

Note 1: For operation at ambient temperatures greater than 25°C the LM379 must be derated based on a maximum 150°C junction temperature using a thermal resistance which depends upon device mounting techniques. In most applications it is advisable to heat sink to the chassis. See curves.

applications

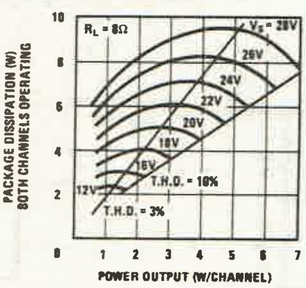
- Multi-channel audio systems
- Tape recorders and players
- Movie projectors
- Automotive systems
- Stereo phonographs
- Bridge output stages
- AM-FM radio receivers
- Intercoms
- Servo amplifiers
- Instrument systems

general description

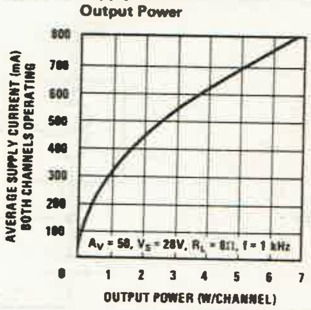
The LM379 is a monolithic dual power amplifier which offers high quality performance for stereo phonographs, tape players, recorders, and AM-FM stereo receivers, etc.

The LM379 will deliver 6W/channel to an 8Ω load. The amplifier is designed to operate with a minimum of external components and contains an internal bias regulator to bias each amplifier. Device overload protection consists of both internal current limit and thermal shutdown.

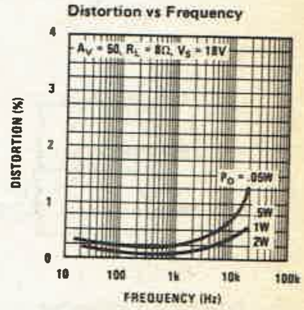
Power Dissipation vs Power Output



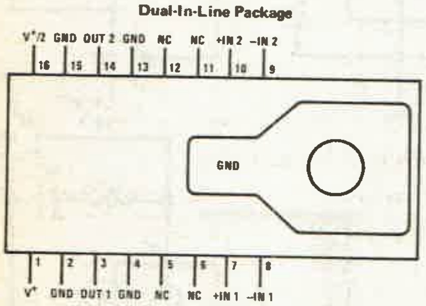
Supply Current vs Output Power



Distortion vs Frequency

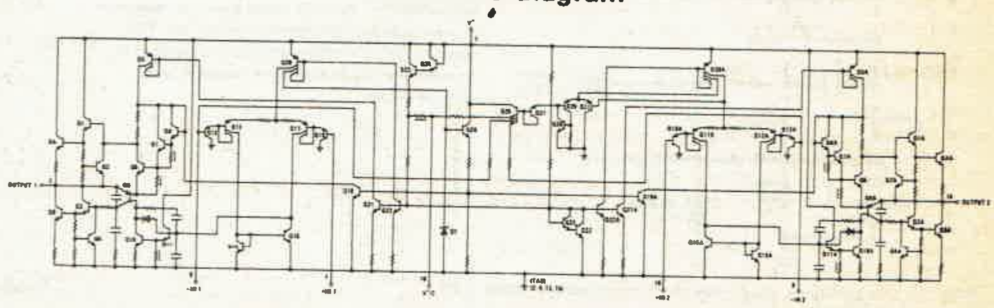


Dual-In-Line Package



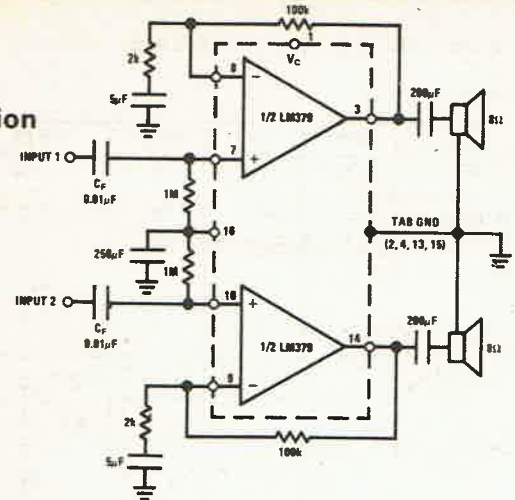
TOP VIEW

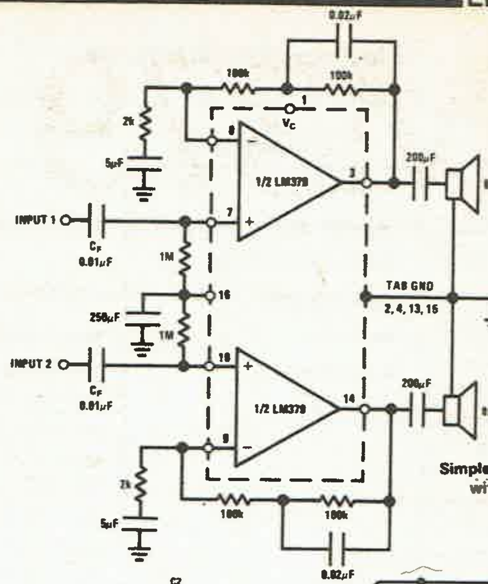
schematic diagram



typical application

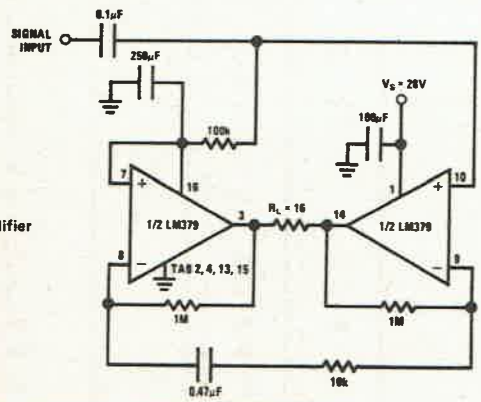
Simple Stereo Amplifier

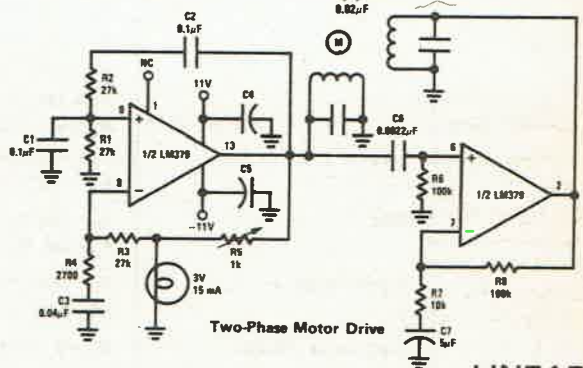




Simple Stereo Amplifier with Bass Boost

12W Bridge Amplifier



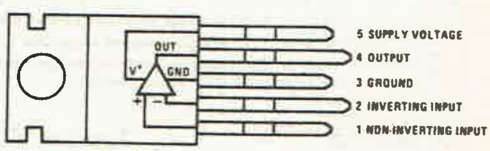


Two-Phase Motor Drive

LM383

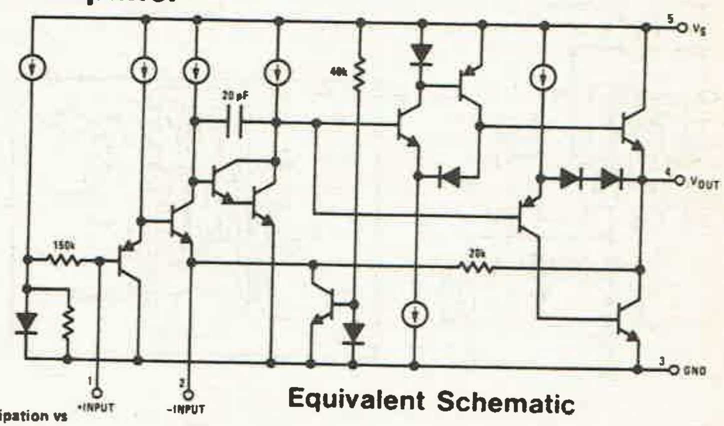
LM383/LM383A 8 Watt Audio Power Amplifier

Plastic Package



Features

- High peak current capability (3.5A)
- Large output voltage swing
- Externally programmable gain
- Wide supply voltage range (5V–20V)
- Few external parts required
- Low distortion
- High input impedance
- No turn-on transients
- High voltage protection available (LM383A)
- Low noise
- Short circuit protected
- Pin for pin compatible with TDA2002

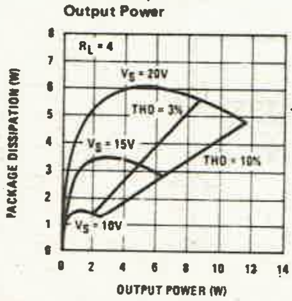


Equivalent Schematic

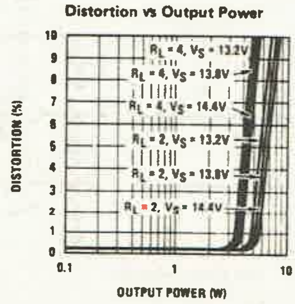
General Description

The LM383 is a cost effective, high power amplifier suited for automotive applications. High current capability (3.5A) enables the device to drive low impedance loads with low distortion. The LM383 is current limited and thermally protected. High voltage protection is available (LM383A) which enables the amplifier to withstand 40V transients on its supply. The LM383 comes in a 5-pin TO-220 package.

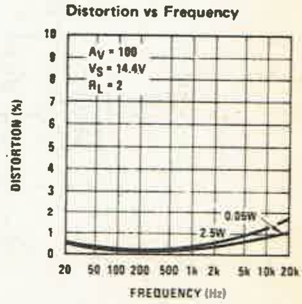
Power Dissipation vs Output Power



Distortion vs Output Power



Distortion vs Frequency



LM383/LM383A 8 Watt Audio Power Amplifier

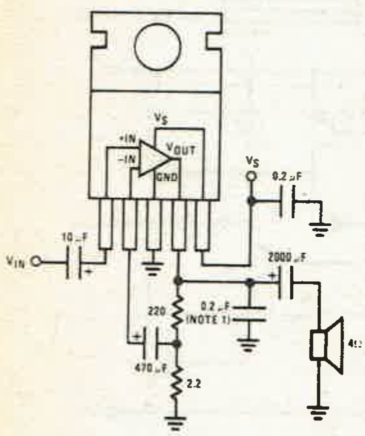
Electrical Characteristics

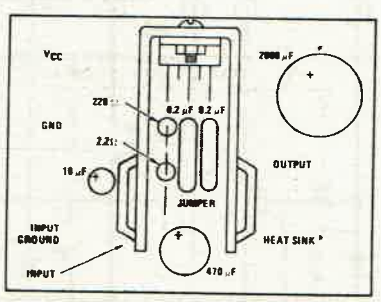
V_S = 14.4V, T_{TAB} = 25°C, A_V = 100 (40 dB), R_L = 4Ω, unless otherwise specified

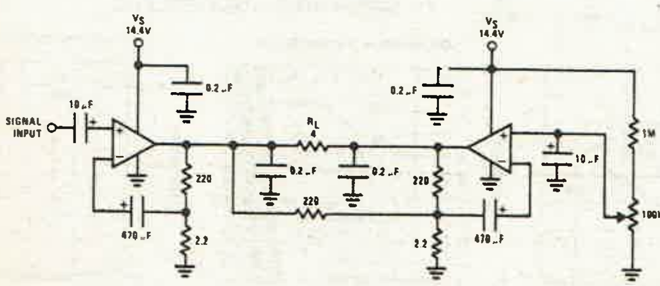
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
DC Output Level		6.4	7.2	8	V
Quiescent Supply Current	Excludes Current in Feedback Resistors		45	80	mA
Supply Voltage Range		5		20	V
Input Resistance			150		kΩ
Bandwidth	Gain = 40 dB		30		kHz
Output Power	V_S = 13.2V, f = 1 kHz				
	R_L = 4Ω, THD = 10%		4.7		W
	R_L = 2Ω, THD = 10%		7.2		W
	V_S = 13.8V, f = 1 kHz				
	R_L = 4Ω, THD = 10%		5.1		W
	R_L = 2Ω, THD = 10%		7.8		W
	V_S = 14.4V, f = 1 kHz				
	R_L = 4Ω, THD = 10%	4.8	5.5		W
	R_L = 2Ω, THD = 10%	7	8.6		W
	R_L = 1.6Ω, THD = 10%	8	9.3		W
	V_S = 16V, f = 1 kHz				
	R_L = 4Ω, THD = 10%		7		W
	R_L = 2Ω, THD = 10%		10.5		W
	R_L = 1.6Ω, THD = 10%		11		W
THD	P_o = 2W, R_L = 4Ω, f = 1 kHz		0.2		%
	P_o = 4W, R_L = 2Ω, f = 1 kHz		0.2		%
Ripple Rejection	R_S = 50Ω, f = 100 Hz	30	40		dB
	R_S = 50Ω, f = 1 kHz		44		dB
Input Noise Voltage	R_S = 0, 15 kHz Bandwidth		2		µV
Input Noise Current	R_S = 100 kΩ, 15 kHz Bandwidth		40		pA

Note 1: A 0.2 µF capacitor should be placed as close as possible to pins 3 and 4 for stability.
Note 2: The LM383 shuts down above 25V.
Note 3: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 4°C/W junction to case.

Typical Applications





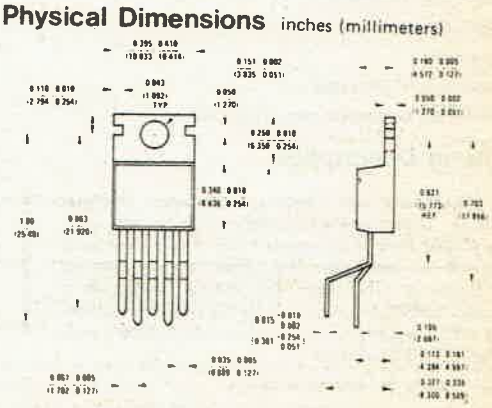


16W Bridge Amplifier

Absolute Maximum Ratings

Peak Supply Voltage (50 ms)	
LM383A (Note 2)	40V
LM383	25V
Operating Supply Voltage	20V
Output Current	
Repetitive	3.5A
Non-repetitive	4.5A
Input Voltage	±0.5V
Power Dissipation (Note 3)	15W
Operating Temperature	0°C to +70°C
Storage Temperature	−60°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

Physical Dimensions inches (millimeters)



LM380

LM380 audio power amplifier

general description

features

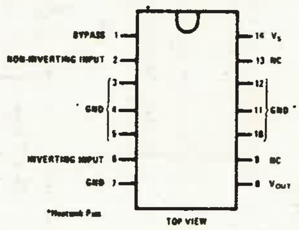
- Wide supply voltage range
- Low quiescent power drain
- Voltage gain fixed at 50
- High peak current capability
- Input referenced to GND
- High input impedance
- Low distortion
- Quiescent output voltage is at one-half of the supply voltage
- Standard dual-in-line package

The LM380 is a power audio amplifier for consumer application. In order to hold system cost to a minimum, gain is internally fixed at 34 dB. A unique input stage allows inputs to be ground referenced. The output is automatically self entering to one half the supply voltage.

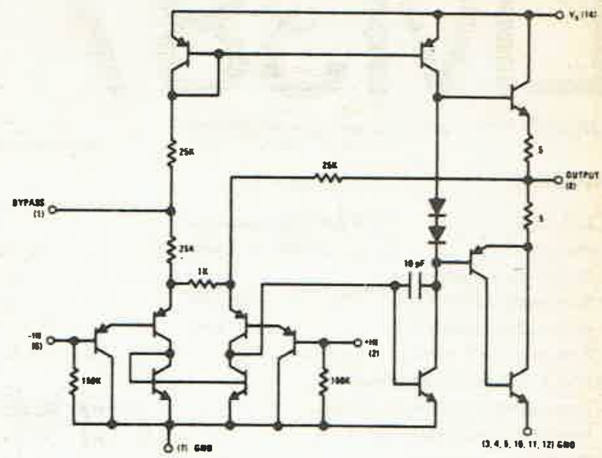
The output is short circuit proof with internal thermal limiting. The package outline is standard dual-in-line. A copper lead frame is used with the center three pins on either side comprising a heat sink. This makes the device easy to use in standard p-c layout.

Uses include simple phonograph amplifiers, intercoms, line drivers, teaching machine outputs, alarms, ultrasonic drivers, TV sound systems, AM-FM radio, small servo drivers, power converters, etc.

Dual-In-Line Package



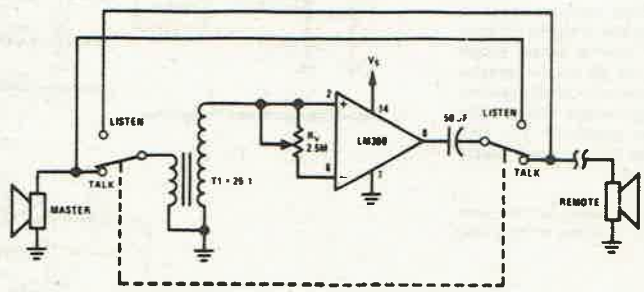
Order Number LM380N
See Package 22



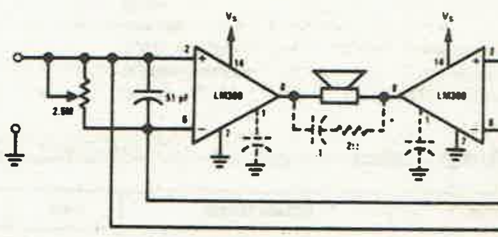
schematic diagram

typical applications

Intercom



Bridge Amplifier



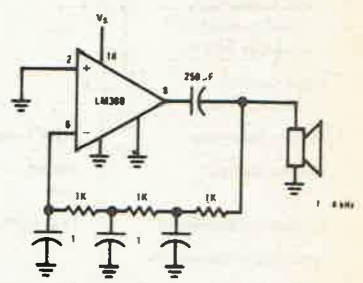
absolute maximum ratings

Supply Voltage	22V
Peak Current	1.3A
Package Dissipation 14-Pin DIP (Notes 6 and 7)	10W
Input Voltage	±0.5V
Storage Temperature	−65°C to +150°C
Operating Temperature	0°C to +70°C
Junction Temperature	+150°C
Lead Temperature (Soldering, 10 sec)	+300°C

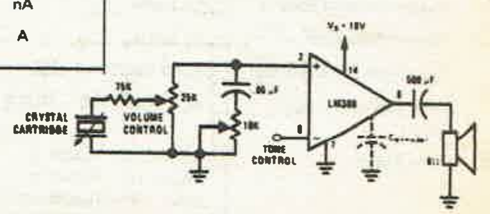
electrical characteristics (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Power	$P_{OUT(RMS)}$	(Notes 3, 4) $R_L = 8\Omega$, THD = 3%	2.5			W
Gain	A_V		40	50	60	V/V
Output Voltage Swing	V_{OUT}	$R_L = 8\Omega$		14		$V_{p\text{-}p}$
Input Resistance	Z_{IN}			150k		Ω
Total Harmonic Distortion	THD	(Note 4, 5)		0.2		%
Power Supply Rejection Ratio	PSRR	(Note 2)		38		dB
Supply Voltage	V_S		8		22	V
Bandwidth	BW	$P_{OUT} = 2W$, $R_L = 8\Omega$		100k		Hz
Quiescent Supply Current	I_Q			7	25	mA
Quiescent Output Voltage	V_{OUTQ}		8	9.0	10	V
Bias Current	I_{BIAS}	Inputs Floating		100		nA
Short Circuit Current	I_{SC}			1.3		A

Phase Shift Oscillator



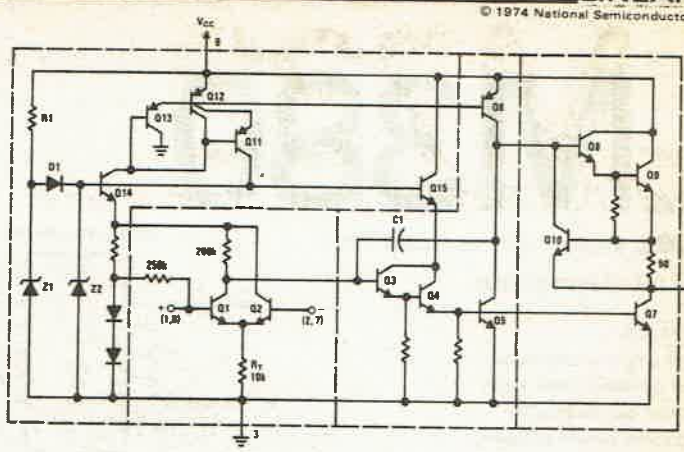
Phono Amplifier



Note 1: $V_S = 18V$ and $T_A = 25°C$ unless otherwise specified.
Note 2: Rejection ratio referred to the output with $C_{BYPASS} = 5\ \mu F$.
Note 3: With device Pins 3, 4, 5, 10, 11, 12 soldered into a 1/16" epoxy glass board with 2 ounce copper foil with a minimum surface of 6 square inches.
Note 4: If oscillation exists under some load conditions, add 2.7Ω and 0.1 μfd series network from Pin 8 to Gnd.
Note 5: $C_{BYPASS} = 0.47\ \mu fd$ on Pin 1.
Note 6: The maximum junction temperature of the LM380 is 150°C.
Note 7: The package is to be derated at 12°C/W junction to heat sink pins.

LM387

LM387 low noise dual preamplifier



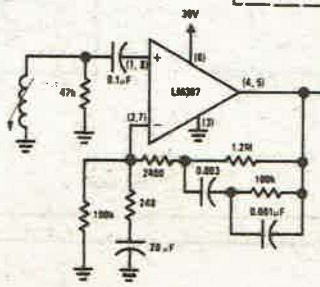
features

- Low noise — 0.8μV total input noise
- High gain — 104 dB open loop
- Single supply operation
- Wide supply range — 9 to 40V
- Power supply rejection — 110 dB
- Large output voltage swing (V_{CC}–2V)p-p
- Wide bandwidth 15 MHz unity gain
- Power bandwidth 75 kHz, 20 Vp-p
- Internally compensated
- Short circuit protected

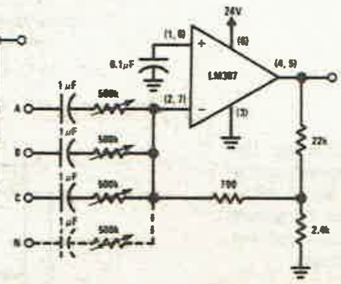
general description

The LM387 is a dual preamplifier for the amplication of low level signals in applications requiring optimum noise performance. Each of the two amplifiers is completely independent, with an internal power supply decoupler-regulator, providing 110 dB supply rejection and 60 dB channel separation. Other outstanding features include high gain (104 dB), large output voltage swing (V_{CC}–2V)p-p, and wide power bandwidth (75 kHz, 20 Vp-p). The LM387 operates from a single supply across the wide range of 9 to 40V.

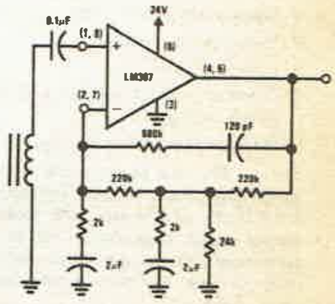
The amplifiers are internally compensated for. All gains greater than 10. The LM387 is available in an 8 lead dual-in-line package.



Typical Magnetic Phono Preamplifier

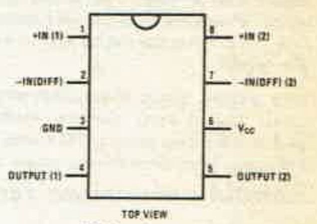


Audio Mixer



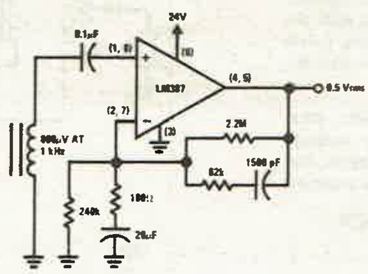
Two-Pole Fast Turn-On NAB Tape Preamplifier

Dual-In-Line Package



absolute maximum ratings

Supply Voltage	+40V
Power Dissipation	660 mW
Operating Temperature Range	0°C to +70°C
Storage Temperature Range	–65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

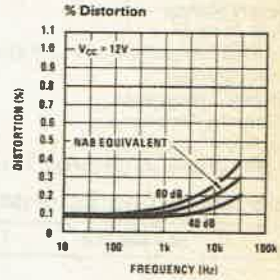


Typical Tape Playback Amplifier

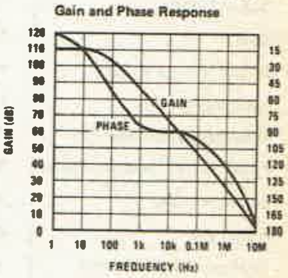
electrical characteristics T_A = 25°C, V_{CC} = 14V, unless otherwise stated.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Voltage Gain	Open Loop		160,000		V/V
Supply Current	V_{CC} 9 to 40V, R_L = ∞		10		mA
Input Resistance Positive Input Negative Input			 100 200		 kΩ kΩ
Input Current Negative Input			 0.5		 μA
Output Resistance	Open Loop		150		Ω
Output Current	Source Sink		8 2		mA mA
Output Voltage Swing	Peak-to-Peak		V_{CC}–2		V
Small Signal Bandwidth			15		MHz
Power Bandwidth	20 Vp-p (V_{CC} = 24V)		75		kHz
Maximum Input Voltage	Linear Operation			300	mVrms
Supply Rejection Ratio	f = 1 kHz		110		dB
Channel Separation	f = 1 kHz		60		dB
Total Harmonic Distortion	75 dB Gain, f = 1 kHz		0.1		%
Total Equivalent Input Noise	R_S = 600Ω, 100 – 10,000 Hz		0.8	1.4	μVrms
Noise Figure	50 kΩ, 10 – 10,000 Hz 10 kΩ, 10 – 10,000 Hz 5 kΩ, 10 – 10,000 Hz		1.0 1.6 2.8		dB dB dB

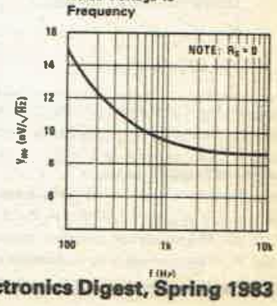
% Distortion



Gain and Phase Response



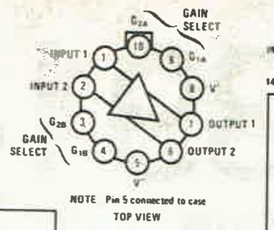
Noise Voltage vs Frequency



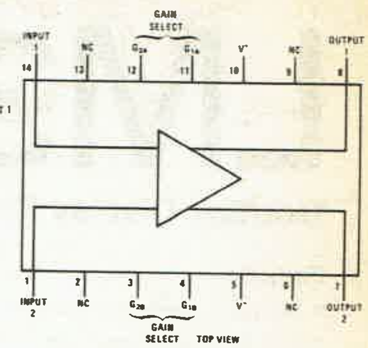
LM733

LM733/LM733C differential video amp

Metal Can Package

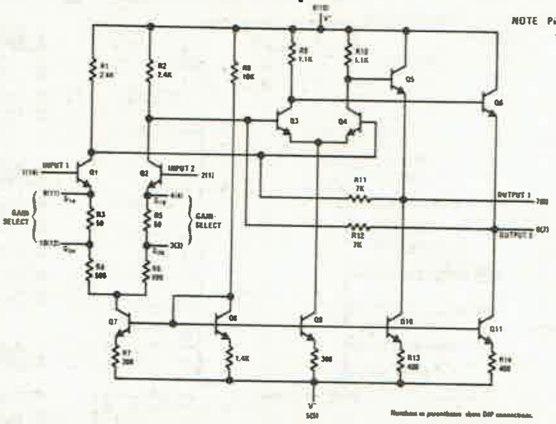


Dual-In-Line Package



features

- 120 MHz bandwidth
- 250 kΩ input resistance
- Selectable gains of 10, 100, 400
- No frequency compensation
- High common mode rejection ratio at high frequencies.



applications

- Magnetic tape systems
- Disk file memories
- Thin and thick film memories
- Woven and plated wire memories
- Wide band video amplifiers.

absolute maximum ratings

Differential Input Voltage	±5V
Common Mode Input Voltage	±6V
V_{CC}	±8V
Output Current	10 mA
Power Dissipation (Note 1)	500 mW
Junction Temperature	+150°C
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range LM733	−55°C to +125°C
LM733C	0°C to +70°C
Lead Temperature (Soldering, 10 sec)	300°C

general description

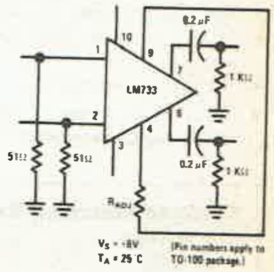
The LM733/LM733C is a two-stage, differential input, differential output, wide-band video amplifier. The use of internal series-shunt feedback gives wide bandwidth with low phase distortion and high gain stability. Emitter follower outputs provide a high current drive, low impedance capability. It's 120 MHz bandwidth and selectable gains of 10, 100, and 400, without need for frequency compensation, make it a very useful circuit for memory element drivers, pulse amplifiers, and wide band linear gain stages.

electrical characteristics (T_A = 25°C, unless otherwise specified, see test circuits)

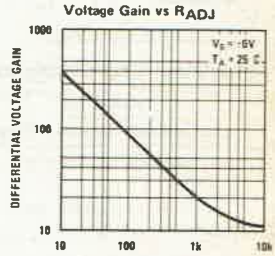
CHARACTERISTICS	TEST CIRCUIT	TEST CONDITIONS	LM733 MIN	LM733 TYP	LM733 MAX	LM733C MIN	LM733C TYP	LM733C MAX	UNITS
Differential Voltage Gain									
Gain 1	1	R_L = 2 kΩ V_{OUT} = 3 V_{pp}	300	400	500	250	400	600	
Gain 2			90	100	110	80	100	120	
Gain 3			9.0	10	11	8.0	10	12	
Bandwidth									
Gain 1	2			40			40		MHz
Gain 2				90			90		MHz
Gain 3				120			120		MHz
Rise Time									
Gain 1	2	V_{OUT} = 1 V_{pp}		10.5			10.5		ns
Gain 2				4.5	10		4.5	12	ns
Gain 3				2.5			2.5		ns
Propagation Delay									
Gain 1	2	V_{OUT} = 1 V_{pp}		7.5			7.5		ns
Gain 2				6.0	10		6.0	10	ns
Gain 3				3.6			3.6		ns
Input Resistance									
Gain 1				4.0			4.0		kΩ
Gain 2			20	30		10	30		kΩ
Gain 3				250			250		kΩ
Input Capacitance		Gain 2		2.0			2.0		pF
Input Offset Current				0.4	3.0		0.4	5.0	µA
Input Bias Current				9.0	20		9.0	30	µA
Input Noise Voltage		BW = 1 kHz to 10 MHz		12			12		µVrms
Input Voltage Range	1		±1.0			±1.0			V
Common Mode Rejection Ratio									
Gain 2	1	V_{CM} = ±1V f ≤ 100 kHz	60	86		60	86		dB
Gain 2		V_{CM} = ±1V f = 5 MHz		60			60		dB
Supply Voltage Rejection Ratio									
Gain 2	1	ΔV_S = ±0.5V	50	70		50	70		dB
Output Offset Voltage									
Gain 1	1	R_L = ∞		0.6	1.5		0.6	1.5	V
Gain 2 and 3				0.35	1.0		0.35	1.5	V
Output Common Mode Voltage	1	R_L = ∞	2.4	2.9	3.4	2.4	2.9	3.4	V
Output Voltage Swing	1	R_L = 2k	3.0	4.0		3.0	4.0		
Output Sink Current			2.5	3.6		2.5	3.6		mA
Output Resistance				20			20		Ω
Power Supply Current	1	R_L = ∞		18	24		18	24	mA

Note 1: The maximum junction temperature of the LM733 is 150°C, while that of the LM733C is 100°C. For operation at elevated temperatures, devices in the TO-100 package must be derated based on a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case. Thermal resistance of the dual-in-line package is 100°C/W.

