



## Two Versatile New Power Supplies for High Power Semiconductor Work

**T**WO years ago -hp- introduced for transistor work a small regulated power supply which had the property of limiting its output current to selectable values for protection of the circuit under test. This power supply became very popular and has now led to the development of two additional regulated supplies for higher power transistor use and similar applications. One of the new supplies provides currents up to  $\frac{1}{2}$  ampere at voltages from 0 to 40 volts, while the other provides currents up to 2 amperes at voltages from 0 to 60 volts. Both supplies incorporate the automatic current-limiting feature in which maximum available output current can be prescribed by front panel controls to current values that

can be set using front panel meters.

Besides the current-limiting feature, the new supplies include a number of other conveniences. They are externally programmable so that they can be easily matched to production-testing situations in which a sequence of accurate, known voltages is required. The 2-ampere supply is arranged with a second set of output terminals that enables the output voltage to be sensed and regulated at the load itself rather than at the output terminals. This feature thus overcomes the loss in regulation caused by large supply currents flowing in the hook-up leads. In addition to the above conveniences, both supplies have isolated output terminals, are free of spurious turn-on and line voltage ef-



Fig. 1. New -hp- Model 722AR regulated power supply provides up to 2 amperes at voltages from 0 to 60 vdc. For safety to load, maximum available current can be set anywhere between 100 ma and 2.2 amperes. Unit is also designed to compensate for effect of hook-up leads on regulation. A companion version of unit is designed to be remotely programmable.

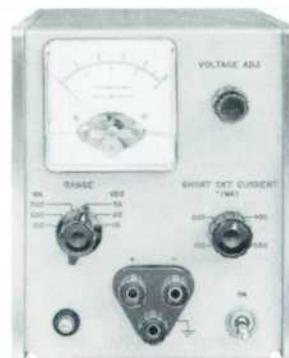


Fig. 2. New -hp- Model 723A regulated power supply provides up to  $\frac{1}{2}$  ampere at voltages from 0 to 40 vdc. Unit is fully transistorized and operates at full ratings up to 55°C as does new supply at left. Unit is programmable and has current-limiting feature.

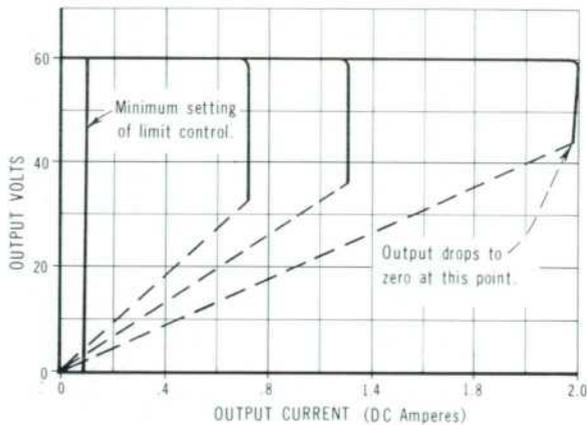


Fig. 3. Typical current-limiting characteristic of hp-Model 722AR for various settings of current-limit control. For large current overloads an electronic circuit turns off output voltage, as shown by dashed lines.

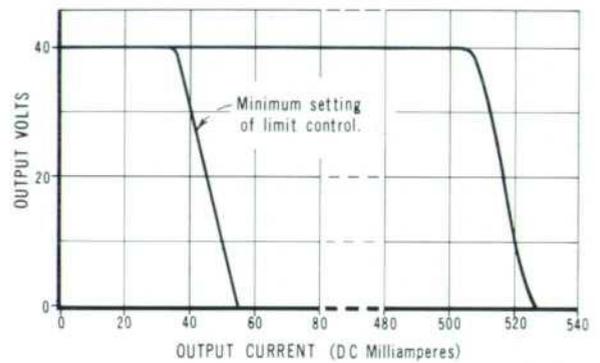


Fig. 4. Typical current-limiting characteristic of hp-Model 723A power supply for two settings of current-limit control.

fects, and can be continuously operated at *full ratings* at ambient temperatures up to 55°C. The supplies themselves are also fully transistorized and have protected internal circuitry.

#### CURRENT LIMITING

The current-limiting characteristics of the new supplies are shown in Figs. 3 and 4. A current limit control on the panel enables the desired maximum-available-current to be selected. When the control has been set, the available output current and voltage will follow the form shown. Up to the current value for which the control is set, the output voltage remains constant; but when the load

conductance becomes sufficiently large that current in excess of the preset value is required, the supply voltage falls so as to limit the current to the specified value.

For the 2-ampere supply the limiting characteristic is very sharp; in fact, for large overloads the supply turns off its output. This characteristic occurs because the power dissipated in the series regulating transistors in the supply is monitored. When internal dissipation becomes sufficiently large, the monitoring circuit turns off the series circuit, thus giving very sharp external circuit protection. If the output voltage falls to zero in this manner, it can be restored to the former value by a

reset switch on the panel. This switch releases the internal lockout circuit which is wholly electronic in nature.