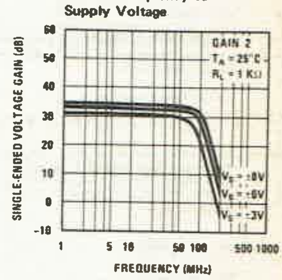
Voltage Gain Adjust Circuit



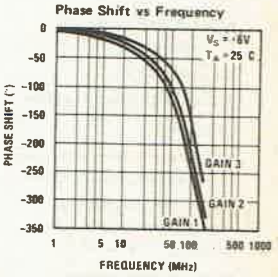
Voltage Gain vs R_{ADJ}



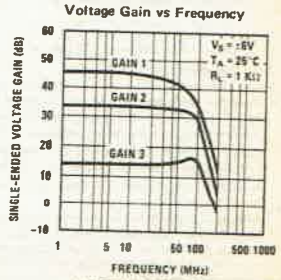
Gain vs Frequency vs Supply Voltage



Phase Shift vs Frequency



Voltage Gain vs Frequency



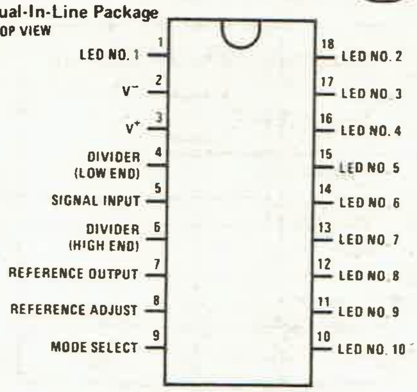
LM3914/15/16

Dot/Bar Display Driver

Features

- Bar or dot display mode externally selectable by user
- Internal voltage reference from 1.2V to 12V
- Operates with single supply of less than 3V
- Inputs operate down to ground
- Input withstands ±35V without damage or false outputs
- Outputs can interface with TTL or CMOS logic
- The internal 10-step divider is floating and can be referenced to a wide range of voltages

Dual-In-Line Package
TOP VIEW



LM3914

- **Linear display**
- Expandable to displays of 100 steps
- Output current programmable from 2 to 30 mA

LM3915

- **Logarithmic display**
- 3 dB/step, 30 dB range
- Expandable to displays of 90 dB
- Drives LEDs, LCDs, or vacuum fluorescents
- Output current programmable from 1 mA to 30 mA

LM3916

- Fast responding electronic VU meter
- Expandable to displays of 70 dB
- Drives LEDs, LCDs, or vacuum fluorescents
- Output current programmable from 1 mA to 30 mA

Absolute Maximum Ratings (Note 5)

Power Dissipation	
Cavity DIP	900 mW
Molded DIP	660 mW
V^+ Voltage	25V
LED Collector Output Voltage	25V
Input Signal Overvoltage (Note 6)	±35V
Voltage on Resistor String	100 mV to V^+
Reference Load Current	10 mA
Signal Input Current (With Overvoltage Applied)	±3 mA

Electrical Characteristics (Note 1)

PARAMETER	CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
COMPARATOR TURN-ON THRESHOLDS					
V_{OS}, Buffer and First Comparator	R_{LO} and R_{HI} at 0V and 12V (Note 2)		3	10	mV
V_{OS}, Buffer and Any Other Comparator	R_{LO} and R_{HI} at 0V and 12V (Note 2)		5	15	mV
Turn ON Voltage Change	10% to 90% of a 20 mA LED Drive		2	6	mV
Input Bias Current (at Pin 5)			10	50	nA
COMPARATOR-VOLTAGE-DIVIDER					
Divider Resistance	Total, Pin 6 to 4	6.5	10	15	kΩ
Divider Non-Linearity	Deviation from Straight Line through 1st and Last Threshold Points. (Note 3)		0.5	2	%
VOLTAGE REFERENCE (Note 4)					
Load Regulation (ΔV_{REF})	I_L = 0.1 mA to 4 mA at V^+ = 5V and V_{LED} = 5V			2	%
Input Regulation	$3V \leq V^+ \leq 18V$		0.01	0.03	%/V
Output Voltage	1 mA Load, V = 5V	1.2	1.28	1.32	V
Output Voltage Change with Temperature	T_A = 0°C to +70°C, I_{LREF} = 1 mA, V^+ = 5V		1		%
Adjust Pin Current			75	120	μA
LED CURRENT REGULATION					
LED Current	V^+ and V_{LED} = 5V, I_{LREF} = 1 mA	7	10	13	mA
LED Current Difference (Between Largest and Smallest LED Currents)	V_{LED} = 5V, I_{OUT} = 2 mA		0.12	0.4	mA
	V_{LED} = 5V, I_{OUT} = 20 mA		1.2	3	mA
Current Change with Supply Voltage (as Measured at LED Cathodes)	I_{OUT} = 2 mA, $2 \leq V_{LED} \leq 17$		0.1	0.25	mA
	I_{OUT} = 20 mA, $2 \leq V_{LED} \leq 17$		1	3	mA
Current Regulation–Dropout Voltage (at LM3914 Pins)	I_{LED} = 20 mA at V_{LED} = 5V Causing 10% I_{OUT} Decrease			1.5	V
Output Saturation of LED Drive Collectors	I_{OUT} = 1.6 mA, Ref Load = 0.32 mA		0.25	0.4	V

Note 1: Unless otherwise stated, all specifications apply with the following conditions: V^+ (supply) 3 V_{DC}–18 V_{DC}. Input signal range–0.015V to (V^+ – 1.5V) V, with a maximum of 12 V_{DC}. Comparator-divider voltages, same limits. T_A = 25°C. Offset and linearity are tested with I_{LED} = 2 mA and V_{LED} = 3V, in bar mode connection. For higher power dissipations, pulse-mode testing is used.

Note 2: Comparator threshold is measured when the first 1 mA flows in the associated LED output pin. When measuring "overlap" an LED is considered to be extinguishing when its current falls below 1 mA.

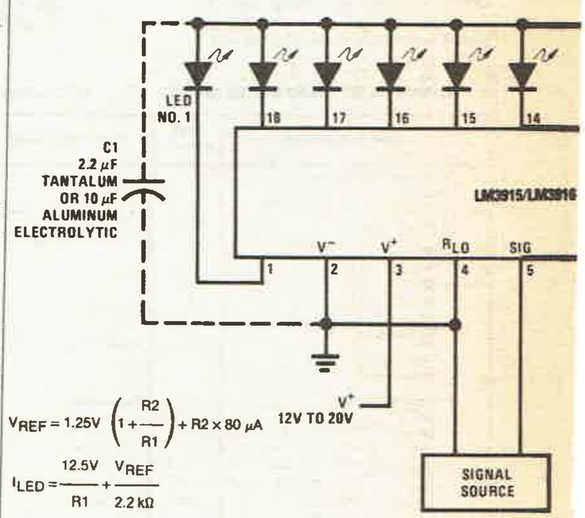
Note 3: Divider linearity is measured with R_{LO} (pin 4) at 0V, and R_{HI} at 10 V_{DC}. (At lower divider voltages, buffer and comparator V_{OS} add significant error.)

Note 4: Minimum reference load current is 80 μA.

Note 5: Although the following situations will not lead to circuit damage, they can result in *incorrect operation*: a) LED No. 9 (pin 11) collector voltage exceeding V^+ voltage on pin 3, or becoming more than 14V below applied V^+, (additionally being limited to less than 200 mV below V^-); b) signal and comparator-voltage-divider becoming higher than the limits of Note 1, above; c) reference load capacitance above 0.05 μF; d) reference current loading above 5 mA.

Note 6: The addition of a 39k resistor in series with pin 5 allows ±100V signals without damage.

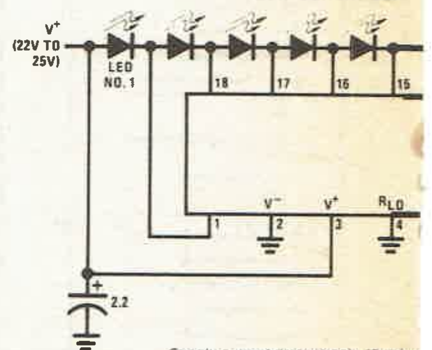
10V Log Display or



$$V_{REF} = 1.25V\left(1 + \frac{R2}{R1}\right) + R2 \times 80\ \mu A$$

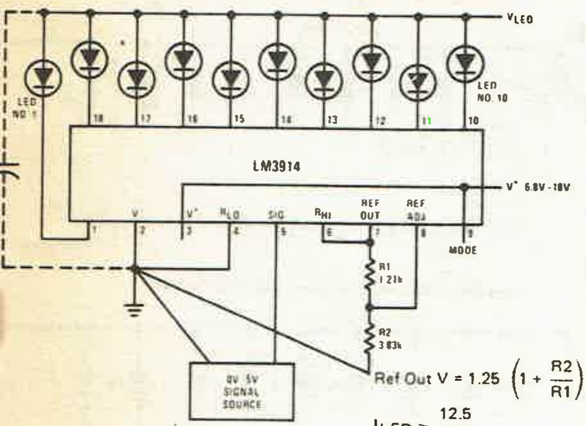
$$I_{LED} = \frac{12.5V}{R1} + \frac{V_{REF}}{2.2\ k\Omega}$$

Low Current Bar



Supply current drain is only 15 mA w
LEDs illuminated.

0V to 5V Bar Graph Meter



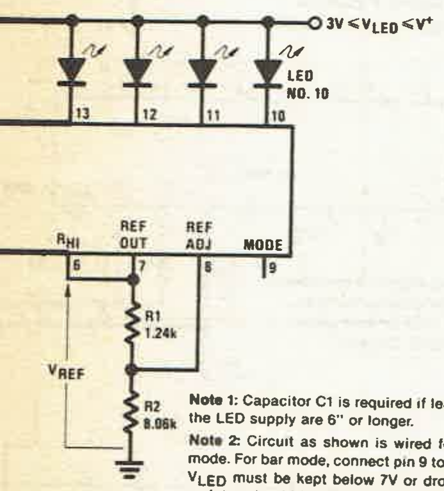
$$\text{Ref Out V} = 1.25\left(1 + \frac{R2}{R1}\right)$$

$$I_{LED} = \frac{12.5}{R1}$$

Note 1: Grounding method is typical of *all* uses. The 2.2 μF capacitor is needed if leads to the LED supply are 6" or longer.

Note 2: Supply voltage (V^+ at pin 2) is recommended to be 1.8V above high signal (pin 5) and 1.5V above Reference V (pin 7) for correct operation at 25°C.

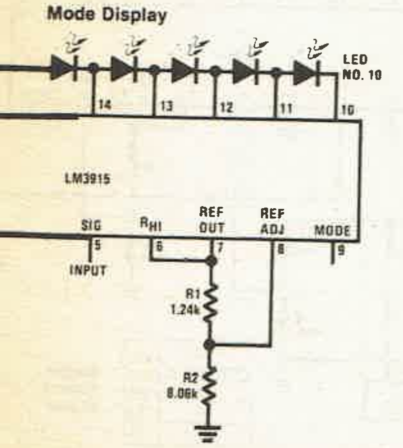
10V Vu Display



Note 1: Capacitor C1 is required if leads to the LED supply are 6" or longer.

Note 2: Circuit as shown is wired for dot mode. For bar mode, connect pin 9 to pin 3. V_{LED} must be kept below 7V or dropping resistor should be used to limit IC power dissipation.

Mode Display



Absolute Maximum Ratings

Power Dissipation (Note 5)	
Ceramic DIP(J)	1W
Molded DIP(N)	625 mW
Supply Voltage	25V
Voltage on Output Drivers	25V
Input Signal Overvoltage (Note 3)	±35V
Divider Voltage	−100 mV to V^+
Reference Load Current	10 mA
Storage Temperature Range	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

Electrical Characteristics (Note 1)

Parameter	Conditions (Note 1)	Min	Typ	Max	Units
Comparators					
Offset Voltage, Buffer and First Comparator	$0V \le V_{RLO} = V_{RHI} \le 12V$, $I_{LED} = 1$ mA		3	10	mV
Offset Voltage, Buffer and Any Other Comparator	$0V \le V_{RLO} = V_{RHI} \le 12V$, $I_{LED} = 1$ mA		3	15	mV
Gain ($\Delta I_{LED}/\Delta V_{IN}$)	$I_{L(REF)} = 2$ mA, $I_{LED} = 10$ mA	3	8		mA/mV
Input Bias Current (at Pin 5)	$0V \le V_{IN} \le (V^+ - 1.5V)$		10	50	nA
Input Signal Overvoltage	No Change in Display	−35		35	V
Voltage-Divider					
Divider Resistance	Total, Pin 6 to 4	16	28	36	kΩ
Relative Accuracy (Input Change Between Any Two Threshold Points)	(Note 2)	2.0	3.0	4.0	dB
Absolute Accuracy at Each Threshold Point	(Note 2)				
	$V_{IN} = -3, -6$ dB	−0.5		+0.5	dB
	$V_{IN} = -9$ dB	−0.5		+0.65	dB
	$V_{IN} = -12, -15, -18$ dB	−0.5		+1.0	dB
	$V_{IN} = -21, -24, -27$ dB	−0.5		+1.5	dB
Voltage Reference*					
Output Voltage	$0.1\ mA \le I_{L(REF)} \le 4$ mA, $V^+ = V_{LED} = 5V$	1.2	1.28	1.34	V
Line Regulation	$3V \le V^+ \le 18V$		0.01	0.03	%/V
Load Regulation	$0.1\ mA \le I_{L(REF)} \le 4$ mA, $V^+ = V_{LED} = 5V$		0.4	2	%
Output Voltage Change with Temperature	$0°C \le T_A \le +70°C$, $I_{L(REF)} = 1$ mA, $V^+ = V_{LED} = 5V$		1		%
Adjust Pin Current			75	120	μA
Output Drivers					
LED Current	$V^+ = V_{LED} = 5V$, $I_{L(REF)} = 1$ mA	7	10	13	mA
LED Current Difference (Between Largest and Smallest LED Currents)	$V_{LED} = 5V$, $I_{LED} = 2$ mA		0.12	0.4	mA
	$V_{LED} = 5V$, $I_{LED} = 20$ mA		1.2	3	mA
LED Current Regulation	$2V \le V_{LED} \le 17V$, $I_{LED} = 2$ mA		0.1	0.25	mA
	$I_{LED} = 20$ mA		1	3	mA
Dropout Voltage	$I_{LED(ON)} = 20$ mA @ $V_{LED} = 5V$, $\Delta I_{LED} = 2$ mA			1.5	V
Saturation Voltage	$I_{LED} = 2.0$ mA, $I_{L(REF)} = 0.4$ mA		0.15	0.4	V
Output Leakage, Each Collector	Bar Mode (Note 4)		0.1	10	μA
Output Leakage	Dot Mode (Note 4)				
Pins 10 − 18			0.1	10	μA
Pin 1		60	150	450	μA
Supply Current					
Standby Supply Current (All Outputs Off)	$V^+ = +5V$, $I_{L(REF)} = 0.2$ mA		2.4	4.2	mA
	$V^+ = +20V$, $I_{L(REF)} = 1.0$ mA		6.1	9.2	mA

Notes

Note 1: Unless otherwise stated, all specifications apply with the following conditions:

$3V_{DC} \le V^+ \le 20V_{DC}$ $\quad -0.015V \le V_{RLO} \le 12V_{DC}$ $\quad T_A = 25°C$, $I_{L(REF)} = 0.2$ mA, pin 9 connected to pin 3 (bar mode).

$3V_{DC} \le V_{LED} \le V^+$ $\quad V_{REF}, V_{RHI}, V_{RLO} \le (V^+ - 1.5V)$ $\quad$ For higher power dissipations, pulse testing is used.

$-0.015V \le V_{RHI} \le 12V_{DC}$ $\quad 0V \le V_{IN} \le V^+ - 1.5V$

Note 2: Accuracy is measured referred to 0 dB = + 10.000V_{DC} at pin 5, with + 10.000V_{DC} at pin 6, and 0.000V_{DC} at pin 4. At lower full scale voltages, buffer and comparator offset voltage may add significant error. See table for threshold voltages.

Note 3: Pin 5 input current must be limited to ±3 mA. The addition of a 39k resistor in series with pin 5 allows ±100V signals without damage.

Note 4: Bar mode results when pin 9 is within 20 mV of V^+. Dot mode results when pin 9 is pulled at least 200 mV below V^+. LED #10 (pin 10 output current) is disabled if pin 9 is pulled 0.9V or more below V_{LED}.

Note 5: The maximum junction temperature of the LM3915 is 100°C. Devices must be derated for operation at elevated temperatures. Junction to ambient thermal resistance is 75°C/W for the ceramic DIP (J package) and 120°C/W for the molded DIP (N package).

THRESHOLD VOLTAGE (Note 2)

Output	dB	Min	Typ	Max	Output	dB	Min	Typ	Max
1	−27	0.422	0.447	0.531	6	−12	2.372	2.512	2.819
2	−24	0.596	0.631	0.750	7	−9	3.350	3.548	3.825
3	−21	0.841	0.891	1.059	8	−6	4.732	5.012	5.309
4	−18	1.189	1.259	1.413	9	−3	6.683	7.079	7.498
5	−15	1.679	1.778	1.995	10	0	9.985	10	10.015

Absolute Maximum Ratings

Power Dissipation (Note 5)	
Ceramic DIP(J)	1W
Molded DIP(N)	625 mW
Supply Voltage	25V
Voltage on Output Drivers	25V
Input Signal Overvoltage (Note 3)	± 35V
Divider Voltage	-100 mV to V^+
Reference Load Current	10 mA
Storage Temperature Range	$-55°C$ to $+150°C$
Lead Temperature (Soldering, 10 seconds)	300°C

Electrical Characteristics (Note 1)

Parameter	Conditions (Note 1)	Min	Typ	Max	Units
Comparators					
Offset Voltage, Buffer and First Comparator	$0V \le V_{RLO} = V_{RHI} \le 12V$, $I_{LED} = 1$ mA		3	10	mV
Offset Voltage, Buffer and Any Other Comparator	$0V \le V_{RLO} = V_{RHI} \le 12V$, $I_{LED} = 1$ mA		3	15	mV
Gain ($\Delta I_{LED}/\Delta V_{IN}$)	$I_{L(REF)} = 2$ mA, $I_{LED} = 10$ mA	3	8		mA/mV
Input Bias Current (at Pin 5)	$0V \le V_{IN} \le (V^+ - 1.5V)$		10	50	nA
Input Signal Overvoltage	No Change in Display	-35		35	V
Voltage Divider					
Divider Resistance	Total, Pin 6 to 4	6.5	10	15	kΩ
Relative Accuracy (Input Change Between Any Two Threshold Points)	(Note 2)				
	$-1\ dB \le V_{IN} \le 3\ dB$	0.75	1.0	1.25	dB
	$-7\ dB \le V_{IN} \le -1\ dB$	1.5	2.0	2.5	dB
	$-10\ dB \le V_{IN} \le -7\ dB$	2.5	3.0	2.5	dB
Absolute Accuracy	(Note 2)				
	$V_{IN} = 2, 1, 0, -1$ dB	-0.25		$+0.25$	dB
	$V_{IN} = -3, -5$ dB	-0.5		$+0.5$	dB
	$V_{IN} = -7, -10, -20$ dB	-1		$+1$	dB
Voltage Reference					
Output Voltage	$0.1\ mA \le I_{L(REF)} \le 4$ mA, $V^+ = V_{LED} = 5V$	1.2	1.28	1.34	V
Line Regulation	$3V \le V^+ \le 18V$		0.01	0.03	%/V
Load Regulation	$0.1\ mA \le I_{L(REF)} \le 4$ mA, $V^+ = V_{LED} = 5V$		0.4	2	%
Output Voltage Change with Temperature	$0°C \le T_A \le +70°C$, $I_{L(REF)} = 1$ mA, $V^+ = V_{LED} = 5V$		1		%
Adjust Pin Current			75	120	μA
Output Drivers					
LED Current	$V^+ = V_{LED} = 5V$, $I_{L(REF)} = 1$ mA	7	10	13	mA
LED Current Difference (Between Largest and Smallest LED Currents)	$V_{LED} = 5V$, $I_{LED} = 2$ mA		0.12	0.4	mA
	$V_{LED} = 5V$, $I_{LED} = 20$ mA		1.2	3	mA
LED Current Regulation	$2V \le V_{LED} \le 17V$ $I_{LED} = 2$ mA		0.1	0.25	mA
	$I_{LED} = 20$ mA		1	3	mA
Dropout Voltage	$I_{LED(ON)} = 20$ mA @ $V_{LED} = 5V$, $\Delta I_{LED} = 2$ mA			1.5	V
Saturation Voltage	$I_{LED} = 2.0$ mA, $I_{L(REF)} = 0.4$ mA		0.15	0.4	V
Output Leakage, Each Collector	Bar Mode (Note 4)		0.1	100	μA
Output Leakage	Dot Mode (Note 4)				
Pins 10 – 18			0.1	100	μA
Pin 1		60	150	450	μA
Supply Current					
	$V^+ = +5V$, $I_{L(REF)} = 0.2$ mA		2.4	4.2	mA
	$V^+ = +20V$, $I_{L(REF)} = 1.0$ mA		6.1	9.2	mA

Notes

Note 1: Unless otherwise stated, all specifications apply with the following conditions.

$3\ V_{DC} \le V^+ \le 20\ V_{DC}$ $\quad -0.015V \le V_{RLO} \le 12\ V_{DC}$ $\quad T_A = 25°C$, $I_{L(REF)} = 0.2$ mA, pin 9 connected to pin 3 (bar mode).

$3\ V_{DC} \le V_{LED} \le V^+$ $\quad V_{REF}, V_{RHI}, V_{RLO} \le (V^+ - 1.5V)$ $\quad$ For higher power dissipations, pulse testing is used.

$-0.015V \le V_{RHI} \le 12\ V_{DC}$ $\quad 0V \le V_{IN} \le V^+ - 1.5V$

Note 2: Accuracy is measured referred to $+3$ dB $= +10.000\ V_{DC}$ at pin 5, with $+10.000\ V_{DC}$ at pin 6, and $0.000\ V_{DC}$ at pin 4. At lower full-scale voltages, buffer and comparator offset voltage may add significant error. See table for threshold voltages.

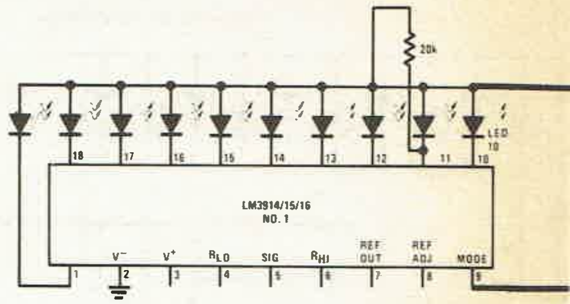
Note 3: Pin 5 input current must be limited to ± 3 mA. The addition of a 39k resistor in series with pin 5 allows ± 100V signals without damage.

Note 4: Bar mode results when pin 9 is within 20 mV of V^+. Dot mode results when pin 9 is pulled at least 200 mV below V^+. LED #10 (pin 10 output current) is disabled if pin 9 is pulled 0.9V or more below V_{LED}.

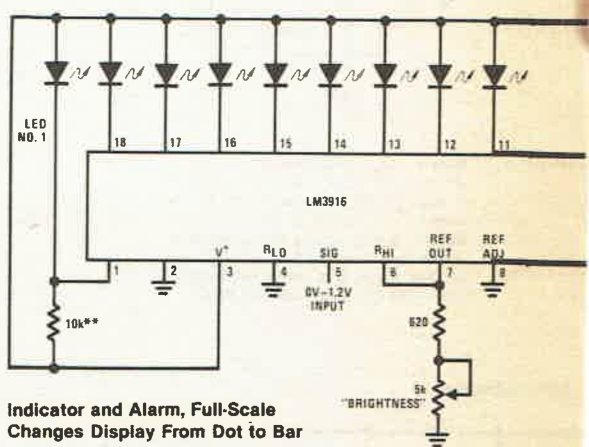
Note 5: The maximum junction temperature of the LM3916 is 100°C. Devices must be derated for operation at elevated temperatures. Junction to ambient thermal resistance is 75°C/W for the ceramic DIP (J package) and 120°C/W for the molded DIP (N package).

LM3916 THRESHOLD VOLTAGE (Note 2)

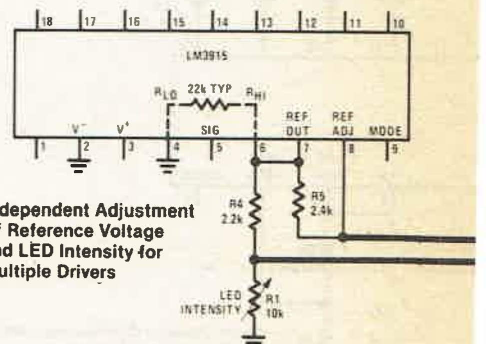
dB	Volts Min	Volts Typ	Volts Max	dB	Volts Min	Volts Typ	Volts Max
3	9.985	10.000	10.015	$-3 \pm 1/2$	4.732	5.012	5.309
$2 \pm 1/4$	8.660	8.913	9.173	$-5 \pm 1/2$	3.548	3.981	4.467
$1 \pm 1/4$	7.718	7.943	8.175	-7 ± 1	2.818	3.162	3.548
$0 \pm 1/4$	6.879	7.079	7.286	-10 ± 1	1.995	2.239	2.512
$-1 \pm 1/2$	5.957	6.310	6.683	-20 ± 1	0.631	0.708	0.794



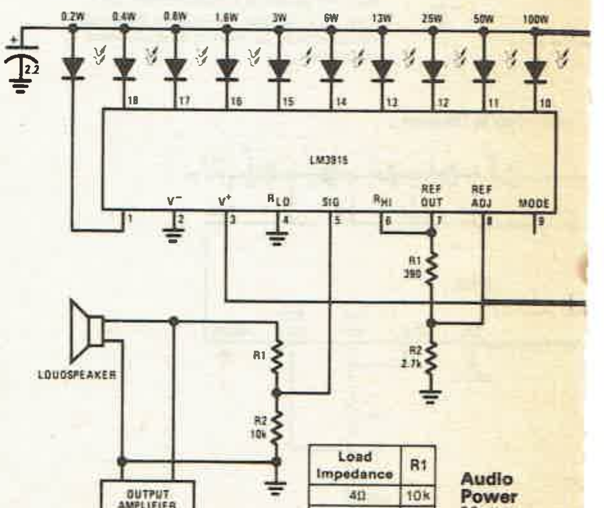
Cascading LM3914/15/16 Series in Dot Mode



Indicator and Alarm, Full-Scale Changes Display From Dot to Bar

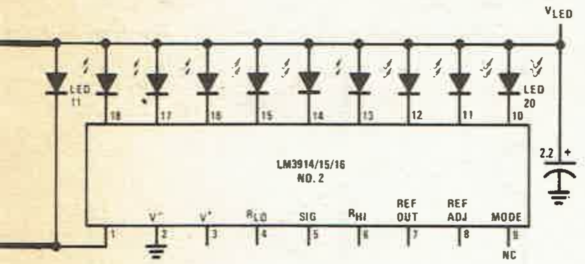


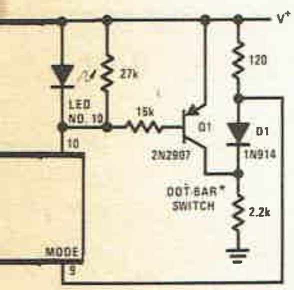
Independent Adjustment of Reference Voltage and LED Intensity for Multiple Drivers



Load Impedance	R1
4Ω	10k
8Ω	18k
16Ω	30k

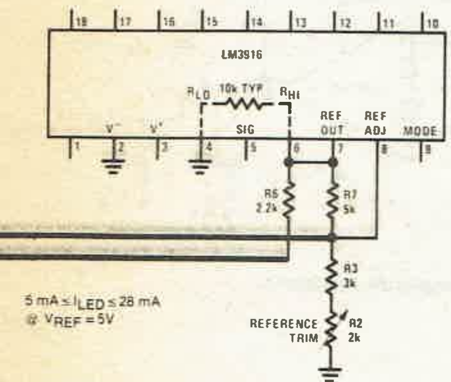
Audio Power Meter



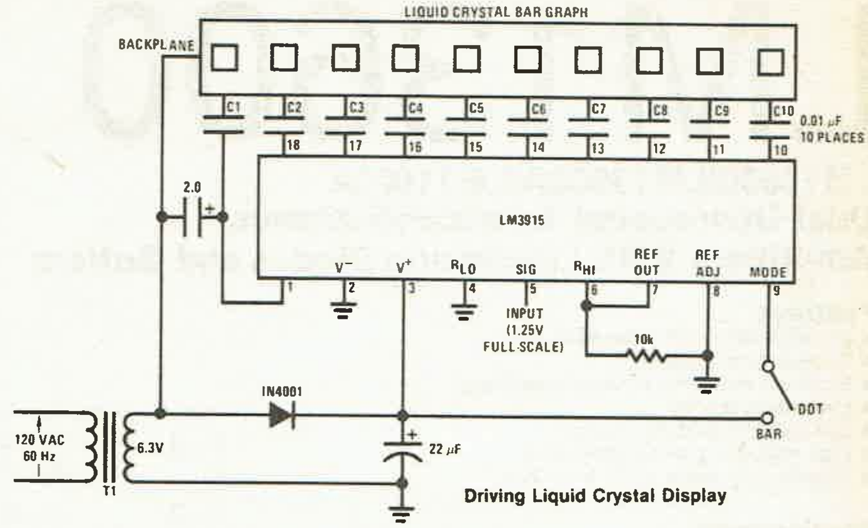


* The input to the Dot-Bar switch may be taken from cathodes of other LEDs. Display will change to bar as soon as the LED so selected begins to light.

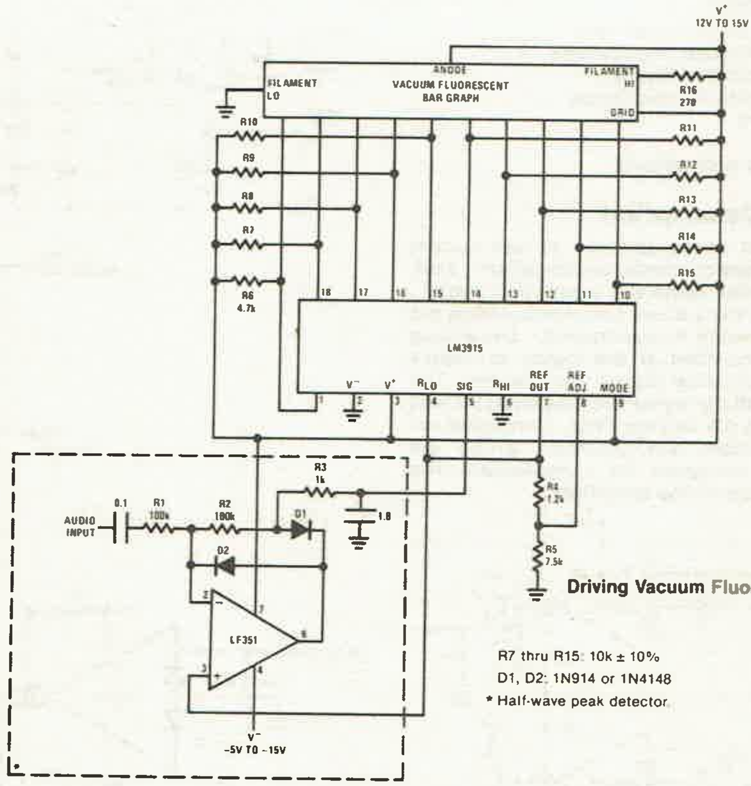
** Optional. Shunts 100 μA auxiliary sink current away from LED #1.



$5 \text{ mA} \le I_{LED} \le 28 \text{ mA}$ @ $V_{REF} = 5V$

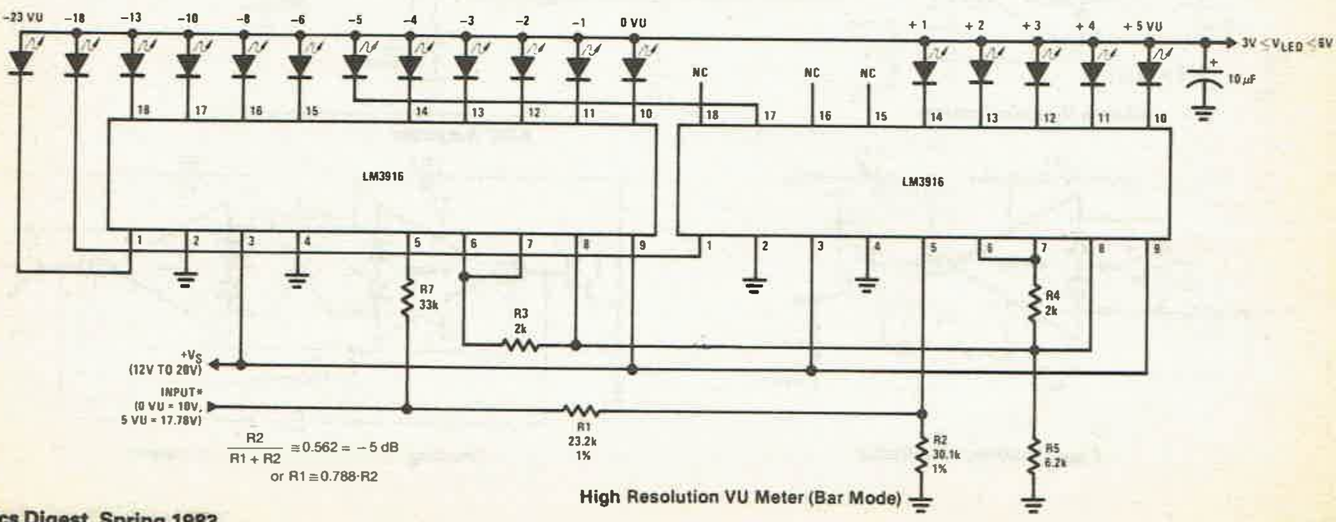


Driving Liquid Crystal Display



Driving Vacuum Fluorescent Display

R7 thru R15: 10k ± 10%
D1, D2: 1N914 or 1N4148
* Half-wave peak detector



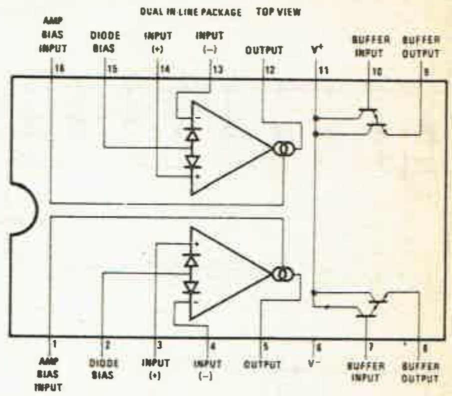
$\frac{R2}{R1 + R2} \cong 0.562 = -5 \text{ dB}$

or $R1 \cong 0.788 \cdot R2$

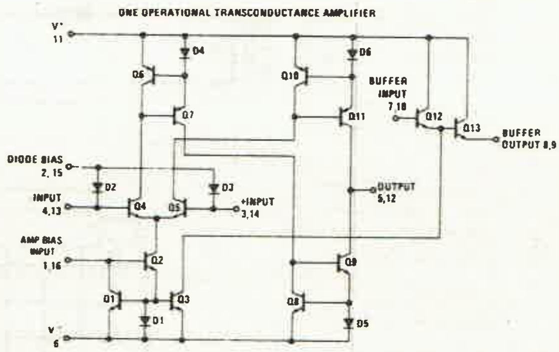
High Resolution VU Meter (Bar Mode)

LM13600

LM13600/LM13600A/LM11600A
Dual Operational Transconductance Amplifiers With Linearizing Diodes and Buffers

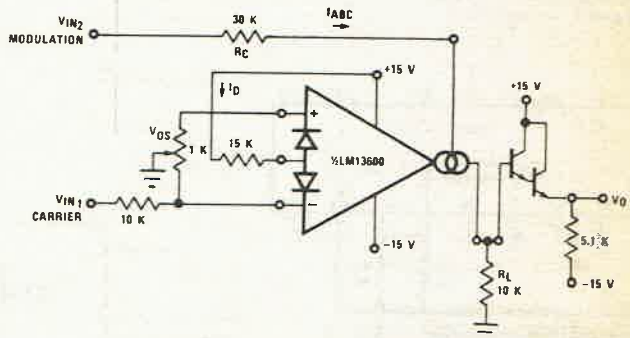


Features
- gm adjustable over 6 decades
- Excellent gm linearity
- Excellent matching between amplifiers
- Linearizing diodes
- Controlled impedence buffers
- High output signal to noise ratio
- Wide supply range ± 2V to ± 22V.

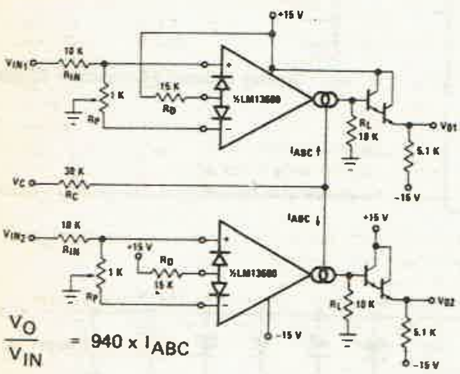


Applications
- Current controlled amplifiers
- Current controlled impedances
- Current controlled filters
- Current controlled oscillators
- Multiplexers
- Timers
- Sample and hold circuits

General Description
The LM13600 series consists of two current controlled transconductance amplifiers each with differential inputs and a push pull output. The two amplifiers share common supplies but otherwise operate independently. Linearizing diodes are provided at the inputs to reduce distortion and allow higher input levels. The results is a 10 dB signal-to-noise improvement referenced to 0.5 percent THD. Controlled impedance buffers are provided which are especially designed to complement the dynamic range of the amplifiers.

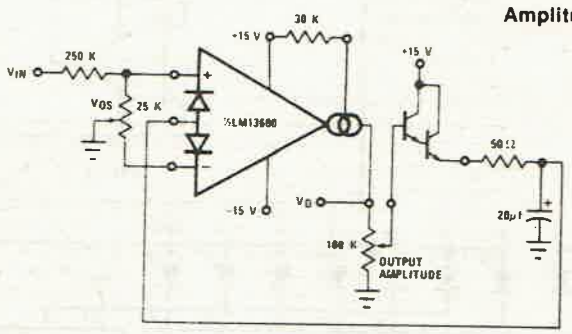


Amplitude Modulator

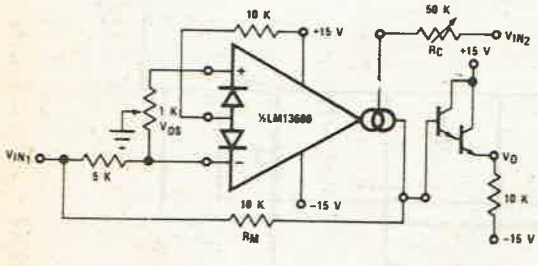


$$\frac{V_O}{V_{IN}} = 940 \times I_{ABC}$$

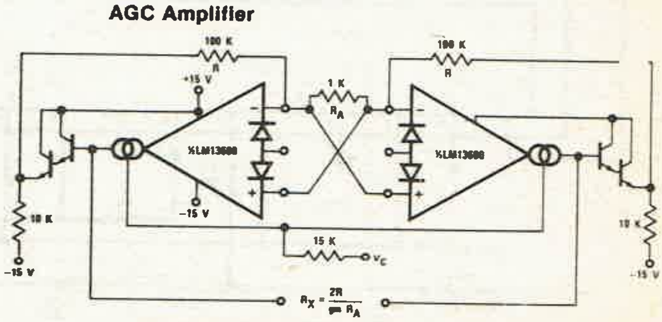
Stereo Volume Control



AGC Amplifier

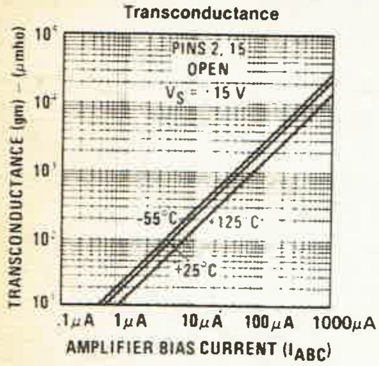


Four-Quadrant Multiplier

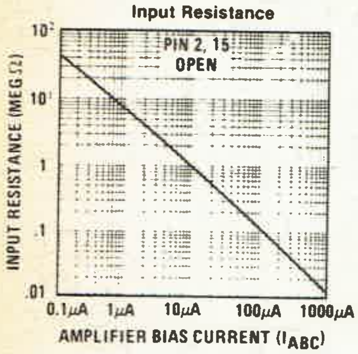


Floating Voltage Controlled Resistor

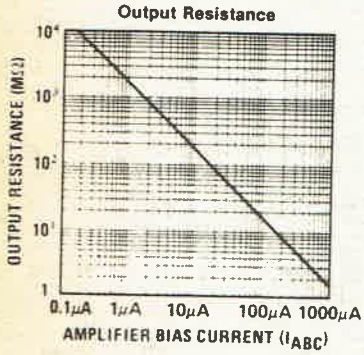
Transconductance



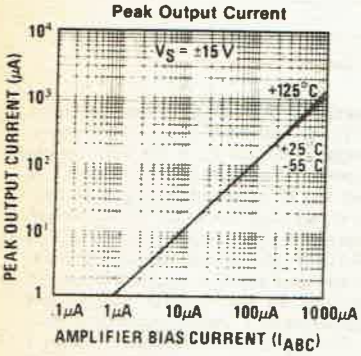
Input Resistance



Output Resistance



Peak Output Current



Absolute Maximum Ratings

Supply Voltage (Note 1)	
LM13600	36 V_{DC} or ± 18 V
LM13600A, LM11600A	44 V_{DC} or ± 22 V
Power Dissipation (Note 2) T_A = 25° C	
LM13600N, LM13600AN	570 mW
LM13600J, LM11600AJ	600mW
Differential Input Voltage	±5 V
Diode Bias Current (I_D)	2 mA
Amplifier Bias Current (I_{ABC})	2 mA
Output Short Circuit Duration	Indefinite
Buffer Output Current (Note 3)	20 mA
Operating Temperature Range	
LM13600N, LM13600AN, LM13600J	0° C to +70° C
LM11600AJ	-55° C to +125° C
DC Input Voltage	$+V_S$ to $-V_S$
Storage Temperature Range	-65° C to +150° C
Lead Temperature (Soldering, 10 Seconds)	300° C

Electrical Characteristics (Note 4)

Parameters	Conditions	LM13600			LM13600A	LM11600A		
		Min	Typ	Max	Min	Typ	Max	Units
Input Offset Voltage (V_{OS})			0.4	5		0.4	2	mV
	Over Specified Temperature Range						5	mV
	I_{ABC} 5 μA		0.3	5		0.3	2	mV
V_{OS} Including Diodes	Diode Bias Current (I_D) = 500 μA		0.5	5		0.5	2	mV
Input Offset Change	5 μA ≤ I_{ABC} ≤ 500 μA		0.1			0.1	3	mV
Input Offset Current			0.1	0.6		0.1	0.6	μA
Input Bias Current			0.4	5		0.4	5	μA
	Over Specified Temperature Range		1	8		1	7	μA
Forward Transconductance(gm)		6700	9600	13000	7700	9600	12000	μmho
	Over specified Temp Range	5400			4000			μmho
gm Tracking			0.3			0.3		dB
Peak Output Current	RL = 0, I_{ABC} = 5μA		5		3	5	7	μA
	RL = 0, I_{ABC} = 500 μA	350	500	650	350	500	650	μA
	RL = 0, Over Specified Temp Range	300			300			μA
Peak Output Voltage								
Positive	RL = ∞, 5 μA ≤ I_{ABC} ≤ 500 μA	+12	+14.2		+12	+14.2		V
Negative	RL = ∞, 5 μA ≤ I_{ABC} ≤ 500 μA	−12	−14.4		−12	−14.4		V
Supply Current	I_{ABC}=500μA, Both Channels		2.6			2.6		mA
V_{OS} Sensitivity								
Positive	$\Delta V_{OS}/\Delta V+$		20	150		20	150	μV/V
Negative	$\Delta V_{OS}/\Delta V-$		20	150		20	150	μV/V
CMRR		80	110		80	110		dB
Common Mode Range		±12	±13.5		±12	±13.5		V
Crosstalk	Referred to Input (Note 5) 20 Hz < f < 20 KHz		100			100		dB
Diff.Input Current	I_{ABC} = 0, Input = ±4 V		0.02	100		0.02	10	nA
Leakage Current	I_{ABC} = 0 (Refer To Test Circuit)		0.2	100		0.2	5	nA
Input Resistance		10	26		10	26		KΩ
Open Loop Bandwith			2			2		MHz
Slew Rate	Unity Gain Compensated		50			50		V/μSec
Buff. Input Current	(Note 5)		0.4	5		0.4	5	μA
Peak Buffer Output Voltage	(Note 5)	10			10			V

Note 1. For selections to a supply voltage above ±22V, contact factory.

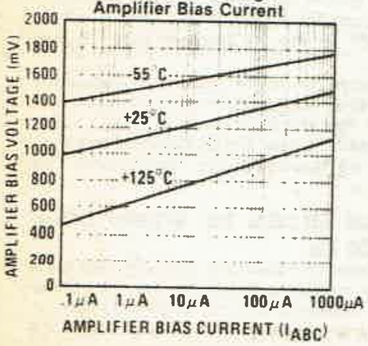
Note 2. For operating at high temperatures, the device must be derated based on a 150° C maximum junction temperature and a thermal resistance of 175° C/W which applies for the device soldered in a printed circuit board, operating in still air.

Note 3. Buffer output current should be limited so as to not exceed package dissipation.

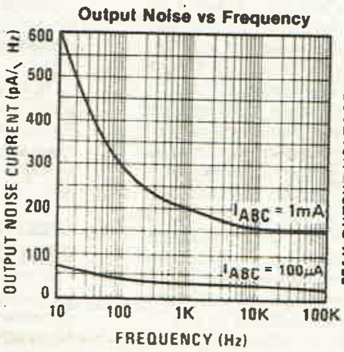
Note 4. These specifications apply for V_S = ±15 V, T_A = 25° C, amplifier bias current (I_{ABC}) = 500μA, pins 2 and 15 open unless otherwise specified. The inputs to the buffers are grounded and outputs are open.

Note 5. These specifications apply for V_S = ±15V, I_{ABC} = 500 μA, R_{OUT} = 5 KΩ connected from the buffer output to $-V_S$ and the input of the buffer is connected to the transconductance amplifier output.

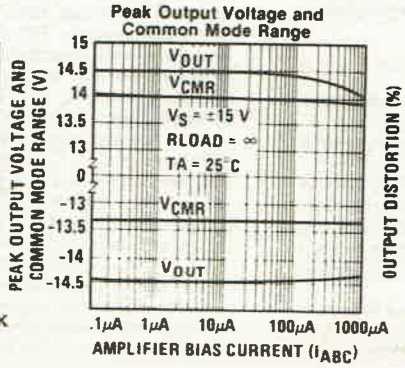
Amplifier Bias Voltage vs Amplifier Bias Current



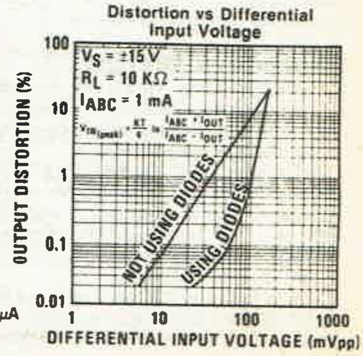
Output Noise vs Frequency



Peak Output Voltage and Common Mode Range



Distortion vs Differential Input Voltage



TDA 1008

Introduction

The TDA1008 integrated circuit provides frequency-dividing and gating functions for tone signal generation in electronic organs and other electronic musical instruments. An increasing variety of electronic organs has become available in recent years, their popularity having been enhanced by the rapid expansion of the home entertainments market. To provide effects such as sustain, percussion, and fifth coupling, the organ designer has usually needed to add special electronic circuits to the basic organ design, increasing overall cost. However, in a system based on TDA1008 ICs, these and many other effects can be easily provided without significantly adding to circuit complexity. The reduction in component count and number of key contacts compared with conventional systems results in a significant saving in cost, greater reliability, and easier servicing. With simplified circuits and fewer components, organ designs using TDA1008 ICs are also ideal for the home constructor.

The main features of the TDA1008 are given below.

The IC is a monolithic bipolar device using I^2L logic, and therefore requires no special handling techniques.

Only a single set of contacts is required for each key, because the TDA1008 provides five octave-related output signals when each of five key inputs is activated. Thus, in a typical system, only one busbar is required for each manual.

An outstanding feature of the TDA1008 is that the tone-output signals are symmetrical about a fixed DC level, and so no DC jump occurs in the outputs when the keys are operated. Thus 'plopping and scratching' sounds are eliminated from the audio output without the need for the usual additional suppression components.

The amplitudes of the five output signals from the IC are proportional to the DC voltage applied to each key input, and because the nominal impedance of these inputs is high, sustain and percussion effects can be added by using simple RC networks in conjunction with the key circuits.

The rate of attack and decay can be adjusted simply by varying a DC voltage applied to a 'sustain control' pin on the IC.

Description of TDA1008

The circuit of the TDA1008 IC with basic peripheral components is shown in Fig. 1. The IC comprises eight divide-by-two circuits and a matrix of gate circuits.

As shown in Fig. 1, the TDA1008 can be driven directly from a top-octave synthesiser, because only one input signal applied to pin 15 is required to produce nine octave-related notes within the IC. The minimum impedance at pin 15 is 28 k ohm.

Up to five keys can be connected to pins 8 to 12. When a DC voltage is applied to one of these inputs, five of the nine octave-related

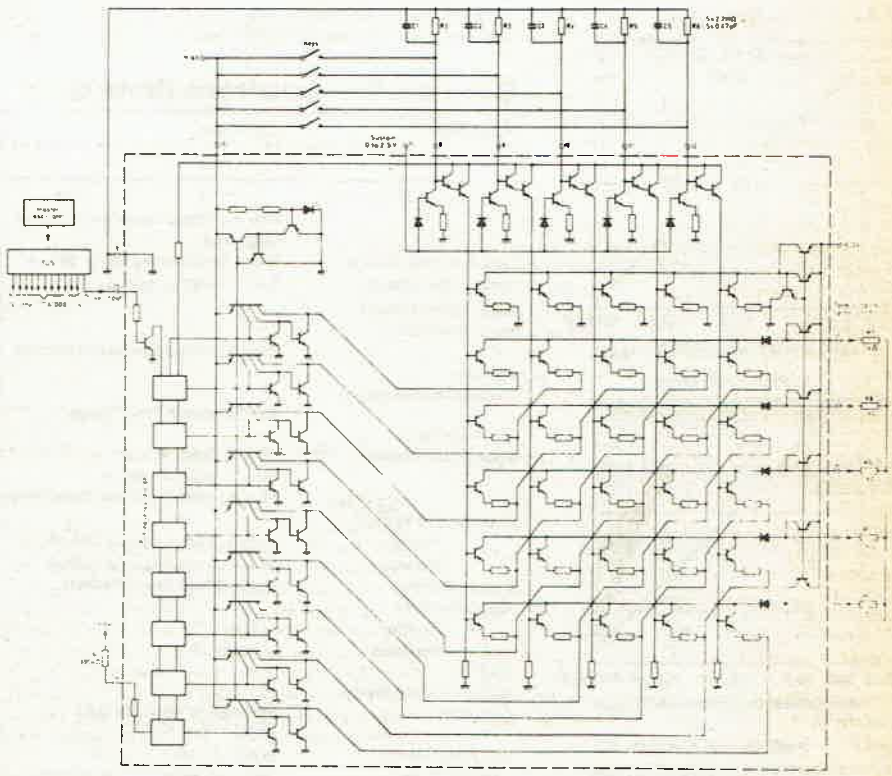


Fig. 1. TDA1008 and basic peripheral circuit.

notes are routed by the matrix circuit to the five tone outputs, as shown in the truth table. Although the maximum input frequency of the TDA1008 is 100 kHz, as can be seen from the truth table the frequency chosen would normally be within the audio range to give the full range of audible tones. If more than one key input is activated, then the signal from each tone output will comprise the sum of all the tones for the activated inputs.

The signal amplitude at each tone output (pins 2 to 6) is proportional to the DC voltage applied to each key input. Sustain and percussion effects can, therefore, be obtained by connecting simple RC networks to the key inputs. Some practical networks are described later. The networks shown in Fig. 1 (resistors R_2 to R_6 and capacitors C_1 to C_5) provide a simple sustain effect. The impedance of the key inputs, and hence the rate of discharge of C_1 to C_5, is determined by the DC voltage applied to pin 7 of the IC. With pin 7 at 0 V, the impedance of each key input is greater than 8 M ohms. When this voltage is increased towards 2.5 V DC, the impedance of each input falls accordingly. Thus the decay of the output waveforms at pins 2 to 6 can be adjusted continuously by simply varying the sustain control voltage at pin 7. The impedance of the tone outputs is determined mainly by the values of the load resistors R_7 to R_{11} (1 k ohms in the circuit shown).

The ungated output from the last divider stage is provided at pin 14. This output is used when the IC is tested during manufacture, but it can also be used by the organ manufacturer for a quick operational check of each TDA1008. (An output signal from pin 14 when an input signal is applied to pin 15 indicates that all the divider stages are operating correctly.) During normal operation, pin 14 should be connected through a resistor to the +6 V supply so that a current of 20 μA is drawn. In a practical circuit, this can be achieved by connecting a 330 k ohms resistor (R_1 in Fig. 4) between pins 14 and 13.

It is possible to derive a low-frequency output signal for a pedal board from pin 14. Provided that the current drain of 20 μA is maintained, a transistor can be used to amplify the low-frequency signal from this pin.

Practical Circuits for Organs Using TDA1008 ICs

The number of TDA1008 ICs required for a particular system depends on the number of octaves required by the organ designer. Normally, a minimum of twelve of these ICs would be required for subdivision of the twelve top-octave notes. For example, a master oscillator, a top-octave synthesiser IC, and twelve TDA1008 ICs would be required for a five-octave single-manual organ. All the ICs, together with the peripheral components, can be mounted on a single compact printed-wiring board.

A brief description of a variety of practical circuits for use with TDA1008 ICs is given below. The five-octave organ has been chosen as a practical example of a system using these circuits.

Master oscillator

The Hartley oscillator is a popular choice for electronic organs because of its inherent high stability. The sinewave output signal from this oscillator must be shaped by a Schmitt trigger to provide a squarewave with the correct slew rate for driving the TOS, as shown in Fig. 2. For TOS circuits that require two input signals of opposite phase, these can be provided as shown.

However, because the TDA1008 IC requires a stabilised supply, use can be made of this supply to simplify the oscillator circuit greatly, as shown in Fig. 3. Only four NAND gates contained in a single HEF4011P IC, three resistors (one variable), and a capacitor, are required to produce an output signal of the correct shape for the TOS. One of the gates can be used as shown to provide an output signal of opposite phase.

Switching and envelope-shaping circuits

The TDA1008 IC can be connected as shown in Fig. 4, and will provide five octave-related tones at pins 2 to 6 by operation of a single key contact connected to each key input (pins 8 to 12). The signal obtained from each output, relative to the three supply voltages, is shown in Fig. 5. The amplitude of this signal is dependent on the voltage applied to the key inputs. If any of the output pins remain unused, these pins should be connected to the +9 V supply to avoid intermodulation between the output signals.

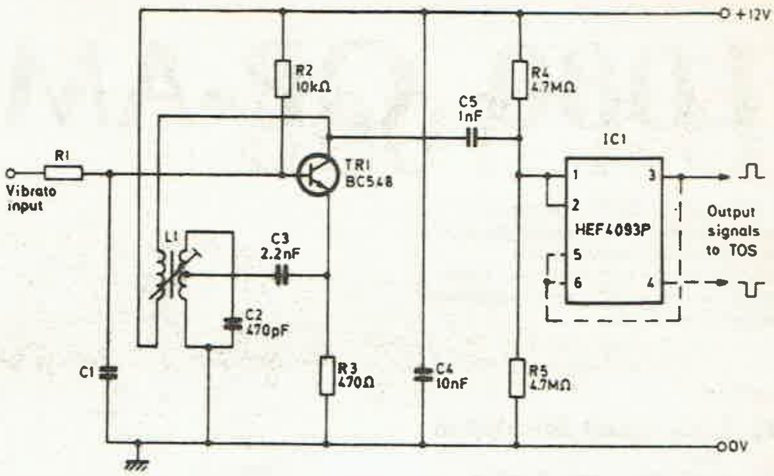


Fig. 2. Hartley oscillator and Wave- Shaping circuit.

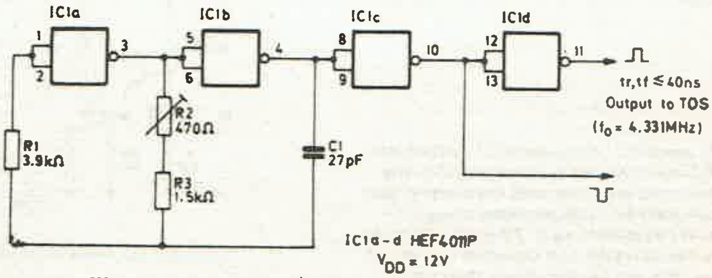


Fig. 3. Master oscillator using NAND gates.

Sustain

The sustain effect, the continuation of a note or notes for a predetermined period after a key has been released, can be easily obtained in an organ system using TDA1008 ICs.

To apply sustain to the five tone-output signals simultaneously, it is only necessary to connect a capacitor between each key input of the TDA1008 and earth, as shown in Fig. 6. With pin 7 either open-circuit or at a low DC voltage, the impedance of each key input is high (≥8M ohms). This impedance, combined with capacitor C_1, provides a time-constant which gives the maximum sustain period (about 4s with the value shown for C_1). Resistor R_2 is included to reduce this maximum period to a practical value, determined mainly by the time-constant of R_2 and C_1. The time-constant is given by:

$$t = C_1R_2,$$

where t is in seconds.

For more details of the device contact Mullard Ltd, at: Mullard House, Torrington Place, London WC1E 7HD.

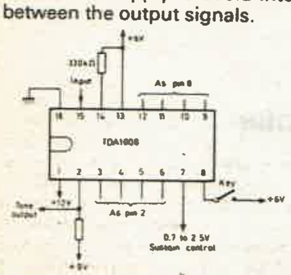


Fig. 4. Simplified connection diagram for TDA1008.

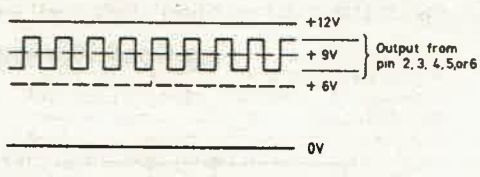


Fig. 5. Output signal from pin 2, 3, 4, 5 or 6.

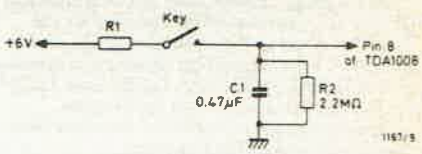


Fig. 6. Sustain circuit.

Tone output pin	Key input pin 8	9	10	11	12
2	f_{in}	$f_{in}/2$	$f_{in}/4$	$f_{in}/8$	$f_{in}/16$
3	$f_{in}/2$	$f_{in}/4$	$f_{in}/8$	$f_{in}/16$	$f_{in}/32$
4	$f_{in}/4$	$f_{in}/8$	$f_{in}/16$	$f_{in}/32$	$f_{in}/64$
5	$f_{in}/8$	$f_{in}/16$	$f_{in}/32$	$f_{in}/64$	$f_{in}/128$
6	$f_{in}/16$	$f_{in}/32$	$f_{in}/64$	$f_{in}/128$	$f_{in}/256$

TDA1008 Truth Table.

TL080 OP-AMP FAMILY

The TL080 family of BIFET operational amplifiers, provides an ideal combination of high-impedance JFET inputs with a low-distortion bipolar output circuit. Quality performance in the TL080 family is achieved without complex circuitry.

TL080 family circuit description

The following sections should be read in conjunction with Fig 1, the basic schematic for one channel.

Bias circuits

FET Q16, zener D2, transistors Q14/Q15 and resistor R6 establish the bias currents for the input differential amplifier and the second gain stage. Epitaxial FET Q16 provides a fixed current to D2 establishing 5.2V on the base of Q15. The resulting 317uA collector current of Q15 flows through Q14 and sets the current levels in Q1 and Q9.

Resistor R1 causes 196uA current in Q1 that is divided between the input stage JFETs Q2 and Q3. The second-gain-stage bias current, about 600uA, is derived from Q9.

Input circuit

Input JFETs Q2 and Q3 operate into the active load circuit consisting of Q4, Q6, and Q7. Current imbalance and input offset voltages may be adjusted on the TL081 and TL083 through connections to the emitters of Q6 and Q7. External offset controls for the TL080 connect to the collectors of Q6 and Q7. The C1 compensation capacitor is internal on the TL080, TL082 and TL083, and TL084. For the TL080 connections for external compensation are provided which allow user adjustment of AC characteristics.

Ion-implanted input devices provide very high input impedance, controlled pinch-off voltage for maximum common-mode input range, and matched characteristics for control of the input offset voltage. JFET inputs also allow adequate drive to the second stage resulting in maximum output peak-to-peak capability and wide power band widths.

Output stage

Q10 and Q11 provide Class AB bias to the output transistors Q12 and Q13. This allows near zero crossover distortion and produces a low total harmonic distortion at the output. The simplicity of the output circuit results in minimum silicon area requirements keeping manufacturing cost down while maintaining quality performance. R2, R3 and R4 form the output short-circuit protection network.

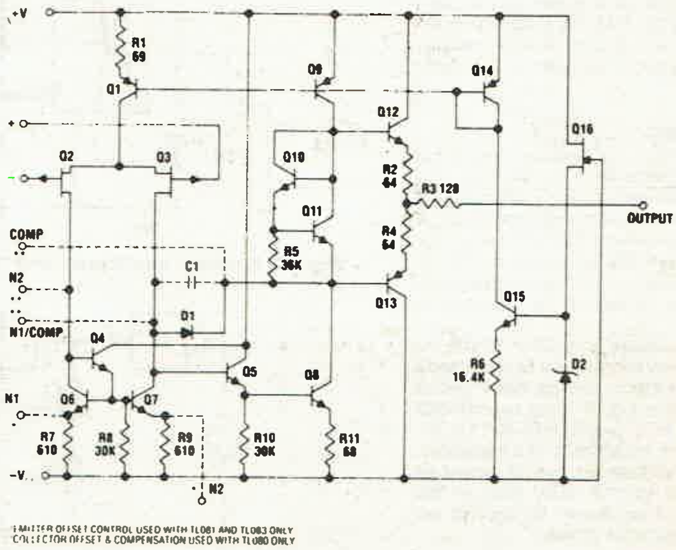
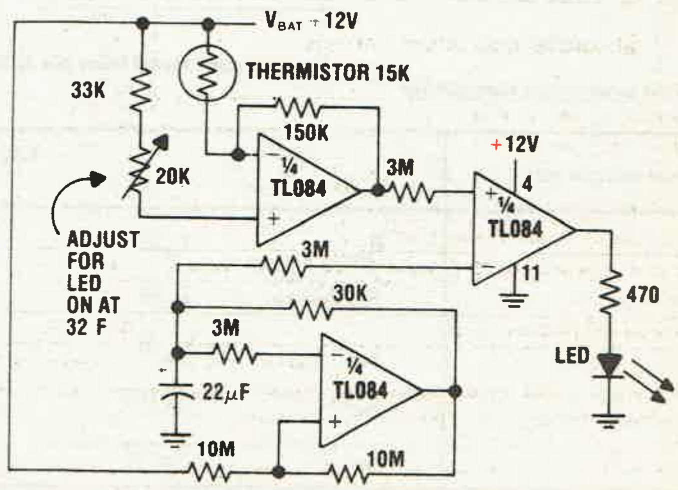


Fig 1. Schematic diagram for TL080 family.

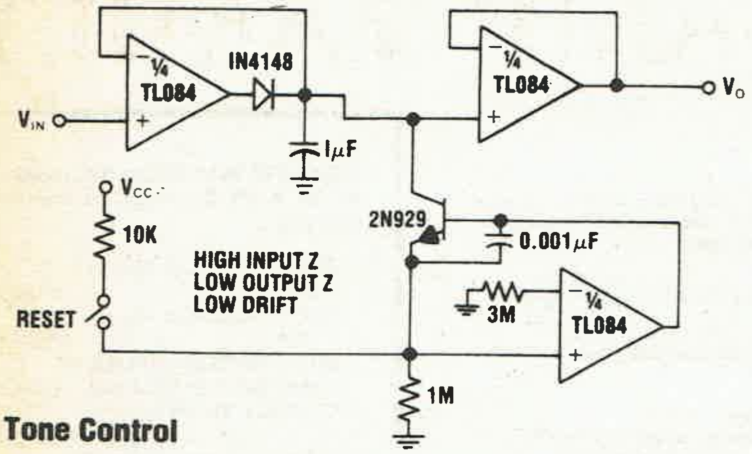
Second stage

Drive from the input stage is single-ended from the collector of Q7. D1 provides a clamping action across Q5 and Q8 preventing saturation of Q8 and excessive current in Q5. Q5 and Q8 form the high-gain second stage. The second stage output, collector of Q8, drives the output stage consisting of bias transistors Q10 and Q11, and output drivers Q12 and Q13.

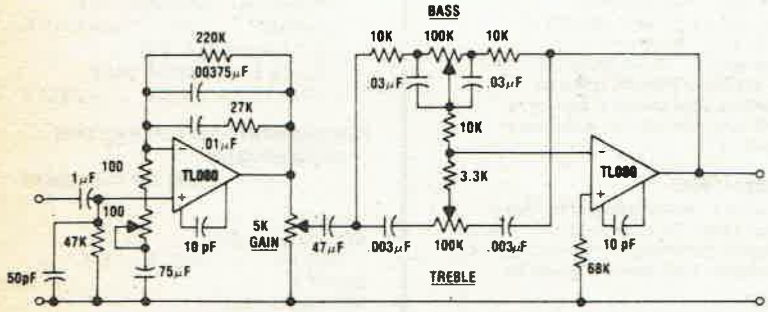
Icy Road Warning Indicator



Peak Detector



Tone Control

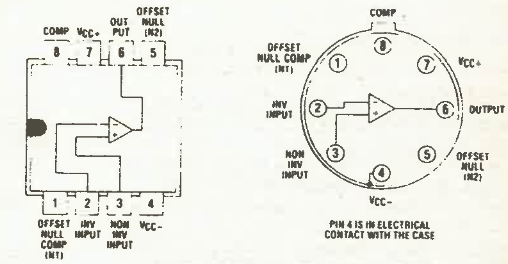


FEATURES	ADVANTAGES
● HIGH INPUT IMPEDANCE	Minimum loading effects allow efficient use with high impedance transducers.
● HIGH SLEW RATE	Provides the desired response characteristics required in audio frequency active filters and quality sound systems.
● LOW DISTORTION	Minimized crossover distortion yields very low total harmonic distortion for maximum performance in critical music systems.
● CONTINUOUS SHORT CIRCUIT PROTECTION	No damage resulting from accidental shorts or operation into low impedance loads.
● LOW POWER CONSUMPTION	Only 2.8 mA per operational amplifier. Less system power required and battery operation is practicable.

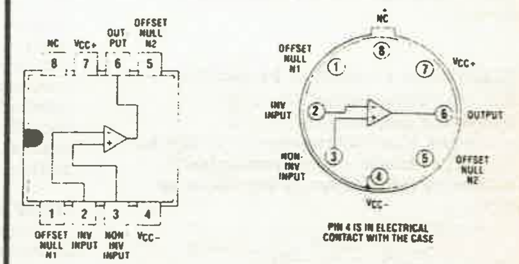
absolute maximum ratings		TL08_C TL08_AC TL08_BC
Supply voltage, V_{CC} (see Note 1)		18 V
Supply voltage, V_{CC} (see Note 1)		−18 V
Differential input voltage (see Note 2)		±30 V
Input voltage (see Notes 1 and 3)		±15 V
Duration of output short circuit (see Note 4)		Unlimited
Continuous total dissipation at 25°C free-air temperature	J,JG,N, or P Package	680 mW
	L Package	625 mW
Operating free-air temperature range		0 to 70°C

PIN OUTS

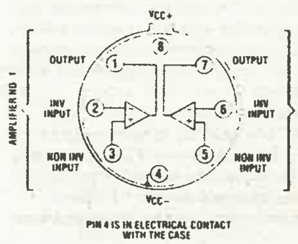
TL080



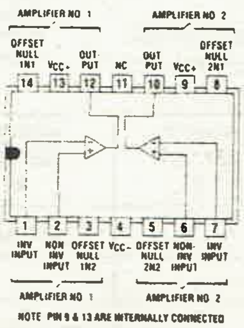
TL081



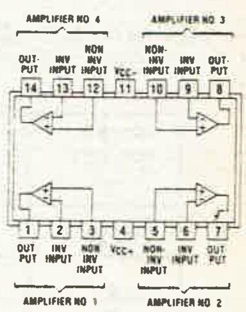
The TL082



The TL083



The TL084



NOTES:
1. All voltage values, except differential voltages, are with respect to the zero reference level (ground) of the supply voltages where the zero reference level is the midpoint between V_{CC+} and V_{CC-}.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

SN76477

THE SN76477 is a bipolar/I^{2}L device that provides a noise source, VCO, low frequency oscillator, envelope generator, plus various mixing and control logic on a single 28 pin DIL package. By the connection of appropriate external components and application of logic level control signals a wide variety of complex sounds can be synthesized. The design of the SN76477 allows for maximum user flexibility and the device should prove useful in applications requiring audio feedback to an operator (home video games, toys, timers, alarms, etc.).