If it is desirable to adjust the maximum-available-current more precisely than is permitted by the current limit control calibrations, use can be made of the panel current meters to obtain higher resolution and accuracy. To set maximum current using the meters, the output voltage can be turned nearly to zero. If the output terminals are then shorted together with a piece of hookup wire, the output current will be read on the panel meter and can be set to the desired maximum value with the current limit control.

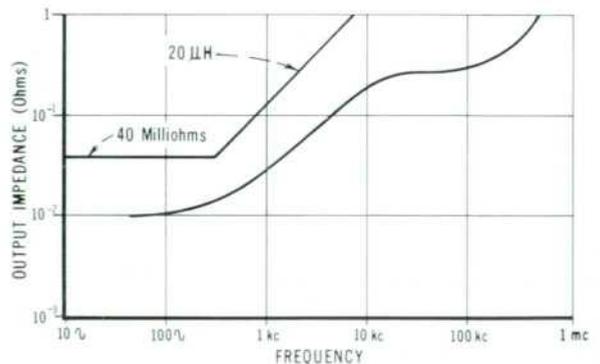
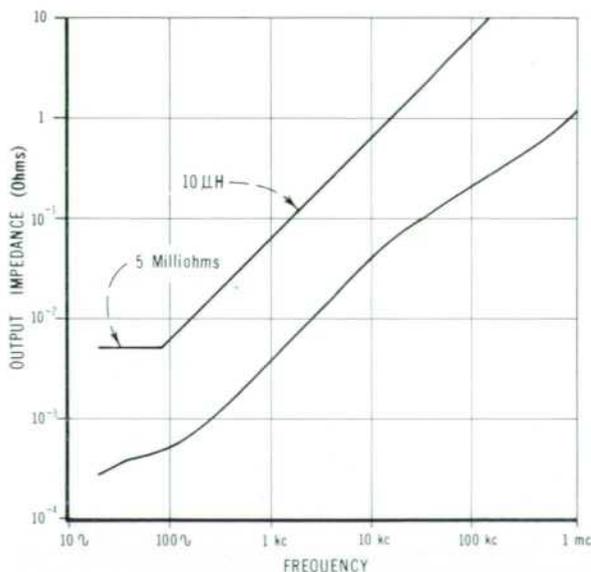


Fig. 6. (above) Typical output impedance of Model 723A power supply.

Fig. 5. (at left). Typical output impedance of Model 722AR power supply.

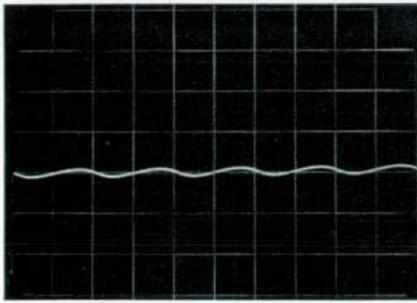
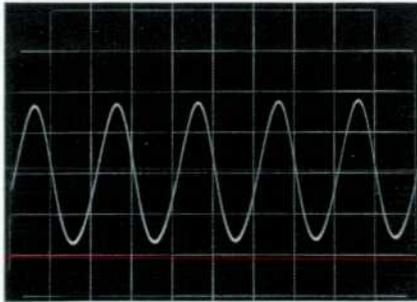


Fig. 7. Oscillograms demonstrating improvement in regulation obtainable at load by use of remote sensing feature of Model 722AR. Normally, remote sensing is used for improvement in dc regulation rather than ac which is shown here for clarity of illustration. Vertical scale is 50 mv/cm.

This technique sets the current with the voltage well below the knee of the curves shown in Fig. 3 and 4, i.e., the current read on the meter is slightly higher than the highest current at which the supply regulates. Allowance can be made for this factor in setting the current limit control, if desired.

#### REMOTE PROGRAMMING

In production testing and in systems work it is often convenient to have available a fixed sequence of accurate dc voltages. Such a sequence enables circuits under test to be checked out in a routine manner without the necessity for manually adjusting to each desired voltage.

For such applications the new supplies have been provided with a simple arrangement to make them remotely programmable.\* Two terminals at the back of the cabinet are designed so that a resistance connected between them will determine the voltage produced by the supply in the proportion of 1 volt per 50

ohms.\*\* Thus, by providing an external switching arrangement with a suitable series of resistances, the supplies can be remotely programmed to give a desired sequence of voltages.

#### REMOTE SENSING

The output impedance of the 2-ampere supply is so low (less than 2.5 milliohms) that it is equal to but an inch or two of hook-up wire. Thus, where the full regulation capabilities of the supply are required, it becomes necessary to minimize the effect of the voltage drop present in the leads used to connect the supply to the load.