SLF (Super Low Frequency Oscillator)

The SLF can be operated in the range 0.1-30 Hz, the specific frequency is determined by a control resistor connected to pin 20, and a capacitor connected to pin 21. The frequency being given by the following equation:

$$F_{SLF} = \frac{0.64}{R_{SLF}\,C_{SLF}}\,\text{Hz}$$

VCO (Voltage Controlled Oscillator)

The VCO provides an output whose frequency is dependent upon a voltage fed to its input, the higher the voltage the lower the frequency. The control voltage may be either the SLF output, or an external voltage applied to pin 16, the SLF output being selected when the voltage applied to pin 22 is a logic '1', and the external source when pin 22 is at logic '0'.

The "range" of the VCO is internally set at a ratio of 10:1. The minimum VCO frequency is determined by a control resistor connected to pin 18 and a capacitor to pin 17. This minimum frequency is given by the equation:

$$F_{MIN\ VCO} = \frac{0.64}{R_{VCO}\,C_{VCO}}\,\text{Hz}$$

The "pitch" of the VCO's output is changed by varying the duty cycle of the output. This is achieved by adjusting the ratio of the voltages at pins 16 and 19. The duty cycle is given by the following equation:

$$\text{VCO Duty Cycle} = 0.5\left[\frac{\text{V pin 16}}{\text{V pin 19}}\right]\%$$

leaving pin 19 high produces an output with 50% duty cycle.

Noise Oscillator

The "noise oscillator" supplies random frequencies for the "noise generator". The noise oscillator requires a 43 k resistor to ground at pin 4. The "noise oscillator" controls the rate of the "noise generator". An external noise oscillator may be used to provide this control. The external source is applied to pin 3 and provides an automatic override of pin 4.

Noise Generator/Filter

The output of the "noise generator" feeds an internal noise filter. This "rounds off" the generator's output, reducing the HF content of the noise. The upper 3 dB point is given by

$$F_{UPPER} = \frac{1.28}{R_{NF}\,C_{NF}}$$

where R_{NF} and C_{NF} are external components connected to pins 5 and 6 respectively.

Mixer

The "mixer" logic selects one, or a combination, of the inputs from the SLF, VCO, and noise generator. Selection is according to Table 1.

System Enable Logic

The "system enable" input provides an enable/inhibit for the system output. The output is inhibited when the voltage at pin 9 is a logic '1', and enabled when logic '0'.

One Shot Logic

The "one shot" logic can be used to provide sounds of a short duration. The duration of the "one-shot" is given by the following equation:

ABSOLUTE MAXIMUM RATINGS AT T_A = 25°C (Unless otherwise specified)

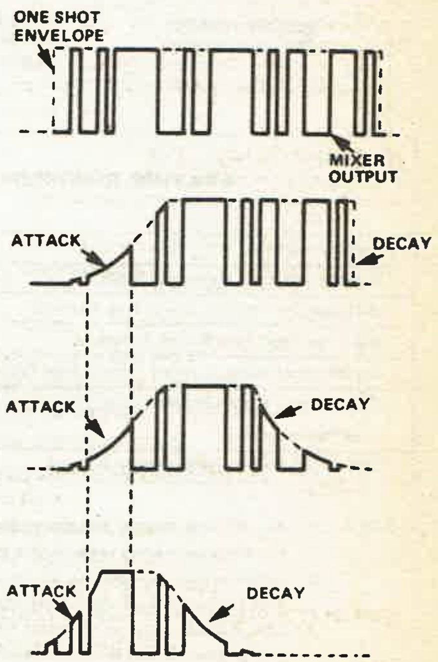
SUPPLY VOLTAGE, Vcc (1), PIN 15 .... 6.0V
SUPPLY VOLTAGE, Vcc (2), PIN 14 .... 12.0V
INPUT VOLTAGE APPLIED TO ANY DEVICE TERMINAL 6.0V
STORAGE TEMPERATURE .... −65°C to +150°C
OPERATING TEMPERATURE RANGE . −55°C to +120°C
LEAD TEMPERATURE 1/16 INCH FROM CASE FOR 10 SECONDS . +260°C

RECOMMENDED OPERATING CONDITIONS

	MIN	TYP	MAX	UNITS
SUPPLY VOLTAGE, Vcc1, PIN 15	4.5	5.0	5.5	V
SUPPLY VOLTAGE, Vcc2, PIN 14	5.7		9.0	V
OPERATING FREE-AIR TEMPERATURE	0	25	70	°C

OPERATING CHARACTERISTICS AT T_A=25°C AND Vcc1=5.0V

Fig. 1. Showing the various envelopes that the SN 76477 circuitry can produce.



MIXER SELECT C	MIXER SELECT B	MIXER SELECT A	MIXER OUTPUT
PIN 27	PIN 25	PIN 26	
0	0	0	VCO
0	0	1	SLF
0	1	0	NOISE
0	1	1	VCO/NOISE
1	0	0	SLF/NOISE
1	0	1	SLF/VCO/NOISE
1	1	0	SLF/VCO
1	1	1	INHIBIT

TABLE 1

Fig. 2. Block diagram

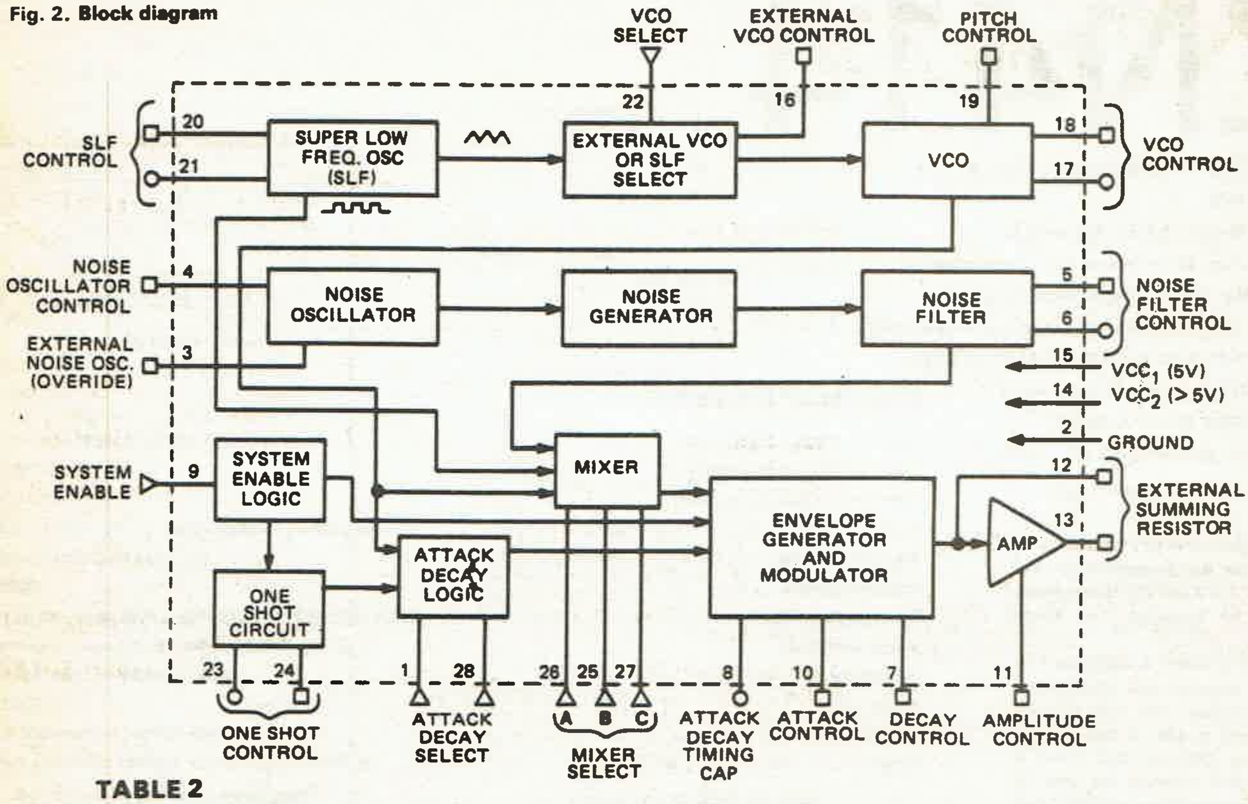


TABLE 2

ADL SELECT 1 PIN 1	ADL SELECT 2 PIN 28	OUTPUT
0	0	VCO
0	1	MIXER ONLY
1	0	ONE–SHOT
1	1	VCO WITH FLIP–FLOP

$T_{OS} = 0.8\ R_{OS}\ C_{OS}$

where R_{OS} and C_{OS} are external components connected to pins 24 and 23 respectively. The maximum duration of the "one-shot" is about two seconds.

The "one-shot" logic is triggered by the trailing edge of the system enable logic control signal.

ADL (Attack/Decay Logic)

The ADL determines the envelope for the mixer's output. The envelope selected is determined by the ADL control inputs to pins 1 and 28, the output selected being shown in Table 2.

Envelope Generator and Modulator

The attack/delay characteristics of the output are determined by the components connected to pins 7, 8 and 10.

The attack and delay times are given by the following:

$T_{ATTACK} = R_A\ C_{A/D}$ secs

$T_{DELAY} = R_D\ C_{A/D}$ secs

where $C_{A/D}$ is the attack delay capacitor connected to pin 8, and R_A and R_D are resistors connected to pins 7 and 10.

Output Amplifier

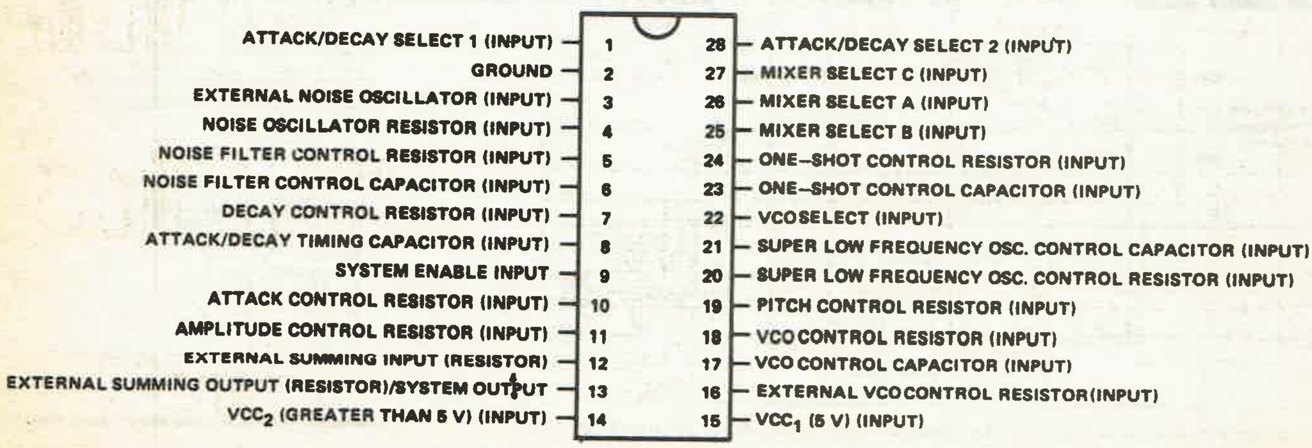
The output amplifier provides a low impedance output. The peak output voltage is determined by the following equation:

$$V_{OUT} = \frac{3.4\ R_S}{R_G}$$

where R_S is a summing resistor connected to pins 12 and 13 (set equal to 10 k) and R_G is a gain resistor connected to pin 11.

Notes:

1. Supplies greater than 5VO may be used, in which case they should be connected to pin 14 to allow the internal regulator to supply the internal circuit requirements.
2. For dedicated sound logic inputs (pins 1, 9, 22, 25, 26, 27 and 28) may be hard-wired to high or low logic levels.



ZN414

ZN414 AM Radio Receiver

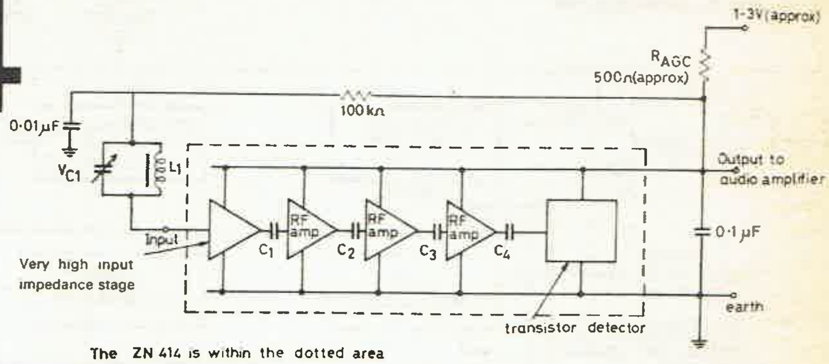
FEATURES

- 1·2-1·6 volt operating range.
- Less than 0·5mA current consumption.
- 150kHz-3MHz frequency range.
- Easy to assemble, no alignment necessary.
- Effective and variable A.G.C. action.
- Will drive an earphone direct.
- Excellent audio quality.
- Typical power gain of 72dB.

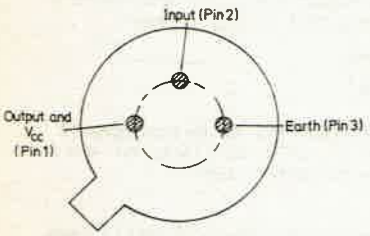
GENERAL DESCRIPTION

The ZN414 is a 10 transistor tuned radio frequency (TRF) circuit using the Ferranti C.D.I. technology and packaged in a 3 pin TO-18 transistor package for simplicity and space economy.

The circuit provides a complete R.F. amplifier, detector and AGC circuit which requires only six external components to give a high quality A.M tuner. Effective AGC action is available and is simply adjusted by selecting one external resistor value. Excellent audio quality can be achieved, and current consumption is extremely low. No setting-up or alignment is required and the circuit is completely stable in use.



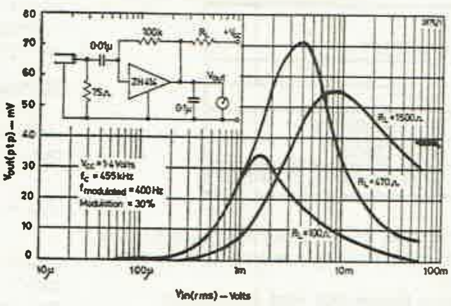
The ZN 414 is within the dotted area



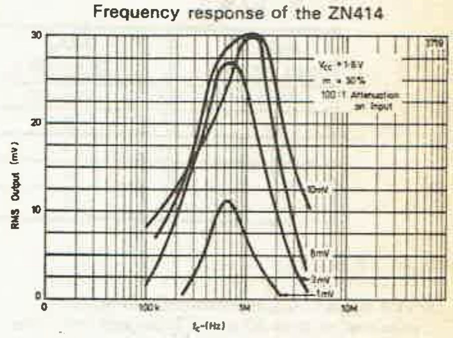
SUMMARY OF PARAMETERS

Supply voltage range	1·2-1·6 volts (1·3 volts recommended)
Storage temperature range	-65°C to +125°C
Operating temperature range	0°C to +70°C
Supply current	0·3 mA typical (0·5mA under strong signal conditions)
Frequency range	150kHz-3MHz useful range
Input resistance	4MΩ typical
Threshold sensitivity	50μV with 1·3 volt supplies (dependent on 'Q' of coil)
Audio distortion	⩽ 2% T.H.D. under correct operating conditions
Selectivity	4kHz bandwidth can be achieved
Power gain	72dB typical
AGC range	20dB typical (dependent on R_{AGC})
Output	⩾ 30mV r.m.s. under correct operating conditions

Gain and AGC characteristics



Frequency response of the ZN414



LAYOUT REQUIREMENTS

As with any high gain R.F. device, certain basic layout rules must be adhered to if stable and reliable operation is to be obtained. These are listed below:—

1. The output decoupling capacitor should be soldered as near as possible to the output and earth leads of the ZN414. Furthermore, its value together with the AGC resistor (R_{AGC}) should be calculated to give a breakpoint at ~ 4kHz, i.e.:—

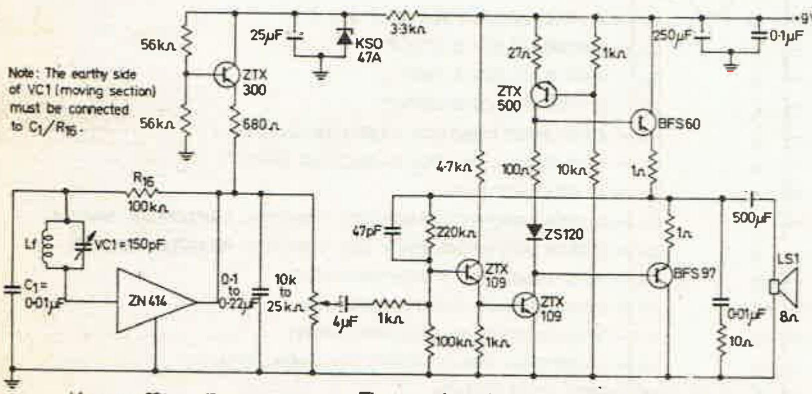
$$C\ (\text{farads}) = \frac{1}{2\pi \cdot R_{AGC} \cdot 4 \cdot 10^3}$$

2. All leads should be kept as short as possible, especially those in close proximity to the ZN414.

3. The tuning assembly should be some distance from the battery, loudspeaker and their associated leads.

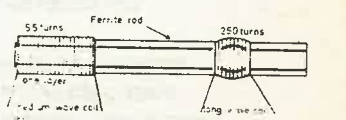
4. The 'earthy' side of the tuning capacitor should be connected to the junction of the 100kΩ resistor and the 0·01μF capacitor.

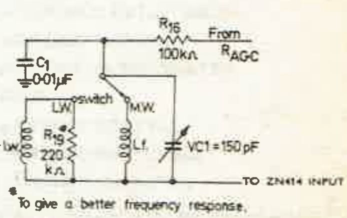
Domestic portable receiver



Lf = approx. 55t. on a 15cm. ferrite rod.

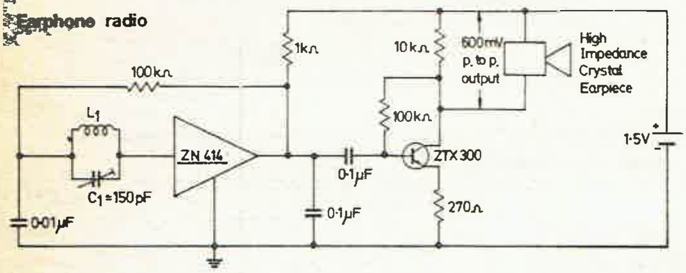
The complete circuit diagram of the Triffid receiver





Coil winding details and waveband selection.

Earphone radio



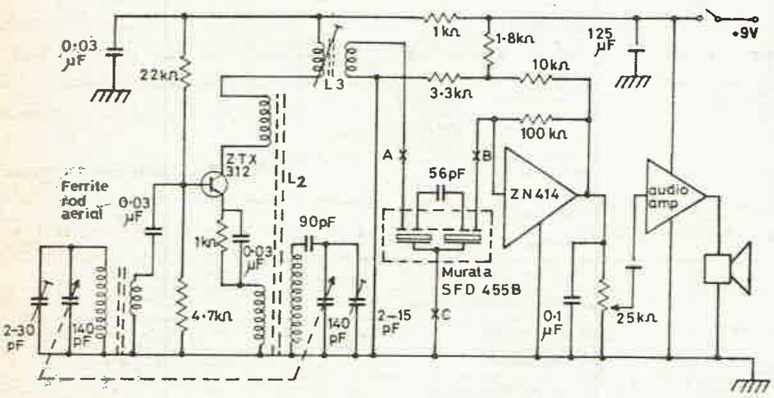
L_1 ~ 80 turns of 0·3 mm. dia. enamelled copper wire on a 5 cm. or 7·5 cm. long ferrite rod. Do not expect to adhere rigidly to the coil-capacitor details given. Any value of L_1 and C_1 which will give a high 'Q' at the desired frequencies may be used.

Volume Control: A 250Ω potentiometer in series with a 100Ω fixed resistor substituted for the 270Ω emitter resistor provides an effective volume control.

(d) Broadcast band superhet using ZN414

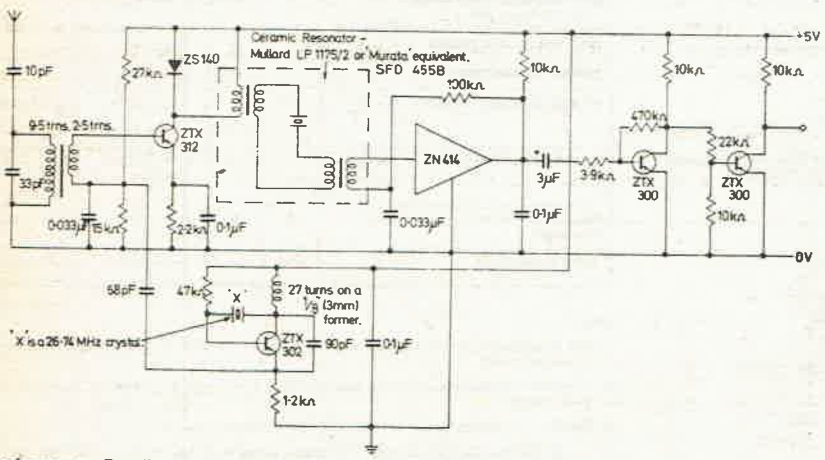
The ZN414 coupled with the modern ceramic resonators offers a very good I.F. amplifier at modest cost, whilst maintaining simplicity and minimal alignment requirements. A typical circuit is shown below.

-6dB Bandwidth = 6kHz.
-30dB Bandwidth = 8kHz.
A.G.C. Range ≃ 40dB.



Use in model control receiver

The circuit below shows a ZN414 used as an I.F. amplifier for a 27MHz superhet receiver.



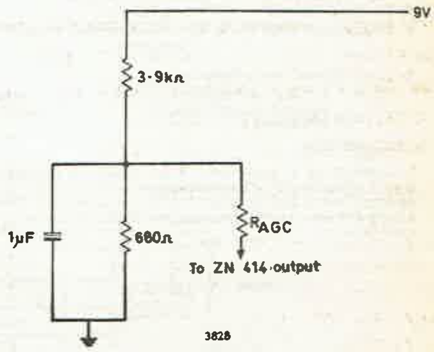
Performance Details:

Sensitivity = 2·5μV for a 5V p.t.p. output measured at f_c = 27·21MHz, 100% modulated with 100Hz square wave.
Selectivity: ±5kHz for < 100mV p.t.p. output.
Input Signal Range: 2·5μV to 25mV (i.e. 80dB).
Supply Current: ~ 4·5mA.

DRIVE CIRCUITS

Three types of drive circuit are shown, each has been used successfully. The choice is largely an economic one, but circuit 3 is recommended wherever possible, having several advantages over the other circuits. Values for 9V supplies are shown, simple calculations will give values for other supplies.

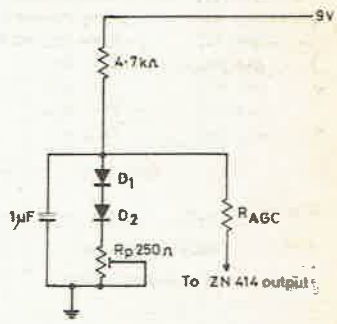
1. Resistive Divider



Current consumption = 2mA.

NOTE.—Replacing the 680Ω resistor with a 500Ω resistor and a 250Ω preset, sensitivity may be adjusted and will enable optimum reception to be realised under most conditions.

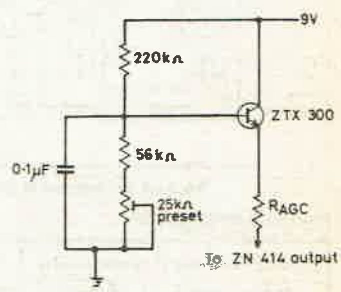
Diode Drive



D_1 = D_2 = ZS120

R_p = Optional sensitivity control, a recommended value being 250Ω.

Current consumption ~ 1·5mA.



Current consumption is virtually that which is taken by the ZN414 (0·3mA).

ZN425

ZN425 Series

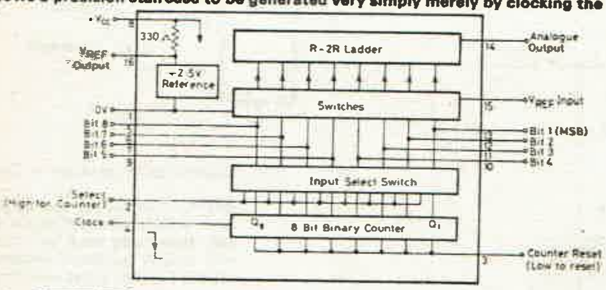
8 Bit Monolithic D to A/A to D Converter

FEATURES

- **8, 7 and 6 bit Accuracy**
- **0°C to +70°C (ZN425E Series)**
- **−55°C to +125°C (ZN425J-8)**
- **TTL and 5V CMOS Compatible**
- **Single +5V Supply**
- **Settling Time (D to A) 1 µsec Typical**
- **Conversion Time (A to D) 1 msec typical, using ramp and compare.**
- **Extra Components Required**
  - **D-A : Reference capacitor (direct voltage output through 10 kΩ typ.)**
  - **A-D : Comparator, gate, clock and reference capacitor**

DESCRIPTION

The ZN425 is a monolithic 8-bit digital to analogue converter containing an R-2R ladder network of diffused resistors with precision bipolar switches, and in addition a counter and a 2.5V precision voltage reference. The counter is a powerful addition which allows a precision staircase to be generated very simply merely by clocking the counter.



PIN CONNECTIONS

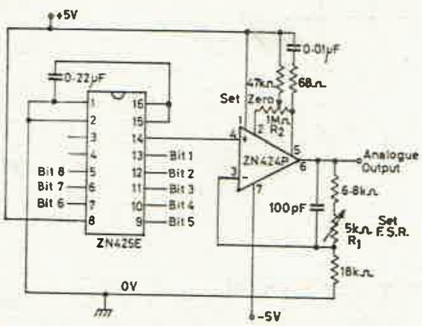
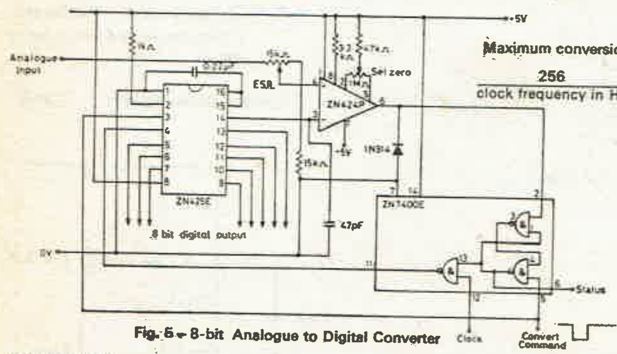


Fig. 4 – 8-bit Digital to Analogue Converter



Maximum conversion time = $\frac{256}{\text{clock frequency in Hz}}$ seconds

Fig. 5 – 8-bit Analogue to Digital Converter

ORDERING INFORMATION

Operating Temperature	8-bit Accuracy	7-bit Accuracy	6-bit Accuracy	Package
0°C to +70°C	ZN425E-8	ZN425E-7	ZN425E-6	Plastic
−55°C to +125°C	ZN425J-8	—	—	Ceramic

ABSOLUTE MAXIMUM RATINGS

Supply voltage V_{CC}	+7·0 volts
Max. voltage, logic and V_{REF} inputs	+5·5 volts *See note 3*
Operating temperature range	0°C to +70°C (ZN425E Series)
	−55°C to +125°C (ZN425J-8)
Storage temperature range	−55°C to +125°C

CHARACTERISTICS (at T_{amb} = 25°C and V_{CC} = +5 volts unless otherwise specified).

Internal voltage reference

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Output voltage	V_{REF}	2·4	2·56	2·7	volts	I = 7·5 mA (internal)
Slope resistance	R_s	—	2	4	ohms	I = 7·5 mA (internal)
V_{REF} Temperature coefficient		—	40	—	ppm/°C	I = 7·5 mA (internal)

Note: The internal reference requires a 0·22 µF stabilising capacitor between pins 1 and 16.

8-Bit D to A Converter and Counter

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Resolution		8	—	—	bits	
Accuracy (useful resolution) ZN425J-8		8	—	—	bits	V_{REF} Input = 2 to 3V
ZN425E-8		8	—	—	bits	
ZN425E-7		7	—	—	bits	
ZN425E-6		6	—	—	bits	
Non-linearity		—	—	±0·5	L.S.B.	*See Note 3*
Differential non-linearity		—	±0·5	—	L.S.B.	*See Note 6*
Settling time		—	1·0	—	µs	1 L.S.B. step
Settling time to 0·5 L.S.B.		—	1·5	2·5	µs	All bits ON to OFF or OFF to ON
Offset voltage ZN425J-8	V_{OS}	—	8	12	mV	All bits OFF *See Note 3*
ZN425E-8, ZN425E-6, ZN425E-7	V_{OS}	—	3	8	mV	
Full scale output		2·545	2·550	2·555	volts	All bits ON Ext. V_{REF}=2·56V
Full scale temperature coeff.		—	3	—	ppm/°C	Ext. V_{REF}=2·56V
Non-linearity error temp. coeff.		—	7·5	—	ppm/°C	Relative to F.S.R.
Analogue output resistance	R_o	—	10	—	kΩ	
External reference voltage		0	—	3·0	volts	
Supply voltage	V_{CC}	4·5	—	5·5	volts	*See Note 3*
Supply current	I_s	—	25	35	mA	
High level input voltage	V_{IH}	2·0	—	—	volts	*See Notes 1 and 2*
Low level input voltage	V_{IL}	—	—	0·7	volts	
High level input current	I_{IH}	—	—	10	µA	V_{CC} = max. V_I = 2·4V
		—	—	100	µA	V_{CC} = max. V_I = 5·5V
Low level input current, bit inputs	I_{IL}	—	—	−0·68	mA	V_{CC} = max. V_I = 0·3V
Low level input current, clock reset and input select	I_L	—	—	−0·18	mA	
High level output current	I_{OH}	—	—	−40	µA	
Low level output current	I_{OL}	—	—	1·6	mA	
High level output voltage	V_{OH}	2·4	—	—	volts	V_{CC} = min. Q = 1 I_{load} = −40 µA
Low level output voltage	V_{OL}	—	—	0·4	volts	V_{CC} = min. Q = 0 I_{load} = 1·6 mA
Maximum counter clock frequency	f_c	3	5	—	MHz	*See Note 5*
Reset pulse width	t_R	200	—	—	ns	*See Note 4*

Notes:

1. **The Input Select pin (2) must be held low when the bit pins (5, 6, 7, 9, 10, 11, 12 and 13) are driven externally.**
2. **To obtain counter outputs on bit pins the Input Select pin (2) should be taken to $+V_{CC}$ via a 1 kΩ resistor.**
3. **The ZN425J differs from the ZN425E in the following respects:**
   - (a) For the ZN425J, the maximum linearity error may increase to ±1 LSB over the temperature ranges −55°C to 0°C and +70°C to +125°C.
   - (b) Maximum operating voltage. Between 70°C and 125°C the maximum supply voltage is reduced to 5.0V.
   - (c) Offset voltage. The difference is due to package lead resistance. This offset will normally be removed by the setting up procedure, and because the offset temperature coefficient is low, the specified accuracy will be maintained.
4. **The device may be reset by gating from its own counter.**
5. **F_{max} in A/D mode is 300 kHz, see page 6.**
6. **Monotonic over full** operating temperature range at resolution appropriate to accuracy.

ZN428

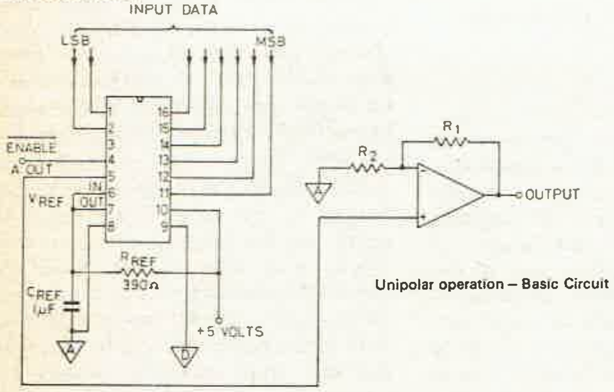
ZN428E-8/J-8 8 Bit Latched Input Monolithic D to A Converter

FEATURES

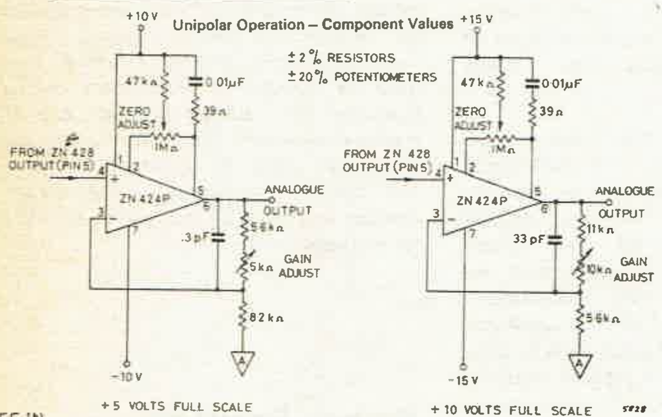
- Contains DAC with data latch and on-chip reference.
- Guaranteed monotonic over the full operating temperature range
- Single +5V supply
- Microprocessor compatible
- TTL and 5V CMOS compatible
- 800 ns settling time
- Complementary to ZN427 A to D Series
- ZN428E-8 Commercial temperature range 0°C to +70°C
- ZN428J-8 Military temperature range −55°C to +125°C

GENERAL DESCRIPTION

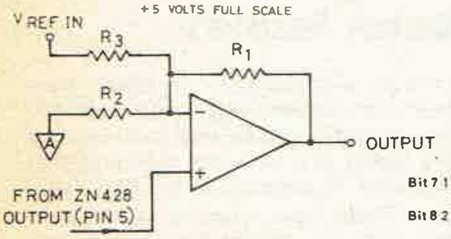
The ZN428 is a Monolithic 8 bit D to A converter with input latches to facilitate up-dating from a data bus. The latch is transparent when $\overline{\text{Enable}}$ is LOW and the data is held when $\overline{\text{Enable}}$ is taken HIGH. The ZN428 also contains a 2.5 volt reference the use of which is pin optional to retain flexibility. An external fixed or varying reference may therefore be substituted.



Unipolar operation – Basic Circuit

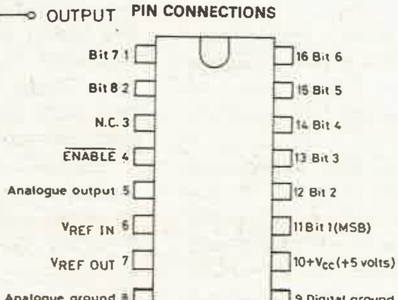


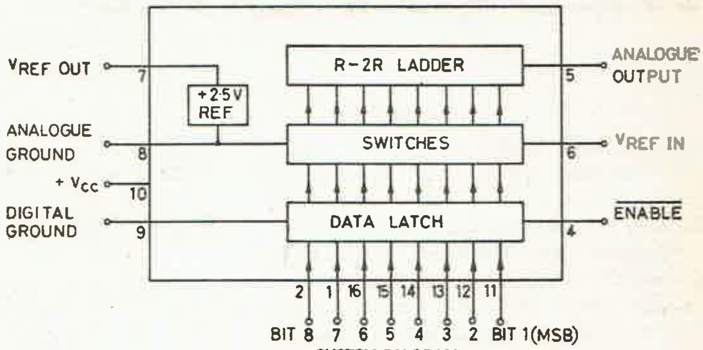
Unipolar Operation – Component Values



Bipolar Operation – Basic Circuit

PIN CONNECTIONS





SYSTEM DIAGRAM

ABSOLUTE MAXIMUM RATINGS

Supply voltage V_{CC}	+7.0 volts
Max. voltage, logic and V_{REF} input	$+V_{CC}$
Operating temperature range	0°C to +70°C (ZN428E-8) −55°C to +125°C (ZN428J-8)
Storage temperature range	−55°C to +125°C
Analogue Ground to Digital Ground	±200 mV

ELECTRICAL CHARACTERISTICS (V_{CC} = +5 volts, T_{amb} = 25°C unless otherwise specified).

Parameter	Min.	Typ.	Max.	Units	Conditions
Internal Voltage Reference					
Output voltage	2.475	2.550	2.625	volts	R_{REF} = 390Ω, C_{REF} = 1 μF
Slope resistance		0.5	2	Ω	
$V_{REF\,OUT}$ T.C.		50		ppm/°C	
Reference current	4		15	mA	Note 1
D to A Converter					
Linearity error			±0.5	LSB	2.0V ≤ $V_{REF\,IN}$ ≤ 3.0V
Differential non-linearity		±0.5		LSB	
Linearity error T.C.		±3		ppm/°C	
Differential non-linearity T.C.		±6		ppm/°C	
Offset voltage		2	5	mV	All bits OFF
Offset voltage T.C.		±6		μV/°C	
Full scale output	2.545	2.550	2.555		External reference $V_{REF\,IN}$ = 2.560 volts, all bits ON
Full scale output T.C.		2		ppm/°C	
Analogue output resistance		4		kΩ	
External reference voltage	0		3.0	volts	
Settling time to 0.5 LSB		800		ns	1 LSB Major Transition (Note 2)
		1.25		μs	All bits ON to OFF or OFF to ON (Note 2)
Operating temperature range: ZN428E-8	0		70	C	
ZN428J-8	−55		125	C	
Supply voltage (V_{CC})	4.5	5.0	5.5	volts	
Supply current		20	30	mA	Note 3
Power consumption		100		mW	
Logic (over specified operating temperature range)					
High level input voltage	2.0			V	
Low level input voltage			0.8	V	
High level input current			60	μA	V_{IN} = 5.5V, V_{CC} = Max.
			20	μA	V_{IN} = 2.4V, V_{CC} = Max.
Low level input current			−5	μA	V_{IN} = 0.4V, V_{CC} = Max.
Input Clamp Diode Voltage		−1.5		V	I_{IN} = −8 mA
Enable pulse width	100			ns	
Data set-up time	150			ns	Note 4
Data hold time	10			ns	Note 5

Note 1 See REFERENCE, page 4.
Note 2 R_L = 10 MΩ, C_L = 10 pF.
Note 3 All inputs HIGH (V_{IH} = 3.5 volts).
Note 4 Set up time before $\overline{\text{Enable}}$ goes high.
Note 5 Hold time after $\overline{\text{Enable}}$ goes high.

RESISTORS

RESISTORS MUST BE THE MOST commonly used of electronic components — to the point where they tend to be taken for granted.

Resistors are, however, made in a variety of ways either for general use or because their particular characteristics suit certain areas of application. Modern resistors can be classified into four broad groups:

(a) composition resistors
(b) film resistors
(c) wirewound resistors
(d) semiconductor resistors

There is a variety of construction styles in each group, each style having particular characteristics, advantages and disadvantages.

General Characteristics — Resistors are not quite the passive components they are usually taken to be. All the resistors vary in value with variations in temperature. They also change value with applied voltage and with frequency. All resistors generate noise, and thus certain types are better suited to applications requiring low noise components, such as audio amplifier input circuits. Knowing what the various characteristics of a resistor mean in different situations enables you to make a proper selection for a particular application — or to make substitutes without introducing problems. There is a generally agreed convention on how the various resistor characteristics are expressed and these are explained below.

Temperature coefficient — With many resistors, the change in value of resistance is fairly linear across a large range of temperature. With such resistors the temperature coefficient is usually expressed in 'parts per million per degrees centigrade' or ppm/°C. It is also sometimes expressed in percent of value per degrees centigrade, or %/°C. Some resistors have a nonlinear temperature coefficient and this characteristic is usually referred to as the 'resistance-temperature' characteristic. Some types of resistor, particularly those in the semiconductor group, are manufactured to have a large, controlled resistance-temperature characteristic. They are usually used for temperature sensing, compensation, or in measurement applications.

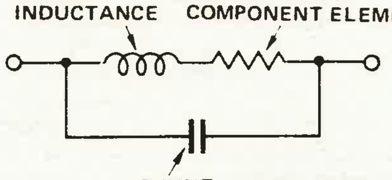


Fig.1. Equivalent circuit of practical resistor.

Voltage Coefficient — The nominal value of a resistance is not independent of the applied voltage, usually decreasing with increase in applied voltage. The voltage coefficient is usually expressed as a percentage of the change in resistance against variation in applied voltage from 10% of maximum working voltage to maximum working voltage. This is a characteristic that is only of importance with carbon composition resistors and some types of semiconductor resistors (i.e. voltage dependant resistors).

Frequency Effects — All resistors have an inherent small amount of inductance and capacitance and this affects the way they behave at high frequencies and above. The length of the actual resistance path in the resistor and the length of the leads contributes inductance in series with the apparent dc resistance. Capacitance, which may be distributed along the resistor body or through the resistance path, contributes capacitance which is effectively in parallel with the apparent dc resistance. This changes what should look like an ordinary resistor into a circuit like that in Fig. 1. The actual amount of series inductance and shunt capacitance depends largely on the type of resistor and its construction. Some styles of resistor are constructed to minimise these effects.

Carbon composition and wirewound resistors are the most affected of any group. Generally, for values above 100 ohms or so, the apparent resistance will decrease as the frequency is increased. Thus low value resistors exhibit the least variation with increasing frequency while the apparent resistance of high value resistors (i.e. about 100 k and above), rapidly decreases as the frequency increases.

Noise — All resistors generate 'noise' in the form of tiny voltage fluctuations which originate in the resistive element. Further noise is generated in the lead connections. The total noise voltage is contributed from a number of different sources. One form of noise that is present in *all* resistors is called 'Johnson Noise' and the magnitude of this depends on the temperature and the value of the resistor. Some resistors (particularly carbon composition types) produce extra noise caused by the current flowing through the component. Faults in the component also cause noise, i.e. for solid body types, minute cracks may add to the noise. Some styles of construction can contribute to noise, for example, those constructed with end caps connecting to the resistive element may become noisy (more noisy) when the end caps are subjected to tension and become slightly loose. For adjustable resistors, added noise may be caused by imperfect contact between the moving contact and the resistive element. The noise is worsened during the time the contact is moving. To obtain the lowest noise from a resistor it should be operated well below its wattage rating.

Carbon Resistors

Carbon composition resistors have been used extensively in the manufacture of radio and television sets since the valve era but are being rapidly replaced in production by film resistors. These have superior characteristics and are becoming increasingly cost competitive.

Carbon resistors are manufactured in wattage ratings ranging from 0.1 watt to 2 watts and resistance values ranging from 10 ohms to 100 M. They are made to tolerances of ± 5% (E24 series, ± 10% (E12 series) and ± 20% (E6 series), although the latter is the more usual and least expensive.

There are three basic types of carbon composition resistor:

(a) uninsulated
(b) insulated
(c) filament or filament-coated

Uninsulated type: In this type, the resistive element consists of fine carbon particles mixed with a refractory filling, which is non-conducting, bonded together by a resin binder. The proportion of carbon particles to filler determines the resistance value. The mixture is compressed into shape, usually cylindrical, and fired in a kiln. The end connections are made by any one of a variety of methods. These are illustrated in Fig. 2. In the first method, Fig. 2(a), the ends of the composition rod are sprayed with metal, and wire leads soldered on to provide radial connections. The resistor is then painted and colour coded. This method was extensively used with 1 W and 2 W resistors. A second method, much more widely used now, involves enlarging the ends of the connecting leads and moulding them directly into the carbon composition rod – Fig. 2(b). This method is used extensively as it is adaptable to all wattage ratings and sizes of the resistor body. A third method is also employed. Pressed metal caps, usually having integral leads, are forced onto the ends of the carbon rod – Fig. 2(c). These caps have radial leads and are particularly suited to printed circuit board mounting as they may be plugged straight into mounting holes on the board without the necessity of preforming the leads as is required with axial lead components. These are also known as 'pluggable' types. Film resistors are also made in this style.

Uninsulated carbon composition resistors are generally smaller than the insulated types for a given wattage as their open construction permits good heat dissipation. There is the danger however, that short circuits may occur to adjacent components, and for this reason, the insulated type is preferred.

Insulated Type: This type has the composition element made in the same manner as just described, but it is then encapsulated in either a silicon lacquer, a thermoplastic moulding or epoxied into a ceramic tube. The first two generally employ a resistance element having embedded connections, as illustrated in Fig. 3(a). The type having the element sealed in a ceramic tube generally have an element constructed as shown in Fig. 3(b). The ends of the element are sprayed with metal and an end-cap having an integral lead is force-fitted over them. This assembly is then put inside the ceramic tube and the ends sealed with an epoxy or other compound.

Filament or Filament-coated Type: With this type, carbon granules are dispersed, along with a filler, in a varnish which is then applied to the surface of a continuous glass or ceramic filament which is then baked. The resistance value depends on the length and mixture, the filament is cut into appropriate lengths and leads applied by one of the methods detailed above. It is usually encapsulated in an insulating compound as per the insulated style of resistor.

Carbon composition resistors have a large voltage coefficient. The value of this coefficient varies with the resistance of the component (being highest for high value resistors) and the size of the resistance element. Small resistors of a given value have less insulating filler in their composition and will have a lower voltage coefficient. Commonly available composition resistors have quoted voltage coefficient between 0.02 and 0.035 for values up to 1M. Values above this have a coefficient of typically 0.05. These values may cause a maximum change in resistance of 2% when used within their ratings. The voltage coefficient of the other types of resistors is considerably smaller than for composition types – typically 0.002% or less.

A large negative temperature coefficient is one of the disadvantages of composition resistors. It is typically

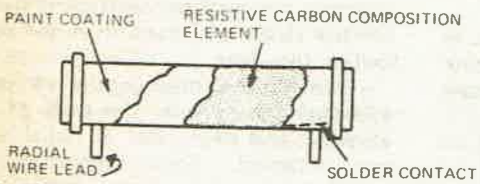


Fig.2(a). Carbon composition resistor with the end connections made by spraying the ends with metal and the leads soldered.

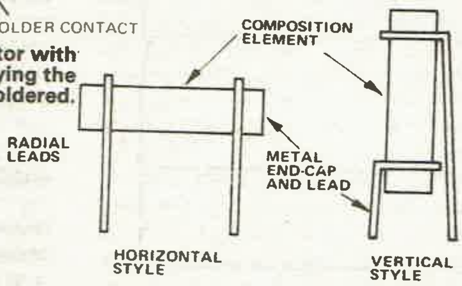


Fig.2(c). Carbon composition resistor with pressed metal end-cap and lead connections for plugging into p.c. boards – the 'plug-gable' style. The end-caps are forced over the ends of the composition rod element.

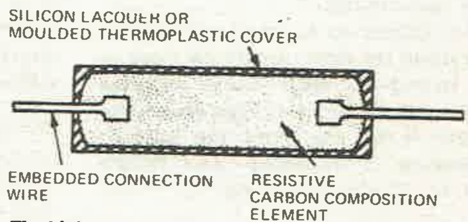


Fig.3(a). Insulated carbon composition resistor construction.

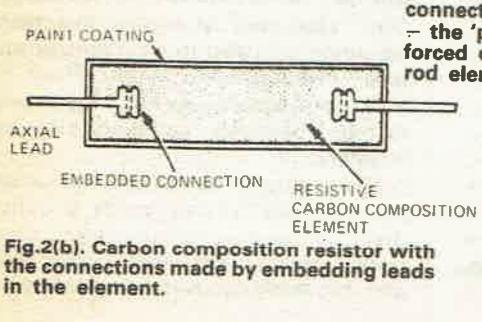


Fig.2(b). Carbon composition resistor with the connections made by embedding leads in the element.

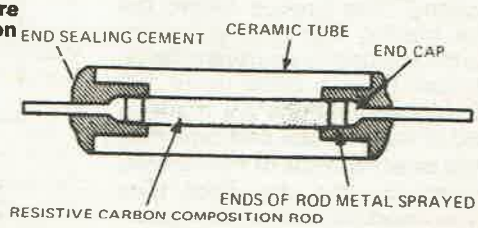


Fig.3(b). Assembly of a ceramic tube type insulated carbon composition resistance.

between 0.1% and 0.15% per °C (i.e. 1000 ppm per °C or greater), across the whole resistance range. This means that a 1 M resistor will change its value by 1 k or more for each °C change in temperature. The curve of percentage resistance change versus temperature is not linear and may be positive over one portion of the temperature range and negative over another.

The amount of noise generated by carbon composition resistors is a function of the materials used in the composition mix. Generally, the noise generated increases with increasing voltage, increasing resistance, and decreasing size, for a given mix of materials. The noise due to current flowing through the resistor is generated by random changes in the material of the element, caused by the current flow. This noise decreases with increasing frequency and Johnson noise, which is frequency independent, becomes dominant above about 1 kHz. The current noise generated by composition resistors is a major limitation against using them at dc and low frequencies. They are not recommended for use in amplifier input stages or DC amplifiers for this reason. Microphony is also noticeable, caused by modulation of the noise voltage generated by the component. Composition resistors having values above about 1 M Johnson noise makes them unsuitable for use in high impedance amplifier inputs or other critical applications.

When subjected to overload, carbon composition resistors usually decrease in value owing to their large negative temperature coefficient. This causes the temperature to rise until the hotspot temperature is exceeded and failure occurs, usually by fracturing.

Film Resistors

Film Resistors are manufactured by forming a deposit of an appropriate resistive material, usually carbon, carbon-boron or some metallic oxide, on a ceramic former, usually a tube or rod. A helical groove is then cut in the film coating. The groove forms the resistive coating into a long continuous path resulting in a compact resistor that can have a value up to 100 megohms. Terminations are made in a variety of ways. Metal end caps may be forced over the ends of the ceramic rod, contacting the deposited film. Leads are attached to the caps by soldering or spot-welding. In some types, the ends of the coated ceramic rod are metallized and leads are wrapped around the metallized portions and soldered. The component is then coated in a suitable lacquer for protection.

Typical construction of a film resistor is illustrated in Figure 4.

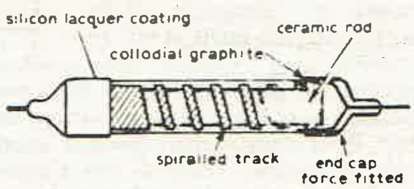


Fig.4. Typical construction of a film resistor

Thick-film resistors are a special type of film resistor. They are generally constructed by depositing the resistive material on a ceramic or aluminium-oxide substrate. A portion of the film coating is then removed, according to a predetermined pattern, to provide a long resistive path between the resistor terminals. Typical construction of one style of thick-film resistor is illustrated in Figure 5. This style is obtainable as a 'fusible' resistor. When overloaded, the substrate cracks, ensuring an open circuit which reduces the possibility of further circuit damage, physical or electronic. These thick-film resistors occupy a minimum of space on a printed circuit board and can dissipate considerable power owing to their large surface area and high hot-spot temperature (150°C).

Thick film resistors are also made in appropriate groupings on a small substrate and encapsulated in a standard

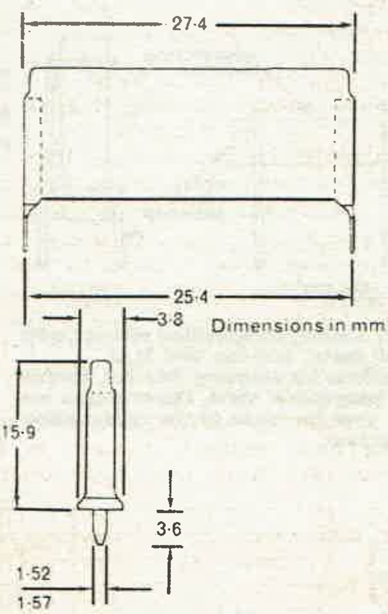


Fig.5. Example of fusible-type of thick-film resistor.

DIL IC package. Certain values of resistance are standard in digital circuitry and this style is used in such applications (for example, as the 'weighting' resistor network in a digital-to-analogue converter). Another application is for 'pull-up' resistors for open-collector logic gates.

Thin film resistors are constructed in a similar fashion but on a considerably smaller scale. They are primarily used in IC manufacture. Some thin film resistor networks are available in standard DIL integrated circuit packages, and these find application in digital circuitry.

There are four basic types of film resistor:–

(a) Carbon Film
(b) Metal Film
(c) Metal Oxide Film
(d) Metal Glaze (Cermet)

Carbon Film Resistors

These resistors are manufactured by a 'cracking' or pyrolytic process where a hydrocarbon vapour at high temperature is decomposed onto a special ceramic rod, producing a thin carbon film on the surface. These are sometimes referred to as 'deposited-carbon' film resistors. Some types use a boron-carbon film; a boron containing gas is introduced during the cracking process. This results in a resistor that has a superior temperature coefficient over a limited range of values than the plain carbon film type.

Terminations may consist of metal end-caps forced over the ends of the element, and then axial or radial leads are attached. Some manufacturers metallize the ends of the element and solder leads to them. Sometimes a combination of the two techniques is used to improve reliability.

Protection for the element is provided in a number of ways. Numerous layers of varnish may be applied followed by a final paint coating. Some modern types are completely sealed in a silicone resin base which is impervious to moisture as well as providing excellent mechanical and thermal protection. Other types may be encased in a plastic moulding or sealed in a ceramic or glass tube. The varnished types afford the least protection against mechanical damage (through handling etc) and moisture.

The voltage coefficient of carbon film resistors is very much less than that of carbon composition types, being usually less than 100 ppm/V and this rarely needs to be considered.

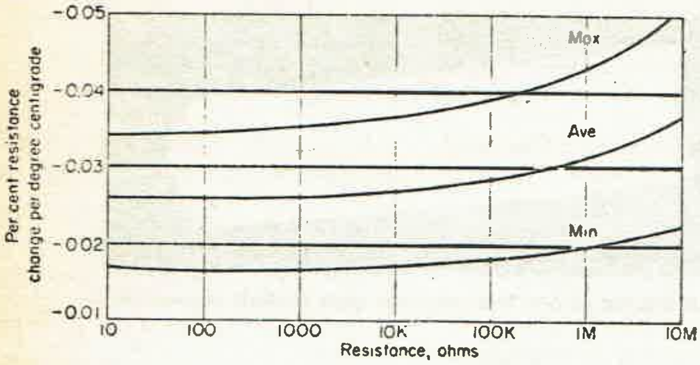


Fig.6. Typical temperature-coefficient spread for deposited-carbon resistors.

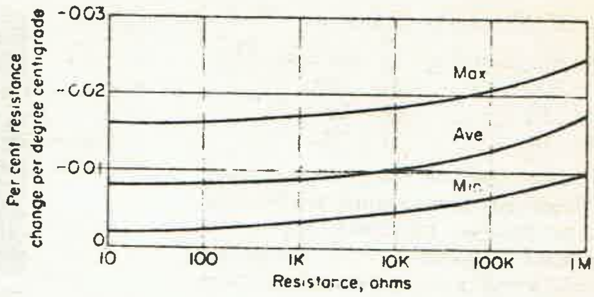


Fig.7. Typical temperature-coefficient spread for boron-carbon resistors.

Getting Heated

Carbon film resistors exhibit temperature characteristics which are superior to composition resistors, but not as good as metal film or wirewound types. Nevertheless, the temperature co-efficient of carbon film resistors is quite acceptable for a wide variety of applications. Only those applications requiring a very good temperature characteristic warrant the use of the other, usually more expensive, film resistors.

As mentioned just previously, the temperature coefficient of boron-carbon film resistors is somewhat better than the deposited-carbon types. The latter may have a temperature coefficient between +350 and −550 ppm/°C for values under 100k, and between +350 and −800 ppm/°C for values under 100k. Generally though, the TC will be negative. The variation of TC with resistance value and the sort of 'spread' that can be expected for a particular batch of components is illustrated in Figure 6 for deposited carbon resistors. The temperature coefficient of boron-carbon resistors is typically between +100 and −200 ppm/°C for values under 100k, and between −50 and −400 ppm/°C for values over 100k. The variation of TC with resistance value and the spread that might be expected is illustrated in **Figure 7.**

The TC of carbon film resistors is also dependant on the wattage rating due to the thickness of the carbon film used in its construction.

Growing Old

All resistors change their value permanently with age and use. Carbon composition resistors are the worst in this regard and may be expected to change as much as 20% Film and wire-wound resistors are considerably better. Carbon film resistors have a stability of better than 1% which is usually more than adequate for all but the most stringent applications.

The high frequency characteristic of carbon film resistors is one of its advantages. Coated types are somewhat better than equivalent moulded or encased units. Generally speaking, the apparent value of the resistor decreases at high frequencies. Values below 1k will maintain their resistive value well beyond 500 MHz. Even relatively high values will not show a decrease of more than 10% until well into the VHF region. This is illustrated for typical coated ½W deposited-carbon film resistors in **Figure 8.**

Noise

The noise generated by carbon film resistors is a function of the applied voltage, the thickness of the film and the length of the spiral track. Consequently, the lower value, higher wattage units generate the least noise. For values below 10k it is typically between .08 and .5 µV/V, and for values between 10k and 100k it may be as low as 0.2 µV/V and up to 1.0 µV/V. For values above 100k, the noise ranges from 0.5 µV/V to 1.5 µV/V.

Carbon film resistors are available in ratings from 0.1W to 2W and in values that range from 10 ohms to 15M for commonly available units and up to 100M on special order. They are manufactured to tolerances of ± 0.5% (E192 series), ± 1% (E96 series), ± 2% (E48 series) and ± 5% (E 24 series).

Carbon film resistors will withstand a short-term overload of twice to 2.5 times the rated maximum working voltage. Failure is more common in the high value resistors. Irregularities in the spiral track and extremely thin film contribute to the failure of the component. The resistor may burst into flame when it fails due to a prolonged overload.

The excellent stability and low cost of carbon film resistors, along with other desirable features such as low noise, small TC and good high frequency characteristics have contributed to their increasing use in a wide range of electronic applications.

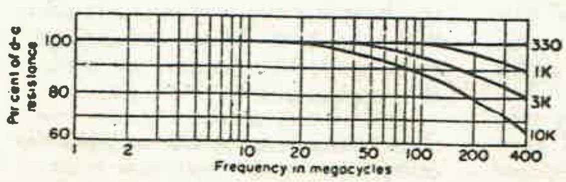


Fig.8. Approximate frequency characteristics for ½-watt deposited-carbon resistor.

Metal Film Resistors

These resistors are much the same in appearance and size to deposited-carbon resistors. The resistive film is deposited on a ceramic or glass former by evaporating a metal or alloy in a vacuum, the metal condenses on the surface of the former, forming a hard, dense film. Nickel-chrome alloys are most commonly used. Some manufacturers use a chemical deposition process to coat a former with a nickel alloy. Packaging and protection for metal film resistors is similar to carbon film resistors.

The temperature coefficient of these resistors is superior to most other types with the exception of precision wire-wound resistors. The TC is typically ± 100 ppm/°C but they are available with a TC as low as ± 20 ppm/°C. The construction of these resistors makes it possible to supply them in controlled values of temperature coefficient over a wide range of values. Typical TC ranges for such types are as follows:–

0 ± 50 (ppm/°C)	0 + 50 (ppm/°C)
0 ± 100 "	0 + 100 "
0 ± 150 "	0 – 50 "
0 ± 200 "	0 – 100 "

The thickness of the film establishes the resultant temperature coefficient. This is positive for thick films; the magnitude decreasing with decreasing film thickness, passing through zero and then turns negative for thin films.

The noise level of metal film resistors is very low, being typically 0.015 μV/V which is only rivalled by metal-glaze resistors. However, wirewound resistors are superior to all the others.

Stability of these resistors under ordinary use is generally better than 0.2% which is only bettered by precision wirewound resistors. As a consequence, metal film resistors are available in tolerances as low as ± 0.25% and ± 0.5%. Generally they are available in tolerances of ± 1%, ± 2% and ± 5%.

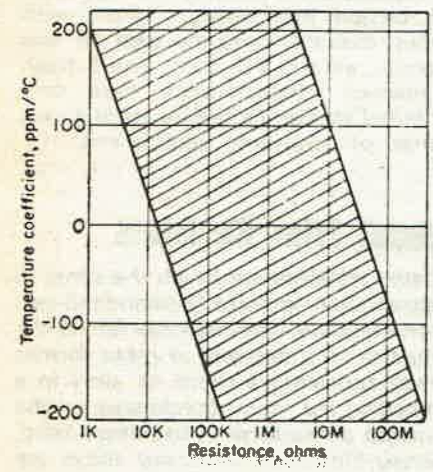


Fig.9. Range of temperature coefficients available for various values of metal film resistors having controlled TC characteristics.

Stable Companion

In general, metal film resistors offer all the advantages of deposited-carbon film resistors as well as exhibiting much superior stability and temperature coefficient characteristics. They generate much lower noise in operation than most other types of resistors. Frequency characteristics are much the same as for carbon film resistors, the construction being largely the same. Metal film resistors are available in wattage ratings from 0.1W to 1W, generally, but higher power types are available.

Metal film resistors are mostly used in applications where reliability, close tolerance and high stability are required or where controlled temperature characteristics are called for. They are generally somewhat more expensive than composition or deposited carbon film resistors but the price differential is decreasing as their use becomes more widespread.

Metal Oxide Film Resistors

In this class of film resistor conducting oxides of tin and antimony are formed on a glass or ceramic rod which is at red heat. The chemical reaction produces hard, glass-like oxide on the surface of the former. The oxide film is conductive and is inert to common chemicals. The resistance value required is obtained by cutting a helical groove in the film, along the former, as explained in the last section. General construction and terminations are similar to the other film resistors. The resistive element is usually coated with a flame-proof epoxy material.

The noise and temperature coefficient characteristics do not vary widely with resistance value, these resistors being superior in this respect than deposited-carbon film resistors. The noise is generally around 0.03 μV/V and may be as low as 0.02 μV/V. The TC of common types is generally ± 250 ppm/°C but may be as low as ± 50 ppm/°C. As the film is of a semi-conductive nature, the TC may be either positive or negative. The limits of precision in controlling the composition of the film produces resistors which have a positive TC over a certain range of values, and a negative TC over a different range of values.

Stability of metal oxide film resistors is better than 0.5% which is better than composition or carbon film resistors but not quite as good as metal film resistors. However, this is better than most commercial grade wirewound resistors. With a stability of the order quoted, metal oxide film resistors are available in tolerances of ± 1%, ± 2%, and ± 5%.

The general characteristics of metal oxide resistors are similar to deposited-carbon film and metal film resistors.

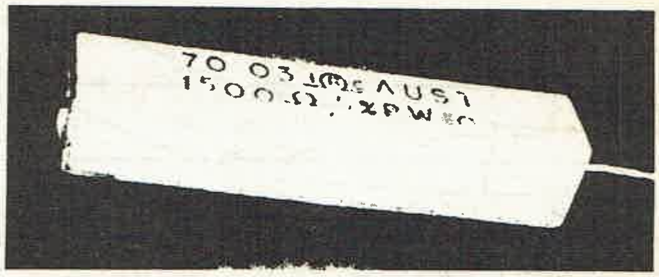


Fig.10. Square section, 'ceramic boat' style medium power film.

Wirewound Resistors

These resistors are made by winding a length of resistance wire on a bobbin (usually of ceramic or fibreglass), the ends being anchored to terminations on the ends of the bobbin. Bobbins are usually cylindrical-shaped or flat. The bobbin and element are generally encapsulated in an impervious coat of vitreous enamel – some styles have the whole bobbin encapsulated in a square ceramic boat, having either axial or radial leads. These are generally the lower power types, up to 20 W.

There are two general types of coating applied to wirewound resistors. One is called Pyrosil D-Coat and consists of a combination of silicone resins and refactory material (which prevents oxidation) of the wire element) and is designed for high temperature operation. It is capable of withstanding temperatures corresponding to five times rated load. The other encapsulation material is known as Tropical C-Coat, another silicone compound and is designed to protect the element under extreme environmental conditions (particularly humidity). The power rating is different for similar resistors coated with different coatings. Resistors coated with tropical C-Coat can only operate at half the power of similar resistors encapsulated with Pyrosil D-Coat.

Terminations for wirewound resistors come in a wide variety of styles. The smaller, low power, types (particularly the completely encapsulated types, often have radial or axial leads and sometimes terminal lugs. High power types may have ferrules on each end – and are plugged into large clips; alternatively they may have terminal lugs, Edison screw threads or flying leads.

The resistance element usually consists of nickel – chromium alloy wire (nichrome). Precision wirewound resistors are usually wound with Eureka wire.

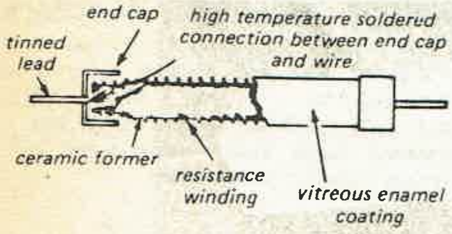


Fig.11. Typical construction of small, cylindrical style wirewound resistor.

Very high power types and some very low resistance types are sometimes wound with flat-tape element instead of wire. It is usually wound edge-on to the bobbin to improve heat dissipation from the element.

Wirewound resistors are made in wattage ratings to 250 W, commonly, and up to 1 kW or more for special applications. There are three basic construction styles: cylindrical, flat and encapsulated ceramic-boat style. The first two are also available as adjustable resistors, having portion of the element exposed and a moveable terminal in contact with it.

Temperature

Wirewound resistors can have excellent temperature characteristics — as low as 5 ppm/°C, but generally less than 200 ppm/°C for the common types.

These resistors exhibit good stability, usually better than 2%, precision types having stabilities better than 0.05%. Common types are available in tolerances of ±5% and ±10% depending on construction style. Tolerance down to 1% can be obtained in precision types.

The noise level and voltage coefficient of wirewound resistors is negligible.

Owing to their construction, wirewound resistors are quite inductive and are generally only useful at low frequencies. Their inherent inductance can be decreased with special winding techniques — occasionally found in precision resistors, but as most wirewound resistors are predominantly used in dc and/or low-frequency circuits where their high power rating is required, this does not present much of a problem.

Mounting & Surrounding

Care must be taken in the mounting of wirewound resistors to prevent the high operating temperature affecting surrounding components. The cylindrical types usually have a hole through the middle through which heat may escape by convection. Mounting these vertically where possible is recommended to keep their operating temperature down. The flat style are mounted using formed 'leaves' which fit into the ends of the former (see Figure 12) — which is hollow, these conducting heat away through the mounting bolts. They are designed for either vertical or horizontal mounting, either singly or in stacks. This style is most suited to applications requiring a high power resistor to be mounted in a limited space.