To assist in minimizing loss of regulation due to leads, the 2-ampere supply is designed to have a remote sensing capability. The arrangement consists of a separate set of terminals which can be connected to the load in parallel with the main supply leads. The sensing terminals have a high internal impedance, however, so that the sensing leads will draw an essentially constant, small current. The terminals can thus sense loss of regulation caused by the main leads. By this means the internal regulator circuits are enabled to compensate for variations in voltage directly at the load. Lead voltage drops of about 0.6 volt can be largely compensated for in this way.

The effectiveness of the remote sensing circuit is shown in Fig. 7. These oscillograms compare the regulation under the two conditions at a load drawing a full 2 amp. p-p through six-foot leads of No. 18 wire. Although the oscillograms show the regulation improvement in terms of a low-frequency ac voltage, the use of ac in this case is primarily for clarity of illustration, since the regulation circuits are intended for dc regulation.

\*The remotely-programmable supply in the 2-ampere version is assigned the model number 726AR and produces a maximum output voltage of 45 volts. The 60-volt, 2-ampere supply (Model 722A) is not remotely programmable.

\*\*In the Model 726AR this value is 1 volt per 100 ohms.

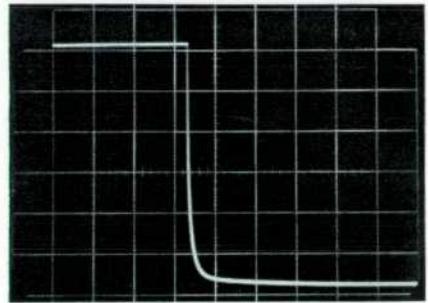
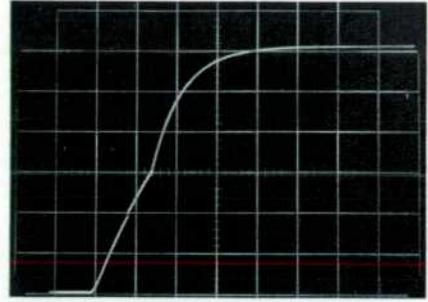


Fig. 8. Oscillograms of turn-on and turn-off characteristics of Model 722AR power supply. Both supplies have been designed to be free from spurious transients for protection to semiconductor or other low-voltage devices. Vertical scale is 10 v/cm; sweep time is 0.2 sec/cm.

#### OUTPUT IMPEDANCE

More than ever, low power supply impedance is often required for present-day circuitry, and a good degree of impedance-reduction has been achieved for the new supplies. The resulting impedance characteristics are shown in Figs. 5 and 6. While these curves show the supply impedances at room temperature, the temperature performance of the supplies is good. As a result the curves are also representative of supply impedance at higher temperatures up to 55°C, while lower temperature operation down to 0°C does not increase the impedance by more than a factor of about 2.

#### SMALL TRANSIENT EFFECTS

When operating low-voltage devices such as transistors from regulated supplies, many cases have occurred where the transistors have been destroyed due to the application of excessive voltage from the power supply. The case under consideration is not that caused by a simple misadjustment of the output voltage control but that caused by

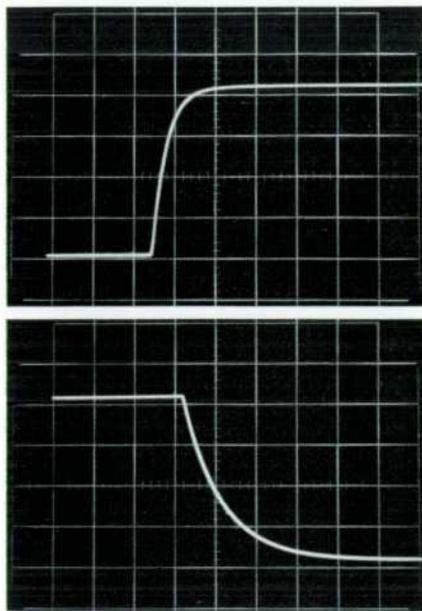


Fig. 9. Oscillograms of turn-on and turn-off characteristics of Model 723A power supply. Vertical scale is 10 v/cm; sweep time is 0.2 sec/cm.

a malfunction of the supply circuit. One common situation in this respect is where the line voltage from which the supply is operated is acci-

dentally lost and then reapplied. When this occurs while the power supply is connected both to the circuit under test and to the supply line, the power supply output voltage may, unless special design precautions have been taken, rise to much higher than normal levels for a brief time. Generally, this voltage surge occurs when power is reapplied and the surge may approach the largest values of dc voltage that are used within the supply.

To avoid this situation, it is incumbent on the supply designer to arrange matters so that the supply output voltage remains within prescribed limits during supply turn-on and turn-off. Considerable care has been taken in this regard with the new supplies\*\*\* and the oscillograms in Figs. 8 and 9 demonstrate that turn-on and turn-off characteristics are free of transistor-damaging voltage surges.