It is a wise precaution with the axial or radial-lead types to mount them so that they are clear of any other components, chassis, pc board, etc by at least their diameter or width, to provide sufficient ventilation and to prevent damage to other components.

Failure

Wirewound resistors fail occasionally. This may be due to one of the following reasons. In high value types, the resistance wire is very thin. The slightest blemish creates a weak point which may eventually cause the wire to break. In the coated types, expansion differences between the ceramic bobbin and the enamel coating may cause cracking of either the coating or the bobbin allowing moisture to penetrate and attack the resistance wire. The wire may corrode under constant dc load conditions due to chemical action in the enamel coating of the component. This latter problem is rare.

Precision wirewound resistors are wound on special bobbins, generally using Manganin wire, and encapsulated or covered in an insulating coating. They are sometimes epoxy-moulded. Other styles are hermetically sealed in a ceramic container. Wire leads or solder lugs are used as terminations. Precision wirewound resistors are not generally designed to dissipate power. Power types are available however, generally consisting of a conventionally constructed wirewound resistor wound to a tight tolerance or selected, and mounted in an extruded aluminium case. This assists heatsinking, allowing precision resistors to be rated up to powers of 200 W.

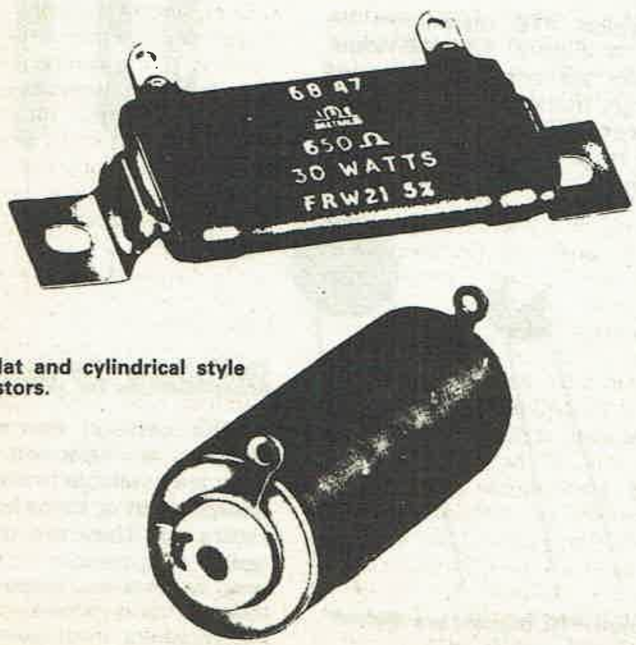


Fig.12. Typical flat and cylindrical style wirewound resistors.

Cermet Resistors

These resistors are made by fusing a suspension of metal and glass particles to a ceramic rod at temperatures between 750C and 930C. This forms a thick resistive film, fused with the surface of the ceramic former, resulting in a resistance element that is virtually impervious to environmental extremes of moisture, temperature, shock and vibration.

The fusion of the metal resistive material and the ceramic rod gives rise to the common name 'CERMET' resistor.

The construction of cermet resistors is generally the same as for film resistors: the desired resistance is obtained by spiralling the resistive element. Owing to the high firing temperatures, these resistors may be rated for higher temperatures and loads than similar sized film resistors. Conduction of heat away from the resistance element is superior, owing to the better thermal contact possible between the resistance element on the rod and the metal end-caps. Body temperature rise is lower than for comparably-sized resistors of other types having similar ratings. As a result of these characteristics, cermet resistors are generally smaller than other resistors of the same rating.

The temperature coefficient of cermet resistors is generally comparable with most metal-film and metal-oxide resistors, common types having a TC of ± 100 ppm/°C. Some types exhibit a TC of +50 ppm/°C and may be as low as ±25 ppm/°C. This characteristic shows little variation with the value of the resistor.

Noise level for these resistors is generally higher than for other types; typically ranging from 0.4 μV/V to 1.0 μV/V, which is worse than other types but far below the level of carbon composition resistors. This level of noise is rarely a problem.

The voltage coefficient is generally better than 100 ppm/V, similar to most other film resistors and is not a consideration in the majority of applications. Generally, the voltage coefficient is only a consideration with carbon composition resistors.

As the construction of cermet resistors is similar to the other types of film resistors they have similar frequency characteristics. Values below 10k show little variation in value well into the UHF region.

Cermet resistors have excellent stability owing to body temperature being low for the amount of power dissipated. Figures of 0.5 – 1.0% are common. Generally, cermet resistors are manufactured in standard tolerances of ± 2% and ± 5%. Tolerances of ±1% are available on special order.

Cermet resistors are generally available in ratings from 0.1 W to 0.5 W, and some less common types up to 5 W. Cost is comparable to most types of film resistors which makes them very attractive where their small size and high power rating is required or in applications where they are likely to experience moisture and temperature extremes, etc. Trimpots are manufactured having cermet resistance elements to take advantage of the ruggedness and resistance to environmental extremes that this type of element offers.

Thermistors

Thermistors belong to a group of resistors made from semiconductor materials and are thermally sensitive, having a controlled temperature coefficient that may be positive (PTC thermistors) or negative (NTC thermistors).

Thermistors are widely used for temperature measurement and control, temperature stabilisation, current surge suppression, and a wide variety of other applications. They are non-reactive and non-polarised and are therefore suitable for use in either ac or dc circuits.

The resistive element consists of barium titanate in PTC thermistors and various metal oxides in NTC thermistors. The compounds are sintered into special shapes, depending on the required application. They are formed into small elements in a variety of shapes - generally discs, rods, blocks or tubes. They may be encapsulated simply with a varnish or epoxy or inside a glass or metal tube. Some types are not encapsulated at all.

PTC thermistors are available in two basic characteristics. The 'A' characteristic type exhibits linear change of logarithmic resistance values against temperature. The 'B' characteristic exhibits abrupt increase of resistance when the temperature increases above a specified value, showing only small change in resistance below this temperature.

Some typical PTC thermistors are illustrated in Figure 13. Individual characteristics are best obtained from manufacturers' literature.

NTC thermistors are available covering a wide range of values and temperature ranges.

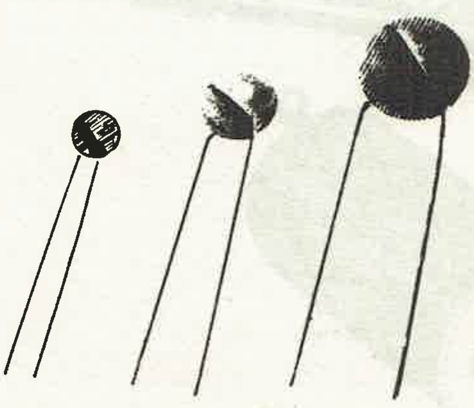


Fig.13. Typical PTC thermistors (actual size).

Voltage Dependent Resistors

These resistors are generally known as 'Varistors' and are another type of semiconductor resistor. They are principally used as voltage surge suppressors, some types being used in voltage stabiliser applications.

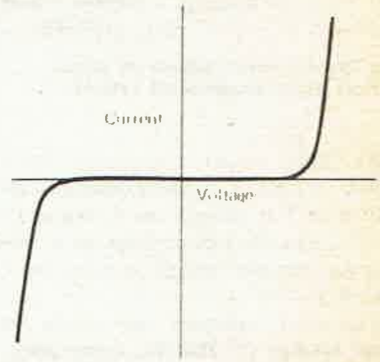


Fig.14. Varistor voltage-current characteristics.

The element generally consists of a sintered ceramic material, the most common types zinc oxide as the main ingredient. Other types employ elements containing titanate ceramic (sometimes known as 'variatite') or silicon carbide (SiC varistors). The common types are often referred to as ZNR varistors from Zinc Oxide Nonlinear Resistor.

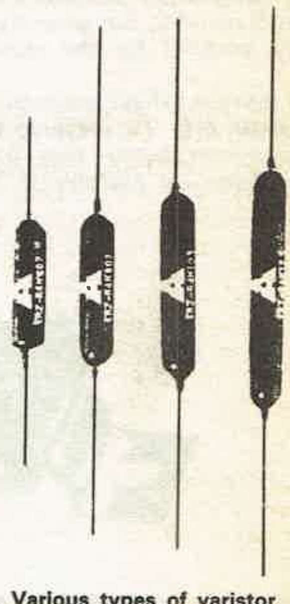


Fig.15. Various types of varistor encapsulations for different applications.

The general characteristics of varistors is illustrated in Figure 14. They are available in a wide variety of encapsulations, some are illustrated in Figure 15. They are often found as 'spike' suppressors in solid state TV sets, as back-emf suppressors across relays, and in rectifier circuits protecting rectifiers from voltage surges.

Resistor Codes

The value and tolerance, and other pertinent characteristics, of resistors may be marked on the body of the component in one of three ways. Viz:

(1) By marking directly on the body.

(2) By using a standard colour code – coloured bands or dots, etc, read in sequence.

(3) By using an appropriate typographic code, consisting of letters and numerals arranged according to a convention.

Which method is used depends on the type and physical size of the component to a large extent and also according to the manufacturer's preference. The larger components, such as power resistors (particularly wire-wound types), usually have the value, tolerance and wattage rating marked directly on the body. Most common low power resistors, from 0.05 W to 2 W, use the standard resistor colour code. Some manufacturers use a typographic code on their resistors, physical size allowing (usually radial-lead types having wattage ratings between 0.25 W and 10 WSThe special resistors (PTC, NTC thermistors and Varistors) also may be marked with a colour code or typographic code to indicate their value and characteristics.

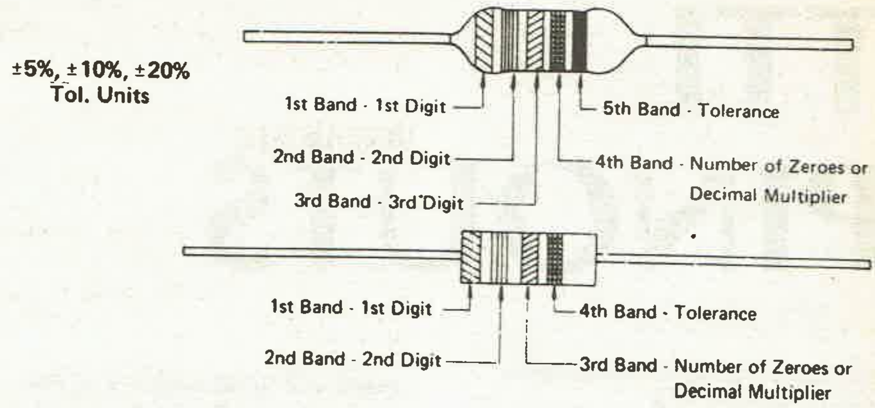


Fig.16. The standard resistor colour code marking.

TABLE 1. STANDARD RESISTOR COLOUR CODE

COLOUR	DIGIT VALUE	MULTIPLIER (No. of zeroes)	TOLERANCE ±%
BLACK	0	1	
BROWN	1	10	1
RED	2	10^2 or 100	2
ORANGE	3	10^3 or 1k	
YELLOW	4	10^4 or 10k	
GREEN	5	10^5 or 100k	
BLUE	6	10^6 or 1M	
VIOLET	7	10^7 or 10M	
GREY	8	10^8 or 100M	
WHITE	9	10^9 or 1000M	
GOLD	–	0.1 or 10^{-1}	5
SILVER	–	0.01 or 10^{-2}	10
none	–	– – – – – –	20

* High Stability (grade 1) resistors are distinguished by a salmon-pink fifth ring or body colour.

The Standard Colour Code

The common axial-lead, composition and film-type resistors are marked with a series of coloured bands, as shown in Figure 16, which are read according to the standard colour code table in Table 1. The standard E24 (5%), E12 (10%) and E6 (20%) series components are marked with either three or four bands. Components below 10 ohms in the E6 series may have only two bands indicating the value. Resistor values in the E48 (2%) and E96 (1%) series are marked with five bands.

The bands are located on the component towards one end. If the resistor is oriented with that end towards the left, the bands are read from left to right as shown. The extreme left (or first) band colour indicates the value of the first digit of the component value; the next, or second, band indicates the second digit of the value and so on. If the bands are not clearly oriented towards one end of the resistor it is best sorted out by trying to locate the tolerance band first. As the most commonly used resistors these days are either E12 or E24 series, the tolerance band is either silver or gold respectively. If still in doubt – resort to an ohmmeter.

The body colour of modern resistors is also used to indicate the resistor type. Carbon film resistors have a very light tan body, and carbon composition resistors have a medium tan body – somewhat darker than the carbon film body colour. Metal film resistors have a brown body colour – quite distinguishable from composition resistors and metal-glazed film resistors have a light blue body colour.

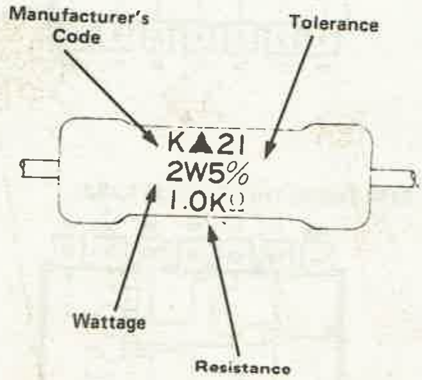
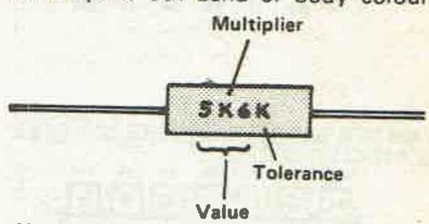


Fig.17. Resistor with characteristics and value marked directly on the body.

High stability resistors (E48, E96, E192 series) are distinguished by salmon-pink 5th band or body colour.



MULTIPLIER		TOLERANCE
R = x1		F = ±1%
K = x1000		G = ±2%
M = x1 000 000		J = ±5%
		K = ±10%
		M = ±20%

**Position of the multiplier indicates the position of the decimal point in the value.*

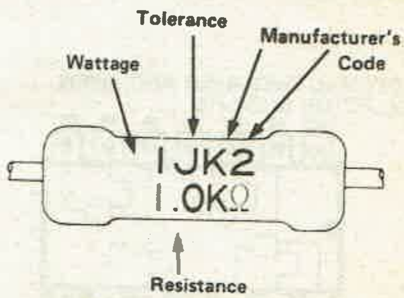
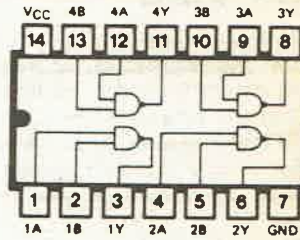


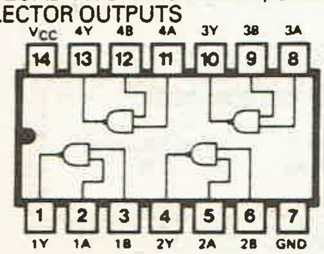
Fig.18. Typographic codes used on resistors.

TTL PINOUTS

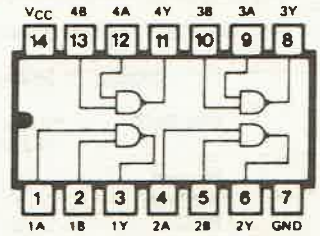
7400 QUAD TWO-INPUT NAND



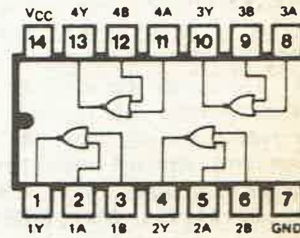
7401 QUAD TWO-INPUT NAND, OPEN COLLECTOR OUTPUTS



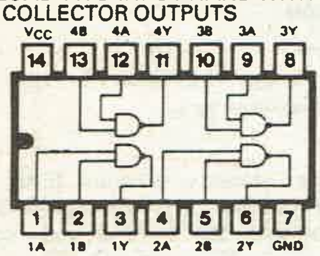
74H01 HIGH SPEED VERSION OF 7401



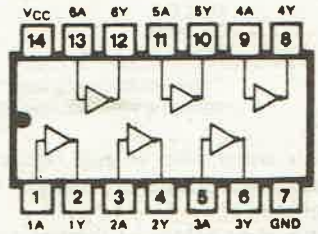
7402 QUAD TWO-INPUT NOR



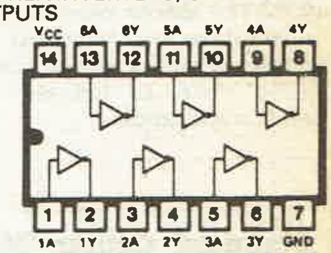
7403 QUAD TWO-INPUT NAND WITH OPEN COLLECTOR OUTPUTS



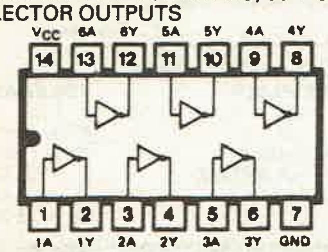
7404 HEX INVERTERS



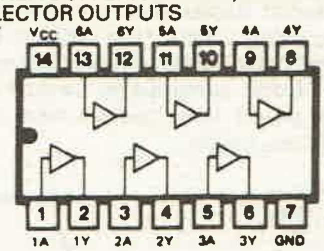
7405 HEX INVERTERS, OPEN COLLECTOR OUTPUTS



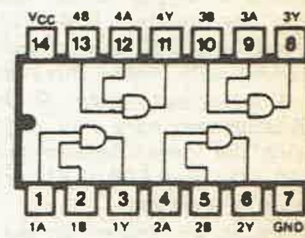
7406 HEX INVERTER/DRIVERS, 30 V OPEN COLLECTOR OUTPUTS



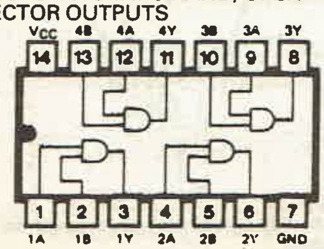
7407 HEX BUFFER/DRIVERS, 30 V OPEN COLLECTOR OUTPUTS



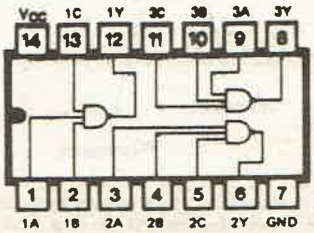
7408 QUAD TWO-INPUT AND



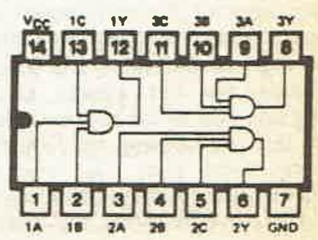
7409 QUAD TWO-INPUT AND, OPEN COLLECTOR OUTPUTS



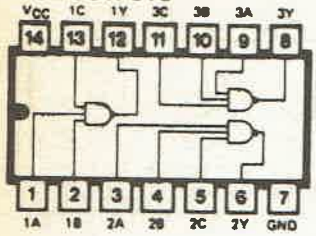
7410 TRIPLE THREE-INPUT NAND



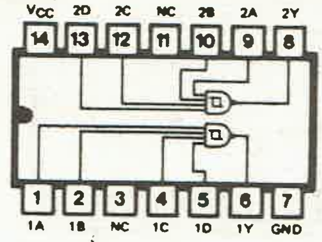
7411 TRIPLE THREE-INPUT AND



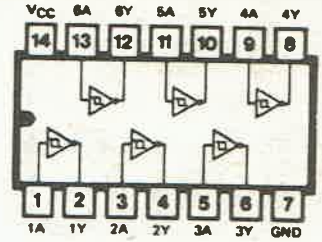
7412 TRIPLE THREE-INPUT NAND, OPEN COLLECTOR OUTPUTS



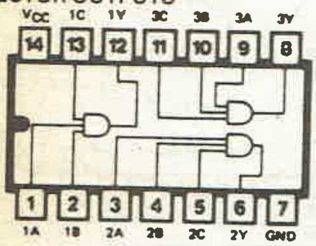
7413 DUAL FOUR-INPUT NAND SCHMITT TRIGGERS



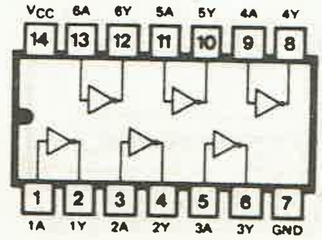
7414 HEX SCHMITT TRIGGER INVERTERS



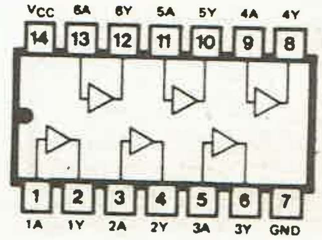
7415 TRIPLE THREE-INPUT AND, OPEN COLLECTOR OUTPUTS



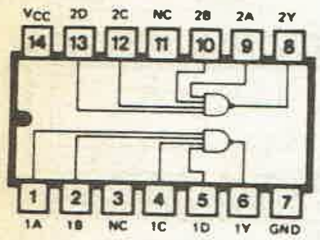
7416 HEX INVERTERS, 15 V OPEN COLLECTOR OUTPUTS



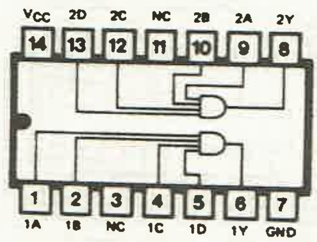
7417 HEX BUFFERS, 15 V OPEN COLLECTOR OUTPUTS



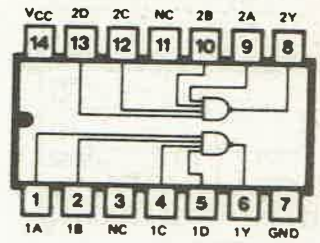
7420 DUAL FOUR-INPUT NAND



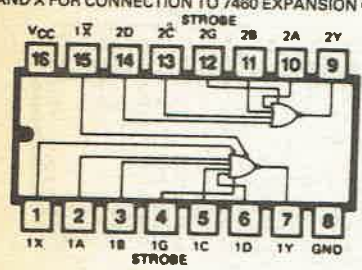
7421 DUAL FOUR-INPUT AND



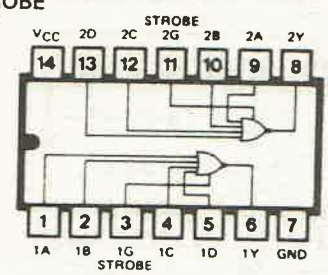
7422 DUAL FOUR-INPUT NAND, OPEN COLLECTOR OUTPUTS



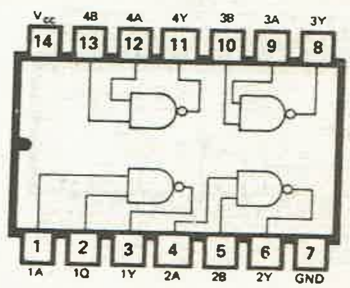
7423 EXPANDABLE DUAL FOUR-INPUT NOR WITH STROBE
X AND X̄ FOR CONNECTION TO 7460 EXPANSION GATE



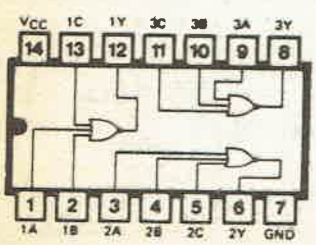
7425 DUAL FOUR-INPUT NOR WITH STROBE



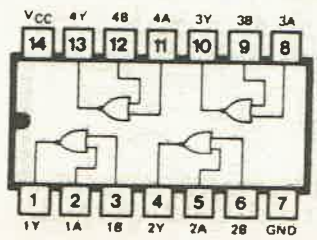
7426 QUAD TWO-INPUT NAND, 15 V OPEN COLLECTOR OUTPUTS



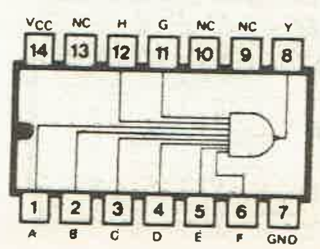
7427 TRIPLE THREE-INPUT NOR



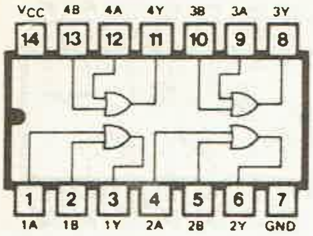
7428 QUAD TWO-INPUT NOR/BUFFERS



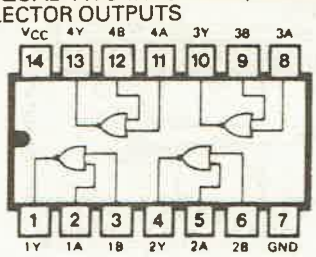
7430 EIGHT-INPUT NAND



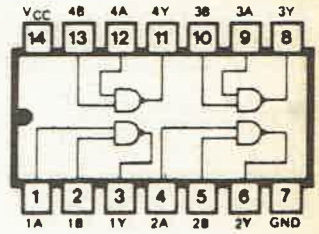
7432 QUAD TWO-INPUT OR



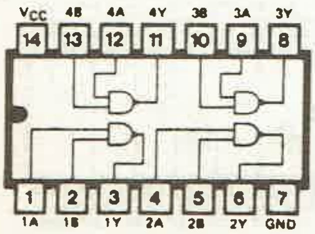
7433 QUAD TWO-INPUT NOR, OPEN COLLECTOR OUTPUTS



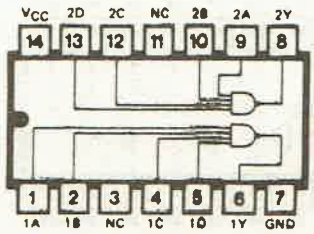
7437 QUAD TWO-INPUT NAND BUFFERS



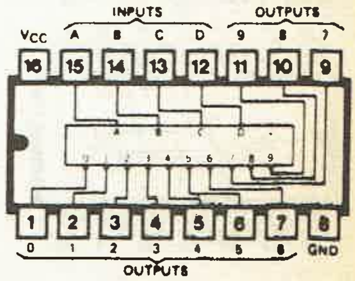
7438 QUAD TWO-INPUT NAND/BUFFER, OPEN COLLECTOR OUTPUTS



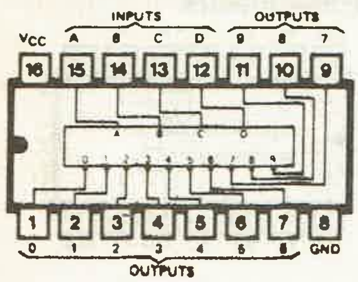
7440 DUAL FOUR-INPUT NAND/BUFFER



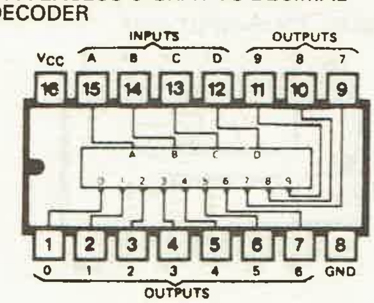
7442 BCD TO DECIMAL DECODER



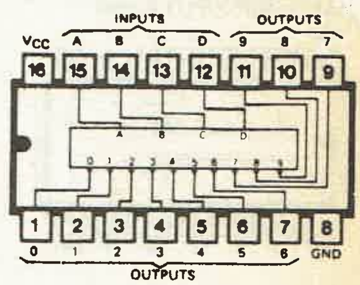
7443 EXCESS-3 TO DECIMAL DECODER



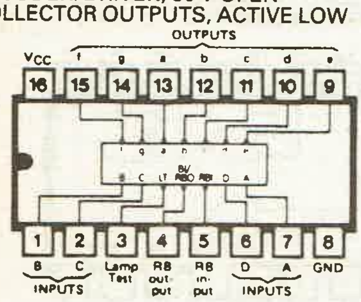
7444 EXCESS-3-GRAY TO DECIMAL DECODER



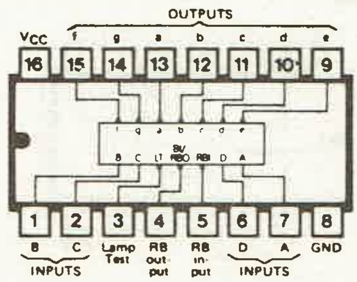
7445 BCD TO DECIMAL DECODER/DRIVER



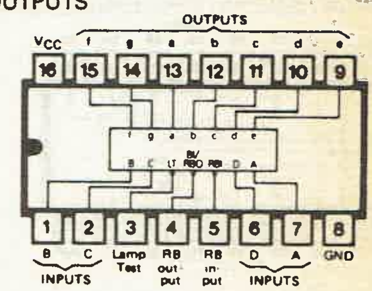
7446 BCD TO SEVEN-SEGMENT DECODER/DRIVER, 30 V OPEN COLLECTOR OUTPUTS, ACTIVE LOW



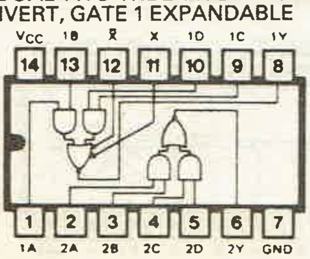
7447 AS 7446, BUT 15 V OUTPUTS



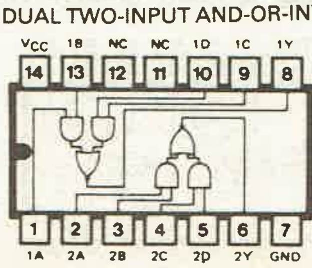
7448 AS 7446, BUT INTERNAL PULL-UP OUTPUTS



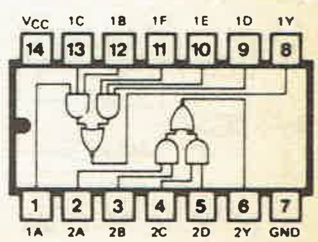
7450 DUAL TWO-WIDE TWO-INPUT AND-OR-INVERT, GATE 1 EXPANDABLE



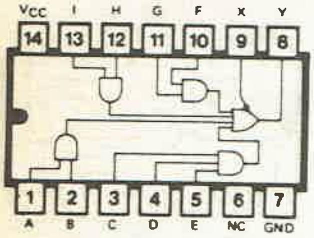
7451 DUAL TWO-INPUT AND-OR-INVERT



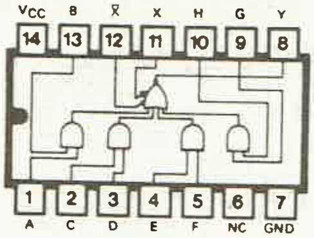
74S51/74LS51 S/LS VERSION OF 7451



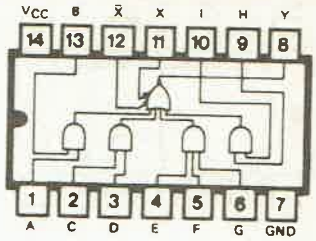
7452 EXPANDABLE FOUR-WIDE AND-OR



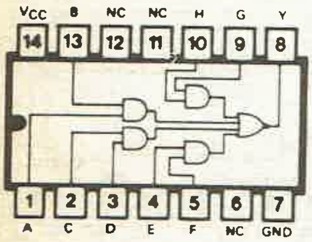
7453 EXPANDABLE FOUR-WIDE AND-OR-INVERT



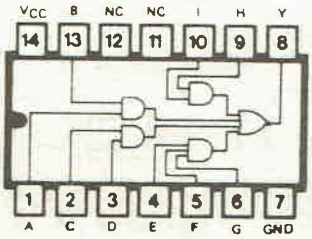
74H53 HIGH-SPEED VERSION OF 7453



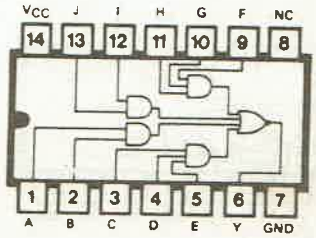
7454 FOUR-WIDE AND-OR-INVERT



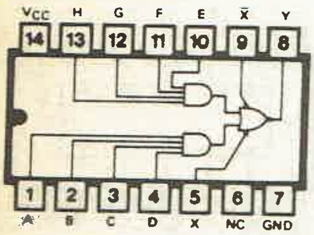
74H54 H VERSION OF 7454



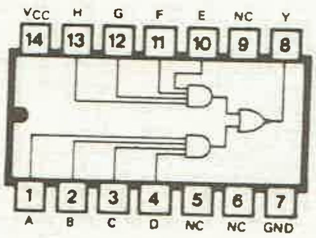
74LS54/74L54 LS AND L VERSIONS OF 7454



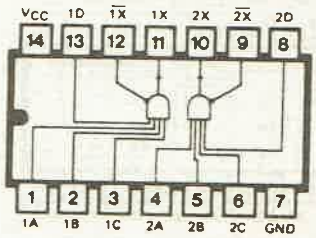
74H55 EXPANDABLE TWO-WIDE FOUR-INPUT AND-OR-INVERT



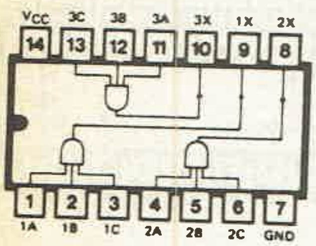
74LS55/74L55 LS AND L VERSIONS OF 74H55



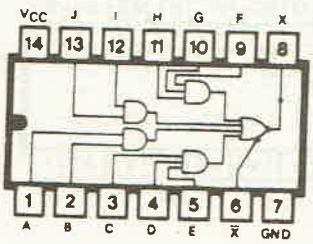
7460 DUAL FOUR-INPUT EXPANDER



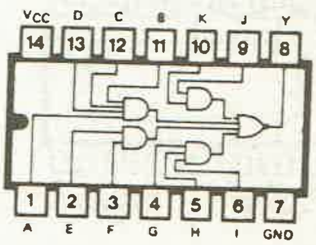
7461 TRIPLE THREE-INPUT EXPANDER



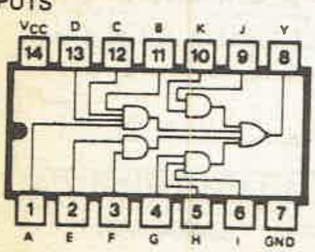
7462 FOUR-WIDE AND-OR EXPANDER



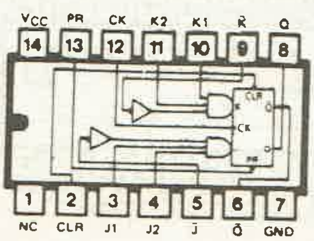
7464 4-2-4-3 INPUT AND-OR-INVERT



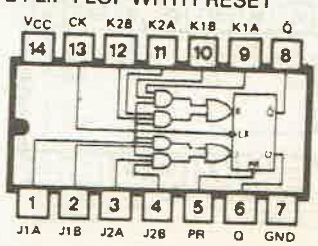
7465 AS 7464 WITH OPEN COLLECTOR OUTPUTS



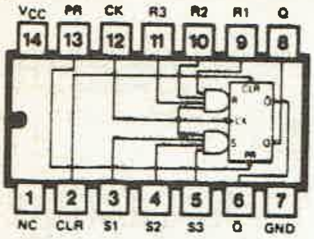
7470 AND-GATED J-K POSITIVE EDGE-TRIGGERED FLIP-FLOP WITH PRESET AND CLEAR



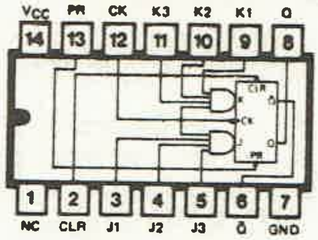
74H71 AND-OR-GATED J-K MASTER-SLAVE FLIP-FLOP WITH PRESET



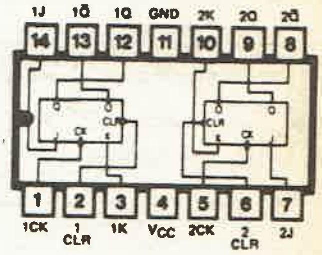
74L71 AND GATED R-S MASTER-SLAVE FLIP-FLOP WITH PRESET AND CLEAR



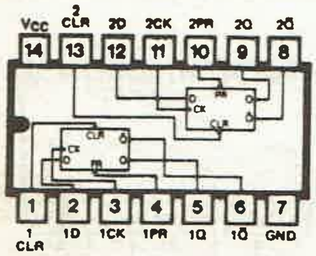
7472 AND-GATED J-K MASTER-SLAVE FLIP-FLOP WITH PRESET AND CLEAR



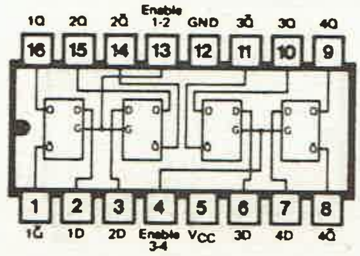
7473 DUAL J-K FLIP-FLOP WITH CLEAR



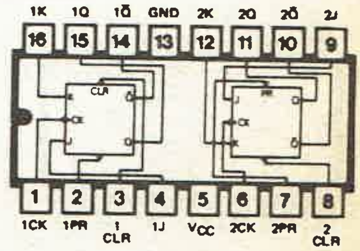
7474 DUAL D-TYPE POSITIVE EDGE TRIGGERED FLIP-FLOP WITH PRESET AND CLEAR



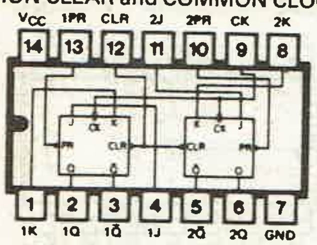
7475 FOUR-BIT BISTABLE LATCHES



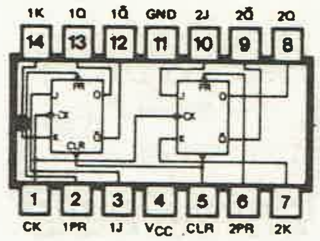
7476 DUAL J-K FLIP-FLOP WITH PRESET AND CLEAR



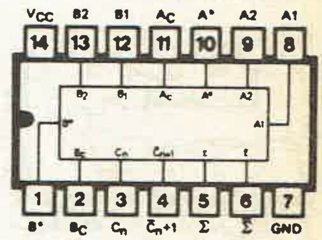
7478 DUAL J-K FLIP-FLOP WITH PRESET, COMMON CLEAR and COMMON CLOCK



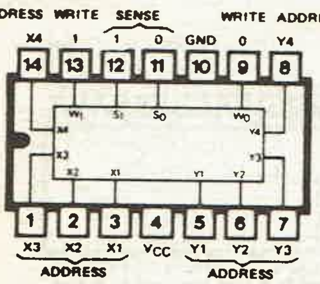
74LS78 LS VERSION OF 7478



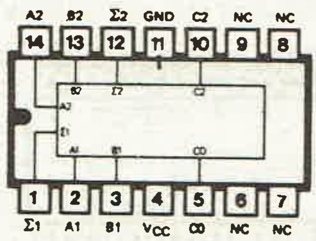
7480 GATED FULL ADDER



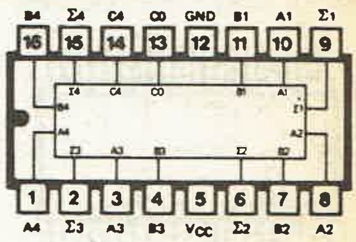
7481 16-BIT RAM



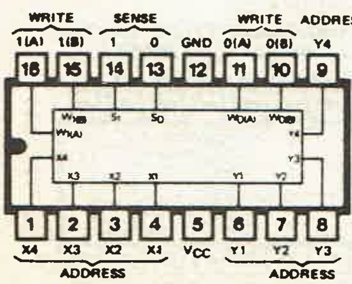
7482 TWO-BIT BINARY FULL ADDER



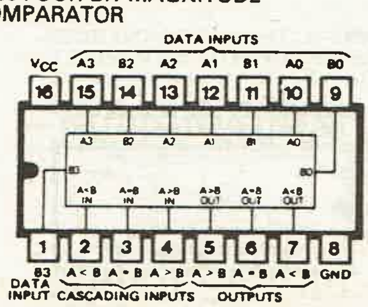
7483 FOUR-BIT BINARY FULL ADDER WITH FAST CARRY



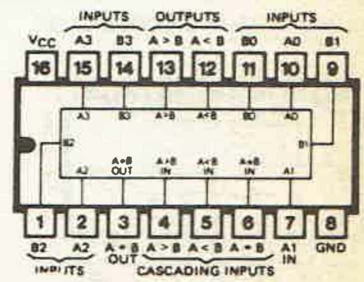
7484 16-BIT RAM



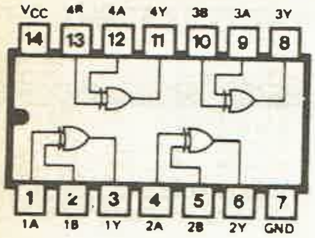
7485 FOUR-BIT MAGNITUDE COMPARATOR



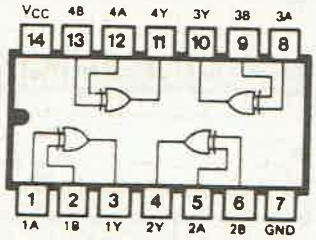
74L85 L VERSION of 7485



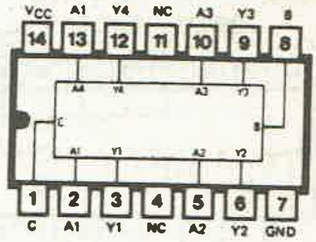
7486 QUAD TWO-INPUT EXCLUSIVE-OR



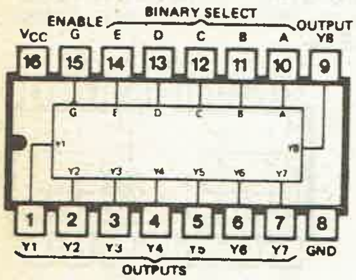
74L86 L VERSION OF 7486



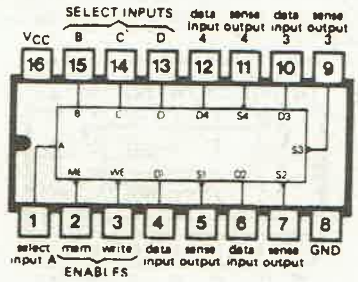
7487 FOUR-BIT TRUE/COMPLEMENT, ZERO/ONE



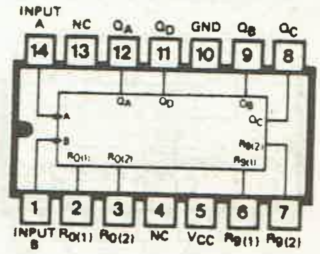
7488 256-BIT ROM (32 BY 8-BIT)



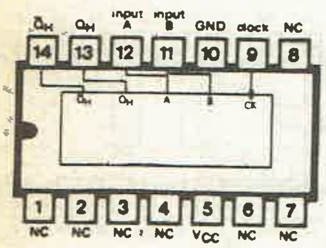
7489 64-BIT RAM (16 BY 4-BIT)



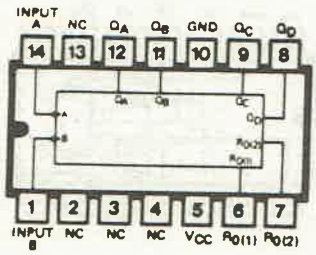
7490 DECADE COUNTER



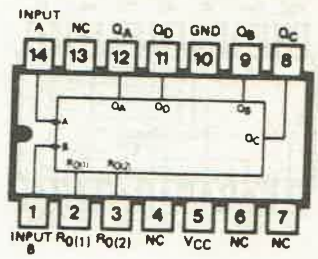
7491 EIGHT-BIT SHIFT REGISTER



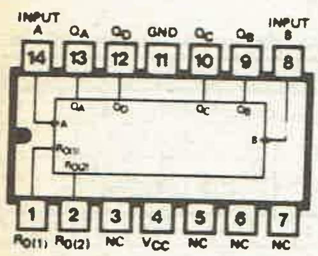
7492 DIVIDE-BY-12 COUNTER



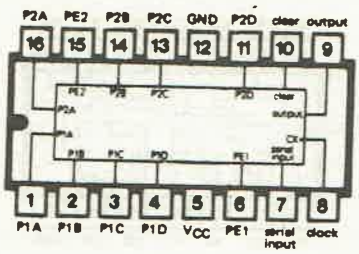
7493 FOUR-BIT BINARY COUNTERS



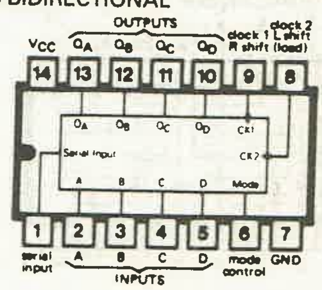
74L93 L VERSION OF 7493



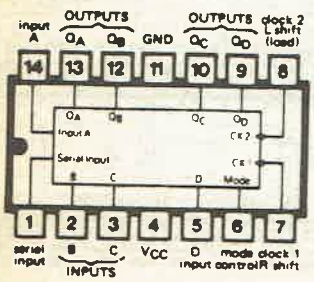
7494 FOUR-BIT SHIFT REGISTER



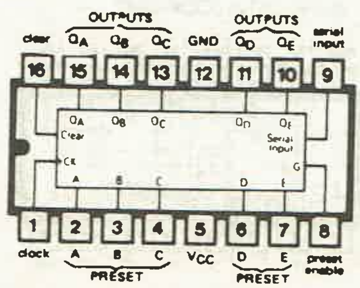
7495 FOUR-BIT SHIFT REGISTER, PIPO AND BIDIRECTIONAL



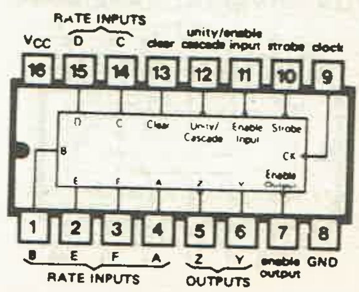
74L95 L VERSION OF 7495



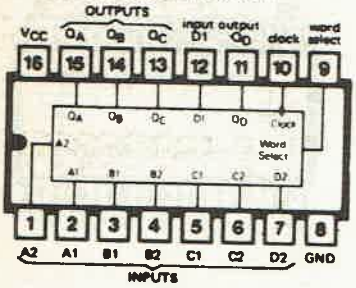
7496 FIVE-BIT SHIFT REGISTER, ASYNC PRESET



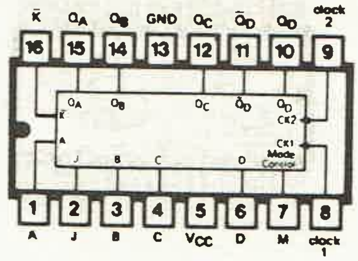
7497 SYNCHRONOUS SIX-BIT BINARY RATE MULTIPLIER



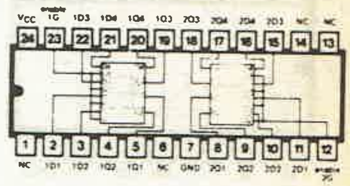
74L98 FOUR-BIT DATA SELECTOR/STORAGE REGISTER



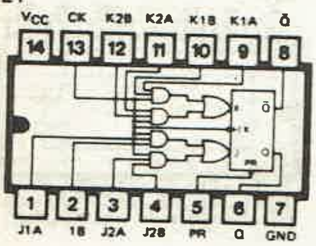
74L99 FOUR-BIT BIDIRECTIONAL UNIVERSAL SHIFT REGISTER, SERIAL J-K INPUTS



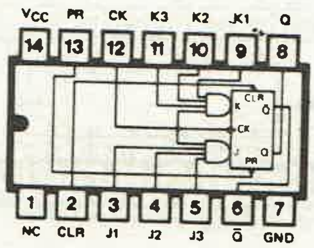
74100 EIGHT-BIT BISTABLE LATCHES



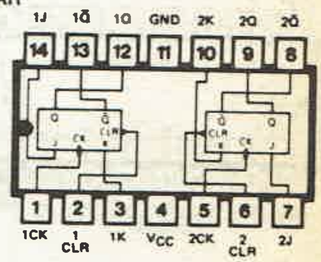
74H101 AND-OR-GATED J-K NEGATIVE EDGE TRIGGERED FLIP-FLOP WITH PRESET



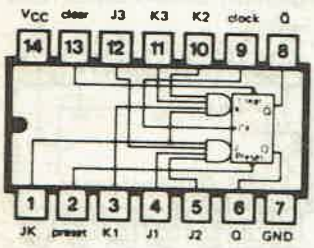
74H102 AND-GATED NEGATIVE EDGE TRIGGERED FLIP-FLOP WITH PRESET AND CLEAR



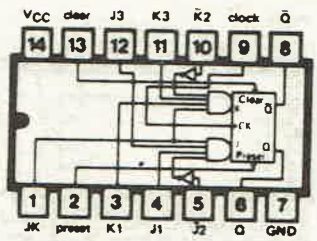
74H103 DUAL J-K NEGATIVE EDGE TRIGGERED FLIP-FLOP WITH PRESET AND CLEAR



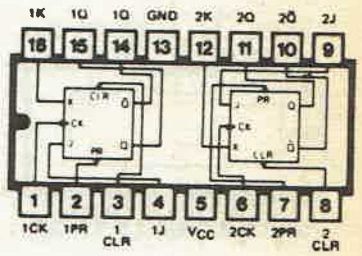
74104 GATED J-K FLIP-FLOP



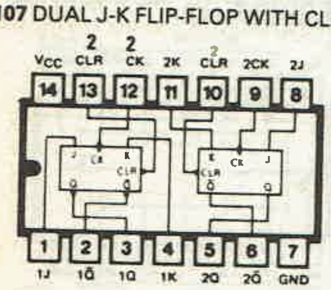
74105 GATED J-K FLIP-FLOP



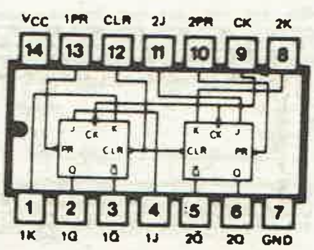
74H106 DUAL J-K EDGE TRIGGERED FLIP FLOP WITH PRESET AND CLEAR



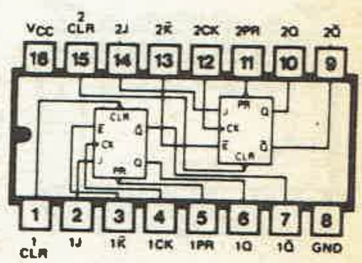
74107 DUAL J-K FLIP-FLOP WITH CLEAR



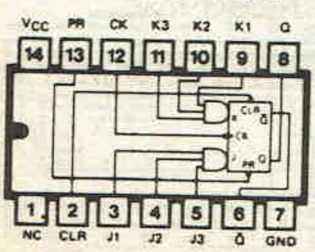
74108 DUAL J-K NEGATIVE EDGE TRIGGERED FLIP-FLOP WITH PRESET, COMMON CLEAR, AND COMMON CLOCK



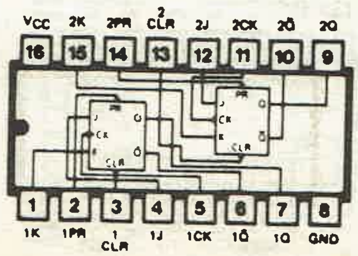
74109 DUAL J-K POSITIVE EDGE TRIGGERED FLIP-FLOP WITH PRESET AND CLEAR



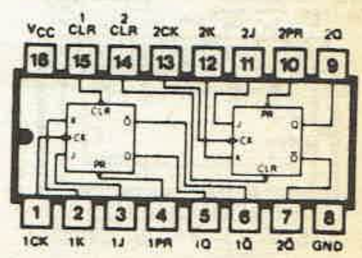
74110 AND-GATED J-K MASTER-SLAVE FLIP-FLOP WITH DATA LOCK-OUT



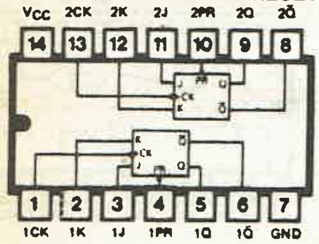
74111 DUAL J-K MASTER-SLAVE FLIP-FLOP WITH DATA LOCK-OUT



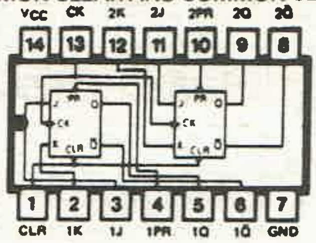
74112 DUAL J-K NEGATIVE EDGE TRIGGERED FLIP-FLOP WITH PRESET AND CLEAR



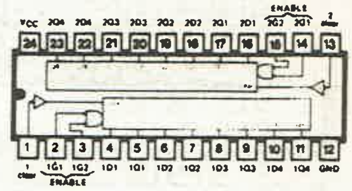
74113 DUAL J-K NEGATIVE EDGE TRIGGERED FLIP-FLOP WITH PRESET



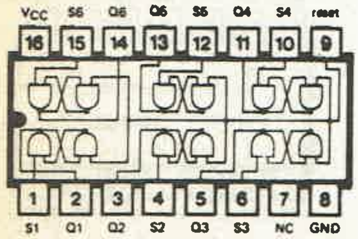
74114 DUAL J-K NEGATIVE EDGE TRIGGERED FLIP-FLOP WITH PRESET COMMON CLEAR AND COMMON CLOCK



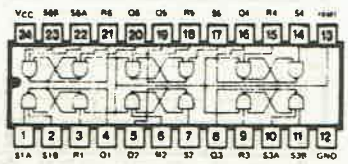
74116 DUAL FOUR-BIT LATCHES



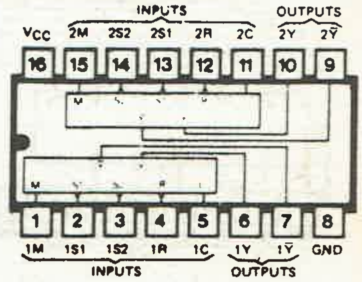
74118 HEX SET-RESET LATCHES



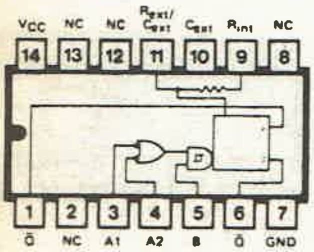
74119 HEX SET-RESET LATCHES



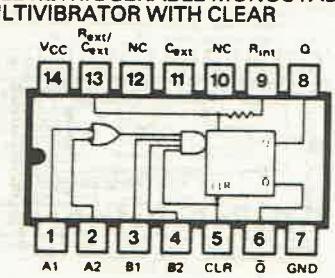
74120 DUAL PULSE SYNCHRONIZERS/DRIVERS



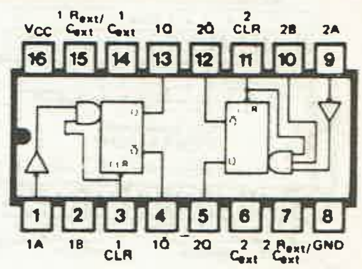
74121 MONOSTABLE MULTIVIBRATOR



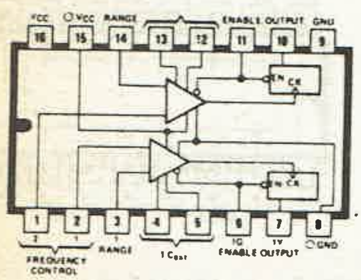
74122 RETRIGGERABLE MONOSTABLE MULTIVIBRATOR WITH CLEAR



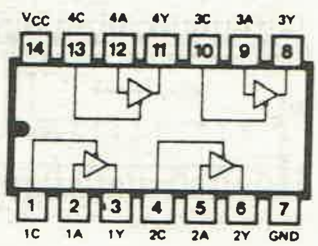
74123 DUAL RETRIGGERABLE MONOSTABLE WITH CLEAR



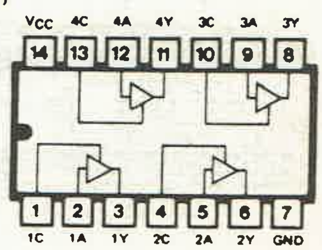
74124 DUAL VCO



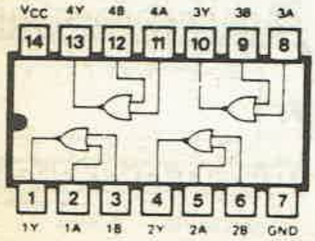
74125 QUAD BUS BUFFER WITH TRI-STATE OUTPUTS (DISABLED WHEN C IS HIGH)



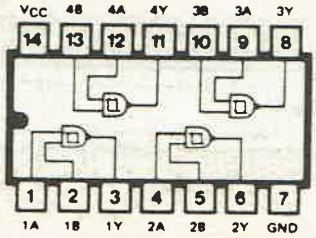
74126 QUAD BUS BUFFER WITH TRI-STATE OUTPUTS (DISABLED WHEN C IS LOW)



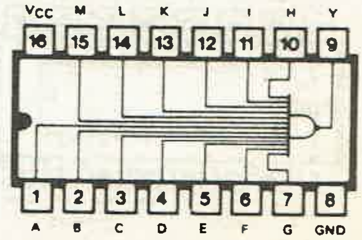
74128 QUAD TWO-INPUT NOR LINE DRIVERS, 50 OHM



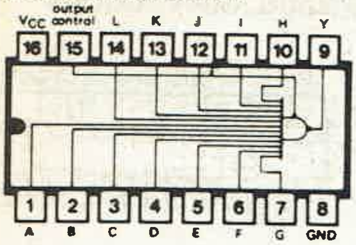
74132 QUAD TWO-INPUT NAND SCHMITT TRIGGERS



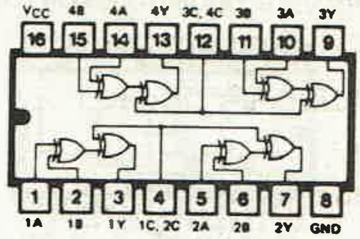
74133 13-INPUT NAND



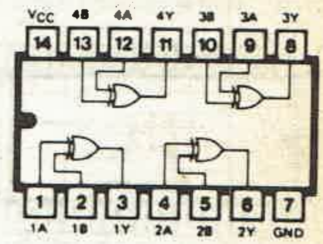
74134 12-INPUT NAND WITH TRI-STATE OUTPUT, OUTPUT IS DISABLED WHEN OUTPUT CONTROL IS HIGH



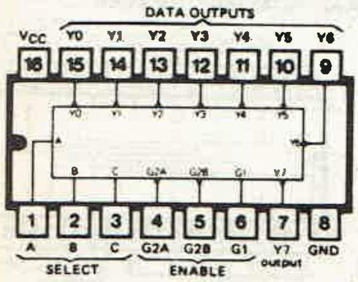
74135 QUAD EXCLUSIVE-OR/NOR (NOTE THAT SOME INPUTS ARE COMMON)



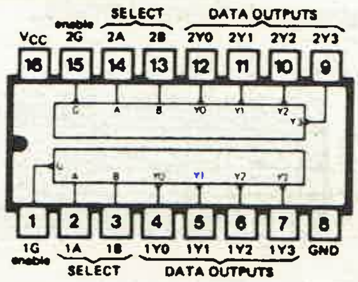
74136 QUAD EXCLUSIVE-OR



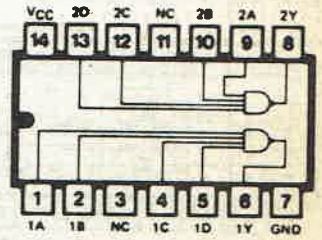
74138 THREE-TO-EIGHT-LINE DECODER/MULTIPLEXER



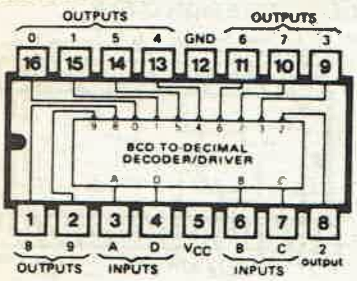
74139 DUAL TWO-TO-FOUR-LINE DECODER/MULTIPLEXER



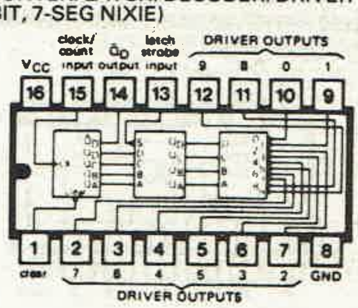
74140 DUAL FOUR-INPUT NAND LINE DRIVER, 50 OHM



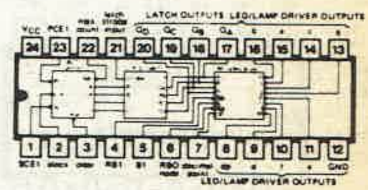
74141 BCD TO DECIMAL DECODER/DRIVER



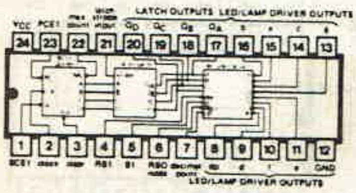
74142 COUNTER/LATCH/DECODER/DRIVER (÷10, 4-BIT, 7-SEG NIXIE)



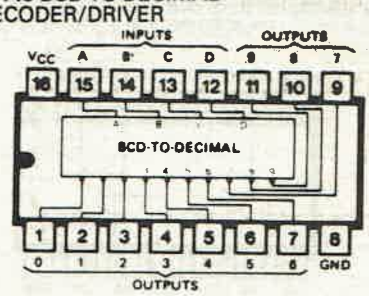
74143 COUNTER/LATCH/DECODER/DRIVER (15 mA CONSTANT CURRENT 1 TO 5 V OUTPUT RANGE)



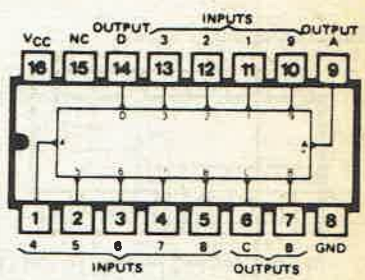
74144 COUNTER/LATCH/DECODER/DRIVER (15 V 25 mA OPEN COLLECTOR OUTPUTS)



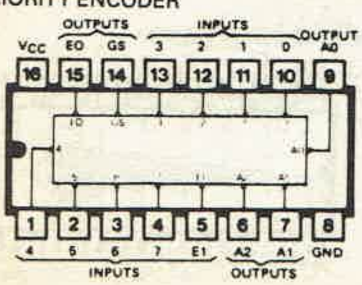
74145 BCD TO DECIMAL DECODER/DRIVER



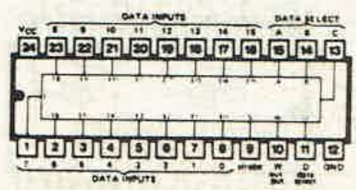
74147 10-LINE DECIMAL TO BCD PRIORITY ENCODER



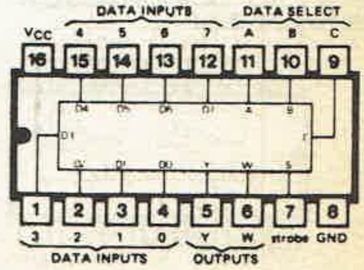
74148 EIGHT-LINE TO THREE-LINE OCTAL PRIORITY ENCODER



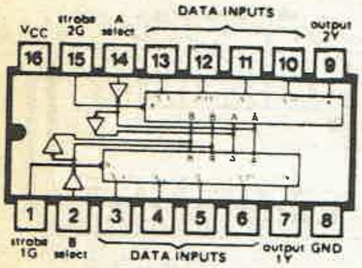
74150 ONE-OF-16 DATA SELECTOR/MULTIPLEXER



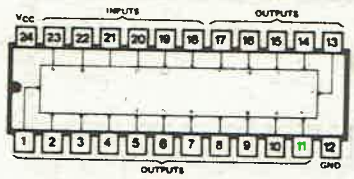
74151 ONE-OF-EIGHT DATA SELECTOR/MULTIPLEXER



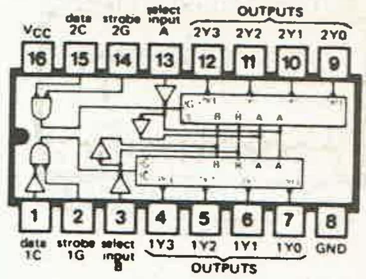
74153 DUAL ONE-OF-FOUR DATA SELECTOR/MULTIPLEXER



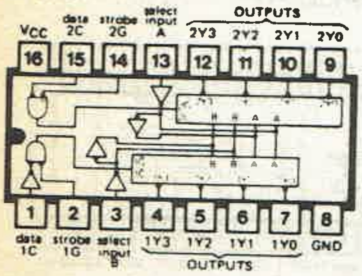
74154 FOUR-LINE TO 16-LINE DECODER/DEMULTIPLEXER



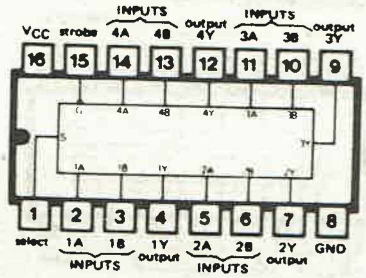
74155 DUAL TWO-TO-FOUR-LINE DECODER/DUAL ONE-TO-FOUR-LINE DEMULTIPLEXER/THREE-TO-EIGHT-LINE DECODER/ONE-TO-EIGHT-LINE DEMULTIPLEXER



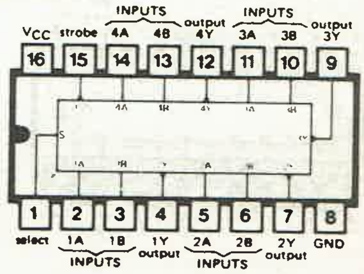
74156 AS 74155 WITH OPEN COLLECTOR OUTPUTS



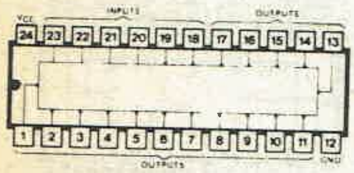
74157 QUAD TWO-TO-ONE LINE DATA SELECTORS/MULTIPLEXERS



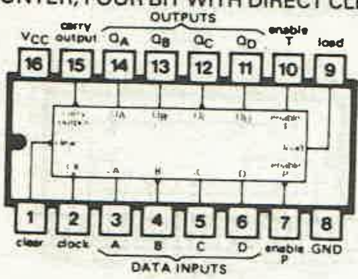
74158 AS 74157 WITH INVERTED OUTPUTS



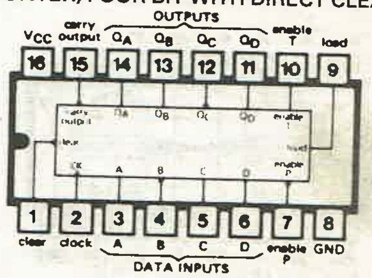
74159 FOUR-TO-16-LINE DECODER/DEMULTIPLEXER, OPEN COLLECTOR OUTPUTS



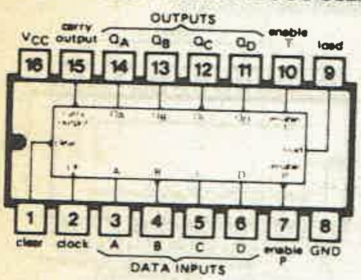
74160 SYNCHRONOUS DECADE COUNTER, FOUR BIT WITH DIRECT CLEAR



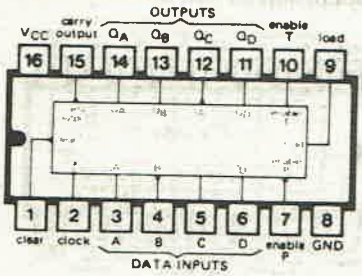
74161 SYNCHRONOUS BINARY COUNTER, FOUR BIT WITH DIRECT CLEAR



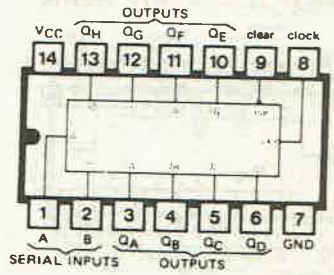
74162 SYNCHRONOUS DECADE CUNTER, FOUR BIT WITH SYNCHRONEOUS CLEAR



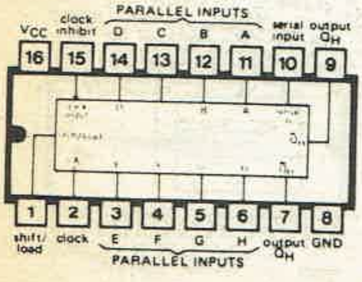
74163 SYNCHRONOUS BINARY COUNTER, FOUR BIT WITH SYNCHRONEOUS CLEAR



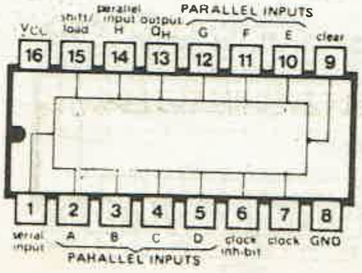
74164 EIGHT-BIT PARALLEL OUT SERIAL SHIFT REGISTER ASYNC. CLEAR



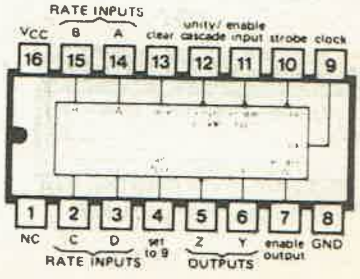
74165 PARALLEL LOAD EIGHT-BIT SHIFT REGISTER WITH COMPLEMENTARY OUTPUTS



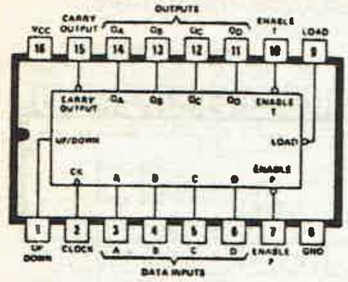
74166 EIGHT-BIT SHIFT REGISTER, SERIAL/PARALLEL INPUT, SERIAL OUTPUT



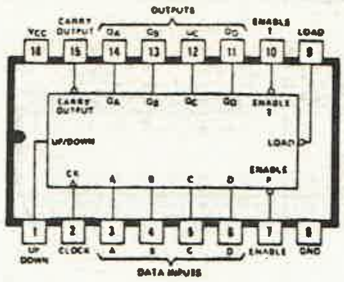
74167 SYNCHRONOUS DECADE RATE MULTIPLIER



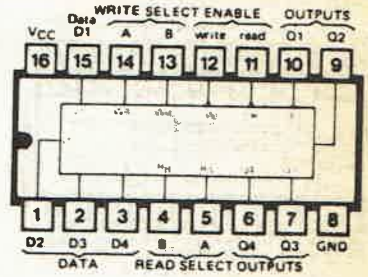
74168 DECADE FOUR-BIT UP-DOWN COUNTER, SYNCHRONOUS



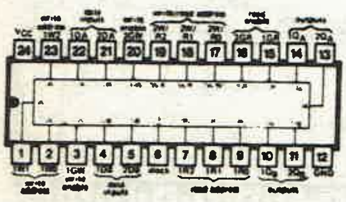
74169 BINARY FOUR-BIT UP-DOWN COUNTER, SYNCHRONOUS



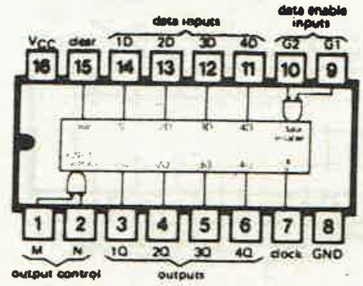
74170 FOUR-BY-FOUR REGISTER FILE



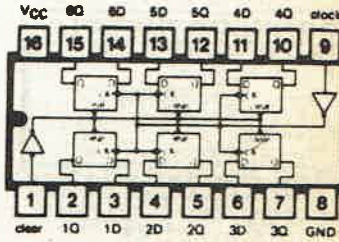
74172 16-BIT REGISTER FILE



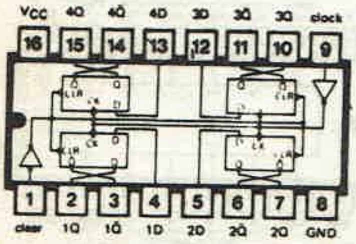
74173 FOUR-BIT D-TYPE REGISTER, TRI-STATE OUTPUTS



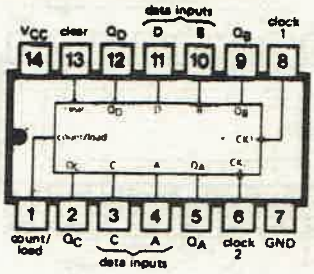
74174 HEX D-TYPE FLIP-FLOP



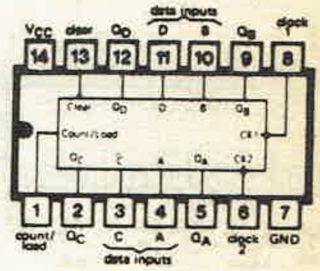
74175 QUAD D-TYPE FLIP-FLOP



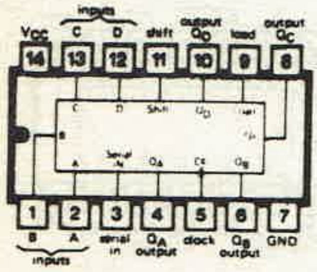
74176 DECADE (BI-QUINARY) PRESETABLE COUNTER/LATCH



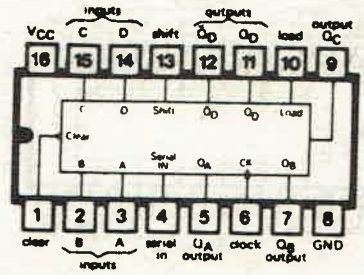
74177 BINARY PRESETABLE COUNTER/LATCH



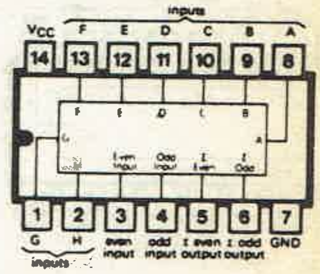
74178 FOUR-BIT UNIVERSAL SHIFT REGISTER



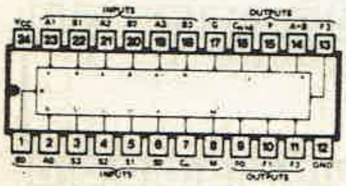
74179 FOUR-BIT UNIVERSAL SHIFT REGISTER, DIRECT CLEAR



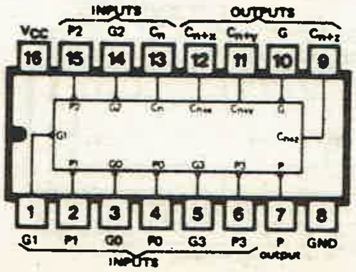
74180 NINE-BIT ODD/EVEN PARITY GENERATOR/CHECKER



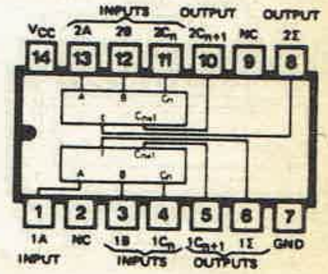
74181 ARITHMETIC LOGIC UNIT/FUNCTION GENERATOR



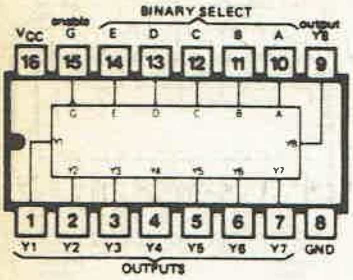
74182 LOOK-AHEAD CARRY GENERATOR



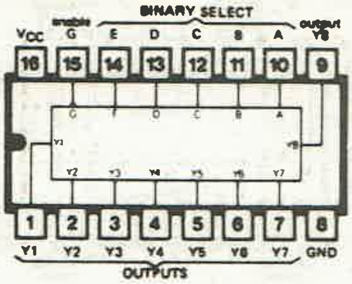
74183 DUAL CARRY-SAVE FULL ADDER



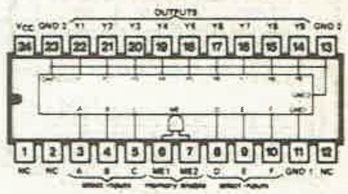
74184 BCD TO BINARY CONVERTOR, CASCADEABLE



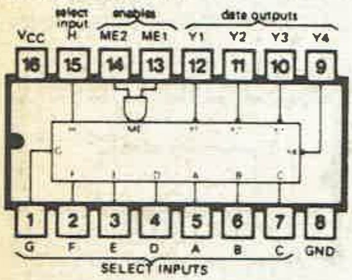
74185 BINARY TO BCD CONVERTOR, CASCADEABLE



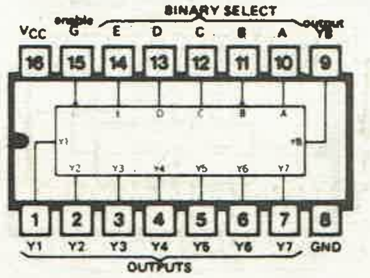
74186 512-BIT (64 BY 8) PROM, OPEN COLLECTOR OUTPUTS



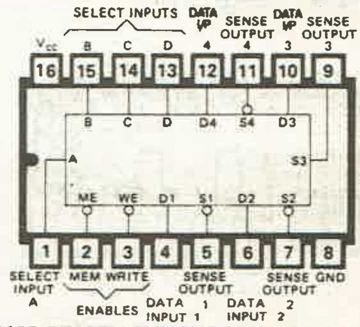
74187 1024-BIT (256 BY 4) ROM, OPEN COLLECTOR OUTPUTS



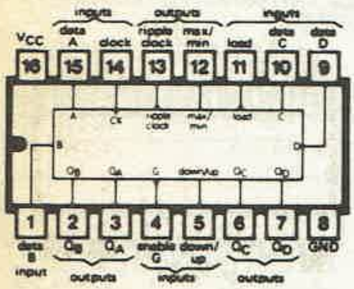
74188 256-BIT (32 BY 8) PROM, OPEN COLLECTOR OUTPUTS



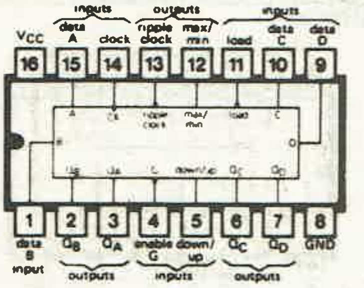
74189 64-BIT RAM, 16 BY 4 BITS, TRI-STATE OUTPUTS



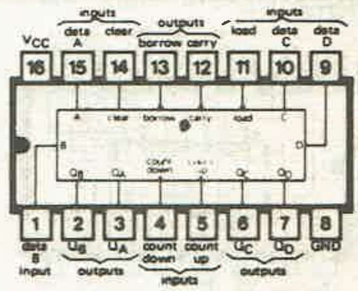
74190 BCD SYNCHRONOUS UP/DOWN COUNTER



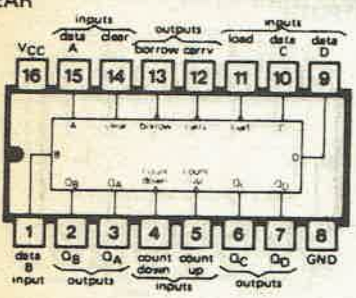
74191 BINARY SYNCHRONOUS UP/DOWN COUNTER



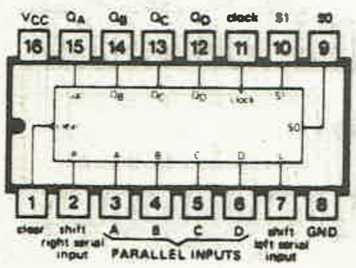
74192 BINARY SYNCHRONOUS UP/DOWN COUNTER, WITH DUAL CLOCK AND CLEAR



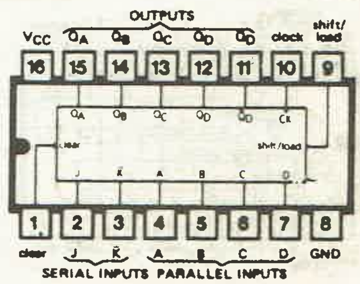
74193 BINARY SYNCHRONOUS UP/DOWN COUNTER, WITH DUAL CLOCK AND CLEAR



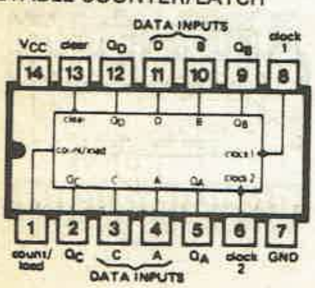
74194 FOUR-BIT BI-DIRECTIONAL UNIVERSAL SHIFT REGISTER



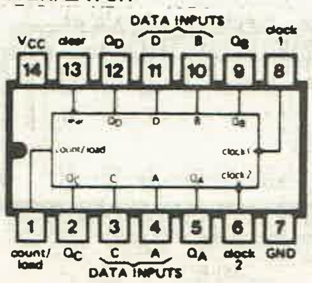
74195 FOUR-BIT PARALLEL ACCESS SHIFT REGISTER



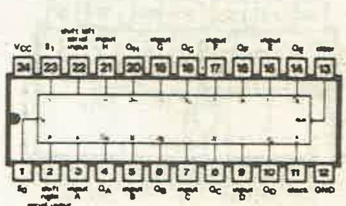
74196 DECADE (BI-QUINARY) PRESETABLE COUNTER/LATCH



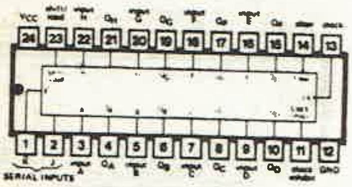
74197 BINARY PRESETABLE COUNTER/LATCH



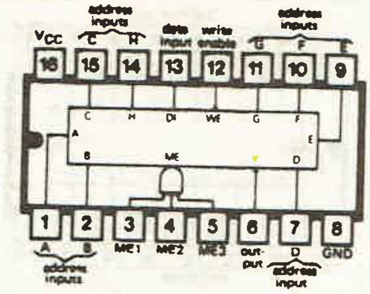
74198 EIGHT-BIT BI-DIRECTIONAL UNIVERSAL SHIFT REGISTER



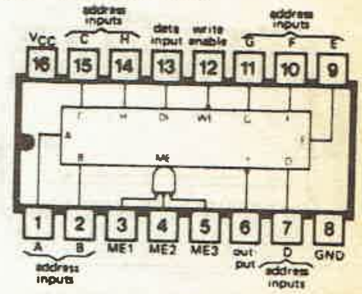
74199 EIGHT-BIT BI-DIRECTIONAL UNIVERSAL SHIFT REGISTER, J-K SERIAL INPUTS



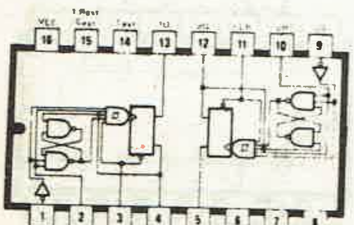
74200 256-BIT (256 BY 1) RAM, TRI-STATE OUTPUTS



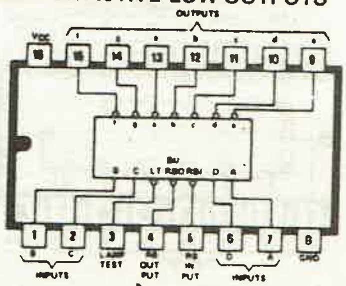
74206 256-BIT (256 BY 1) RAM, OPEN-COLLECTOR OUTPUTS



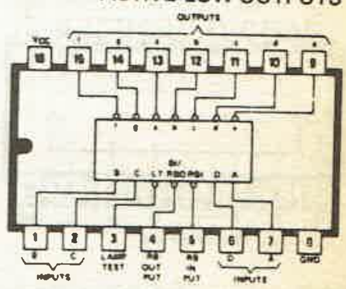
74221 DUAL MONOSTABLE MULTIVIBRATORS



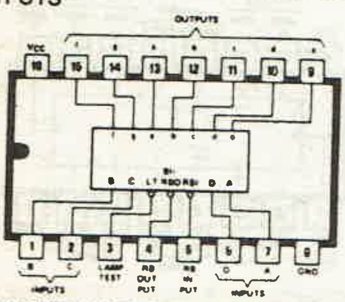
74246 BCD TO SEVEN-SEGMENT DECODER/DRIVER, 30 V OPEN-COLLECTOR ACTIVE-LOW OUTPUTS



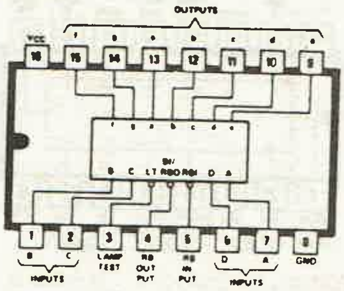
74247 BCD TO SEVEN-SEGMENT DECODER/DRIVER, 15 V OPEN-COLLECTOR ACTIVE-LOW OUTPUTS



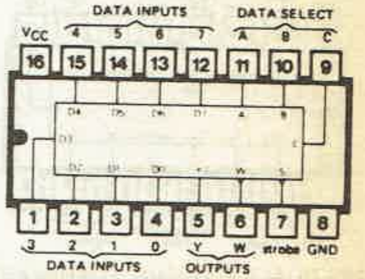
74248 BCD TO SEVEN SEGMENT DECODER/DRIVER, INTERNAL PULL-UP OUTPUTS



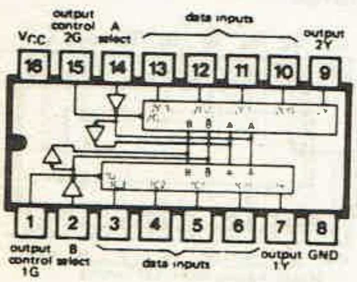
74249 BCD TO SEVEN SEGMENT DECODER/DRIVER, OPEN-COLLECTOR OUTPUTS



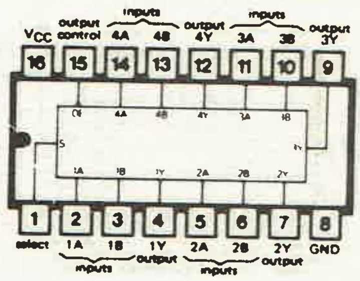
74251 DATA SELECTOR/MULTIPLEXER, TRUE AND INVERTED TRI-STATE OUTPUTS



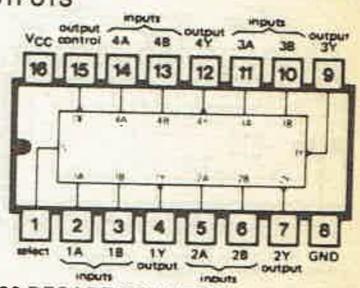
74253 DUAL DATA SELECTOR/ MULTIPLEXER, TRI-STATE OUTPUTS



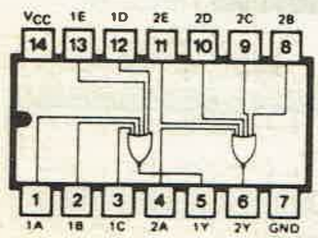
74257 QUAD DATA SELECTOR/ MULTIPLEXER, TRI-STATE OUTPUTS



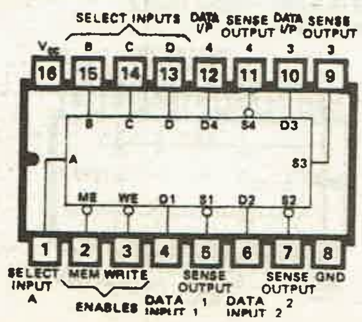
74258 QUAD DATA SELECTOR/ MULTIPLEXER, INVERTED TRI-STATE OUTPUTS



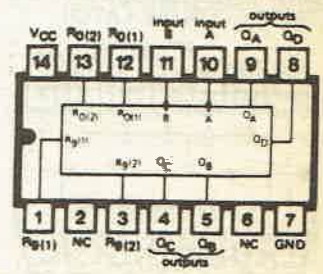
74260 DUAL FIVE-INPUT NOR



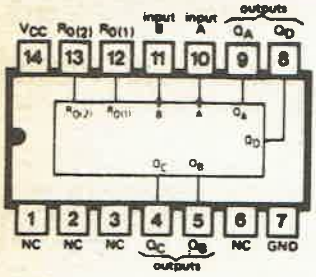
74289 64-BIT (16 BY 4) RAM, OPEN-COLLECTOR OUTPUTS



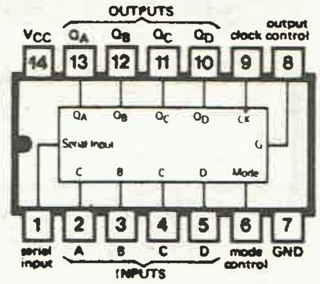
74290 DECADE COUNTER, DIVIDE-BY-TWO AND DIVIDE-BY-TEN



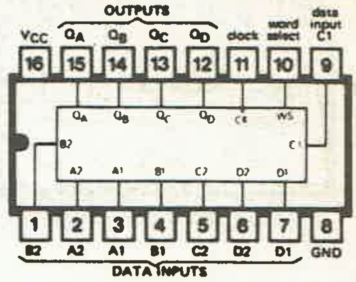
74293 FOUR-BIT BINARY COUNTER, DIVIDE-BY-TWO and DIVIDE-BY-EIGHT



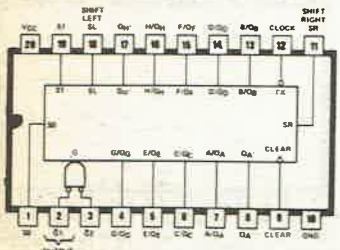
74295 FOUR-BIT BI-DIRECTIONAL UNIVERSAL SHIFT REGISTER



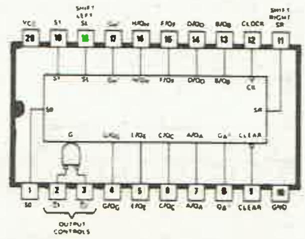
74298 QUAD TWO-INPUT MULTIPLEXER WITH STORAGE



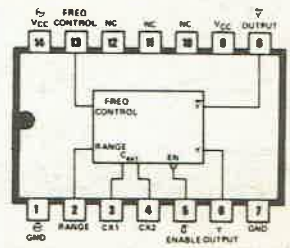
74299 EIGHT-BIT BI-DIRECTIONAL UNIVERSAL SHIFT/STORAGE REGISTER, TRI-STATE OUTPUTS, DIRECT CLEAR



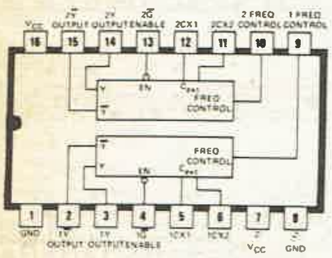
74323 AS 74299 BUT SYNCHRONOUS CLEAR



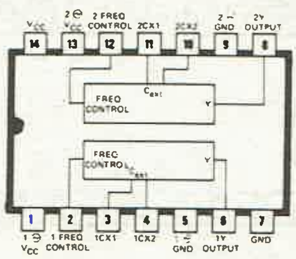
74324 VCO WITH TWO-PHASE OUTPUT AND ENABLE CONTROL



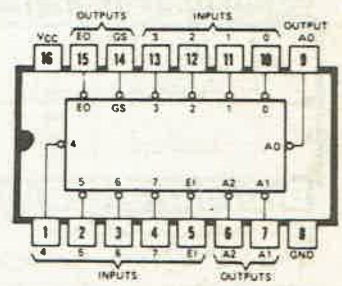
74326 DUAL VCO WITH TWO-PHASE OUTPUT AND ENABLE CONTROL



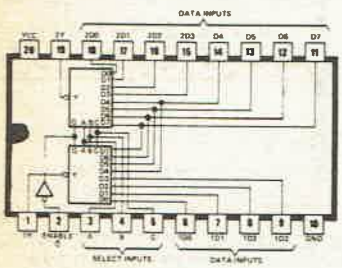
74327 DUAL VCO



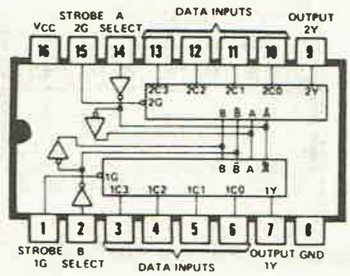
74348 EIGHT-LINE TO THREE-LINE PRIORITY ENCODERS



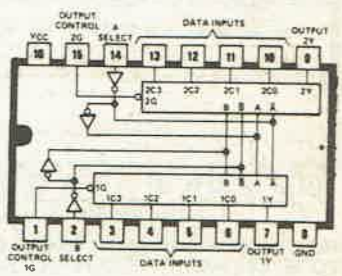
74351 DUAL EIGHT-LINE TO SINGLE-LINE DATA SELECTORS/MULTIPLEXERS, TRI-STATE OUTPUTS



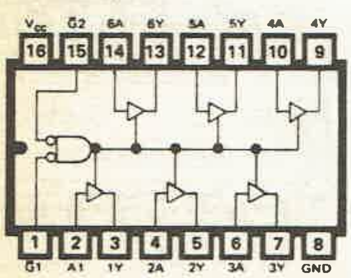
74352 DUAL FOUR-LINE TO SINGLE-LINE DATA SELECTORS/MULTIPLEXERS



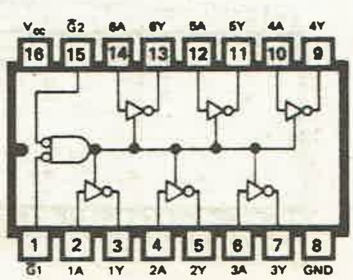
74353 DUAL FOUR LINE TO SINGLE LINE DATA SELECTORS/MULTIPLEXERS, TRI-STATE OUTPUTS



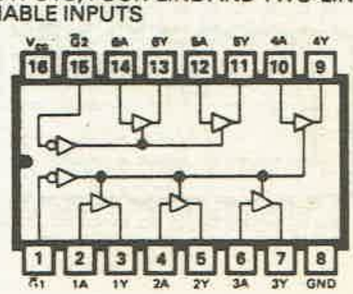
74365 HEX BUS DRIVER, TRI-STATE OUTPUTS, GATED ENABLE INPUTS



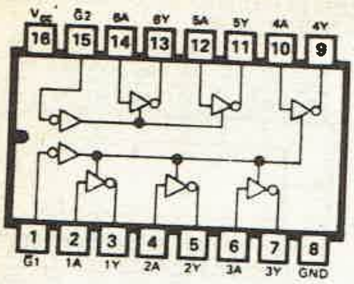
74366 AS 74365 BUT INVERTED OUTPUTS



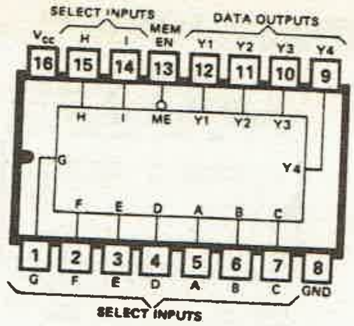
74367 HEX BUS DRIVER, TRI-STATE OUTPUTS, FOUR-LINE AND TWO-LINE ENABLE INPUTS



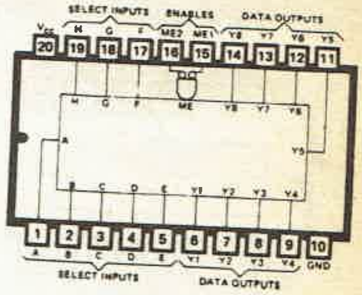
74368 AS 74367 BUT INVERTED OUTPUTS



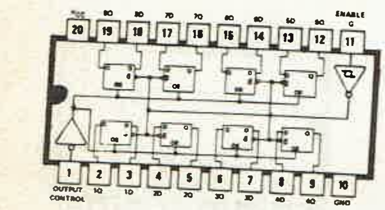
74370 2048-BIT (512 BY 4) ROM, TRI-STATE OUTPUTS



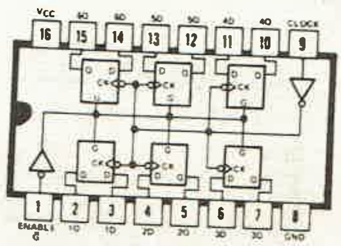
74371 2048-BIT (256 BY 8) ROM, TRI-STATE OUTPUTS



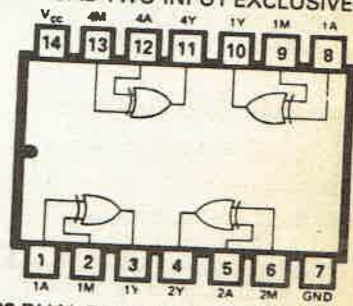
74373 OCTAL D-TYPE LATCHES, TRI-STATE OUTPUTS



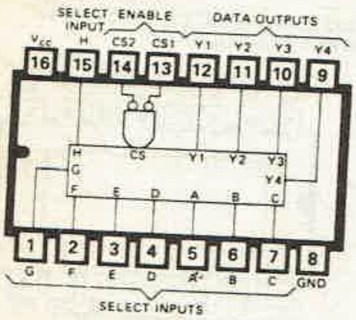
74378 HEX D-TYPE FLIP-FLOP



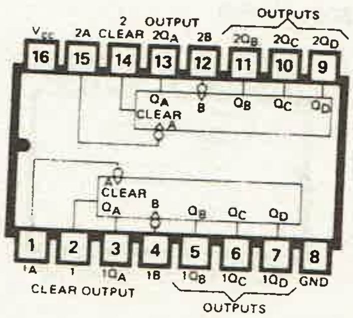
74386 QUAD TWO-INPUT EXCLUSIVE-OR



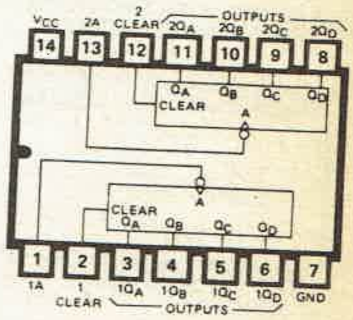
74387 256 BY 4-BIT PROM, OPEN COLLECTOR OUTPUTS



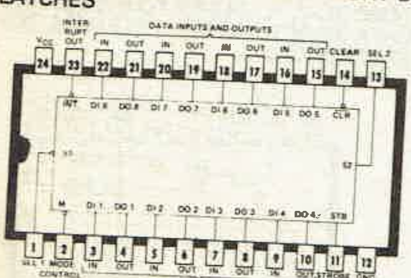
74390 DUAL DECADE COUNTERS, BI-QUINARY OR BCD



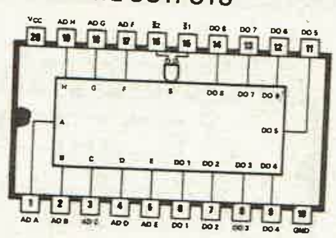
74393 DUAL FOUR-BIT BINARY COUNTERS



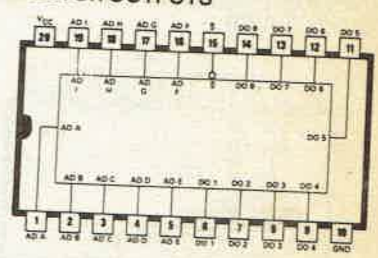
74412 MULTI-MODE BUFFERED EIGHT-BIT LATCHES



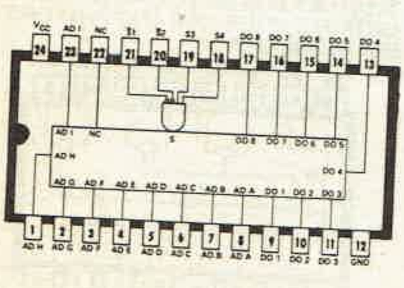
74470, 74471 256-BY-8-BIT PROMS; **470** HAS OPEN COLLECTOR OUTPUTS, **471** HAS TRI-STATE OUTPUTS



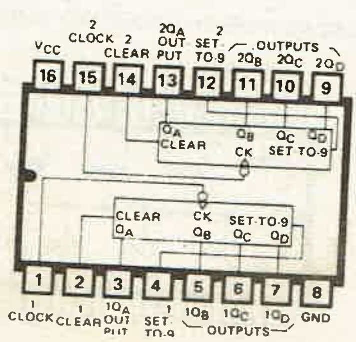
74472, 74473 512-BY-8-BIT PROM; **472** HAS TRI-STATE OUTPUTS, **473** HAS OPEN-COLLECTOR OUTPUTS



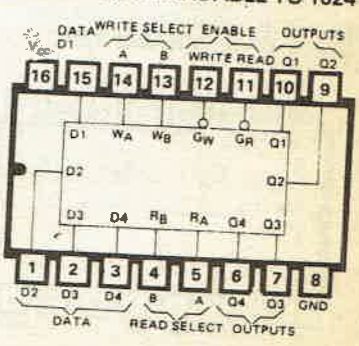
74474, 74475 512-BY-8-BIT PROM, GATED STORE; **474** HAS TRI-STATE OUTPUTS, **475** HAS OPEN-COLLECTOR OUTPUTS



74490 DUAL DECADE COUNTER



74670 FOUR-BY-FOUR REGISTER FILE, TRI-STATE OUTPUTS, SIMULTANEOUS READ/WRITE, EXPANDABLE TO 1024 WORDS



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