\*\*\*The -hp- Model 721A transistorized supply also has been designed with this precaution.

## GENERAL

In other respects the supplies also offer a high order of performance. The effect of line voltage and line voltage transients is negligible, while noise and ripple in the output are well below a millivolt. The output terminals are isolated from ground and can, if desired, be operated up to 400 volts off ground. Transistor circuitry is conservatively operated and carefully designed, resulting in an upper rated temperature range of 55°C for the instruments.

## ACKNOWLEDGMENT

The electrical design of the new supplies was performed by Lyman D. Austin, Edward Heinsen, and William McCullough under section head Donald F. Schulz. The mechanical design was performed by Gale C. Hammelwright and Richard B. Osgood.

—E. Robert Aikin

### -hp- MODEL 723A DC POWER SUPPLY

**Regulated Output Voltage:** 0 to 40 volts dc, continuously variable.  
**Full Load Output Current:** 500 ma over entire voltage range.  
**Load Regulation:** Less than 20 mv change over full operating range.  
**Line Regulation:** Less than 10 mv change for  $\pm 10\%$  power line fluctuations.  
**Ripple and Noise:** Less than 150  $\mu$ v rms.  
**Temperature Stability:** Better than 0.05%/°C or 10 mv/°C, whichever is greater.  
**Temperature Range:** 0 to 55°C for operation within specifications.  
**Output Impedance:** 40 milliohms in series with 20  $\mu$ h; 0.1  $\mu$ f shunt.  
**Meter Ranges:** Full scale indications of: 100 ma, 200 ma, 500 ma, 10 v, 20 v, 50 v.  
**Meter Accuracy:**  $\pm 5\%$  of full scale.  
**Overload Protection:** Output current limiter continuously variable from 60 to 600 ma.  
**Output Terminals:** Three banana jacks spaced  $\frac{3}{4}$  in. apart. Positive and negative terminals are isolated from chassis. A maximum of 400 volts may be connected between ground and either output terminal.  
**Remote Programming:** Rear-mounted terminals accept resistive value for control of output voltage at the rate of 50 ohms per volt.  
**Power:** 115/230 volt  $\pm 10\%$ , 50 to 1000 cps, 70 w max.  
**Dimensions:** 6 $\frac{1}{2}$  in. high, 5 $\frac{1}{2}$  in. wide, 11 in. deep.  
**Weight:** Shipping 21 lbs.  
**Price:** \$225.00.

## SPECIFICATIONS

### -hp- MODEL 722AR DC POWER SUPPLY

**Regulated Output:**  
 0 to 60 volts dc.  
 0 to 2 amperes dc.  
**Line Regulation:** Less than 2.5 mv change for  $\pm 10\%$  line voltage change; output set between 0 and 60 volts.  
**Load Regulation:** Less than 5 mv change for 0 to 2 amperes change; output set between 0 and 60 volts.  
**Noise and Ripple:** Less than 250  $\mu$ v rms.  
**Temperature Stability:** Better than 0.02%/°C or 5 mv/°C, whichever is larger.  
**Temperature Range:** 0 to 55°C for operation within specifications.  
**Output Impedance:**  
 DC: Less than 2.5 milliohms.  
 AC: Less than 5 milliohms in series with 10  $\mu$ h.  
**Output Meters:**  
 Voltage: 0 to 60 v, one range.  
 Current: 0 to 2.5 a, one range.  
**Protection:** Output current limiter continuously adjustable from 100 ma to 2.2 a.  
**Cooling:** Forced air.  
**Power:** 115/230 volt  $\pm 10\%$ , 50 to 60 cps, 300 w max.  
**Size:** 19 in. wide, 5 $\frac{1}{4}$  in. high, 12 in. deep.  
**Weight:** Net 34 lbs.  
**Price:** \$525.00.

Prices f.o.b. factory

Data subject to change without notice

### -hp- MODEL 726AR DC POWER SUPPLY

**Regulated Output:**  
 0 - 45 volts dc.  
 0 - 2 amperes dc.  
**Line Regulation:** Less than 2.5 mv change for  $\pm 10\%$  line voltage change; output set between 0 and 45 volts.  
**Load Regulation:** Less than 5 mv change for 0 to 2 amperes change; output set between 0 and 45 volts.  
**Noise and Ripple:** Less than 250  $\mu$ volts rms.  
**Temperature Stability:** Better than 0.02%/°C or 5 mv/°C, whichever is larger.  
**Temperature Range:** 0 to 55°C for operation within specifications.  
**Output Impedance:**  
 DC: Less than 2.5 milliohms.  
 AC: Less than 5 milliohms in series with 10  $\mu$ h.  
**Output Meters:**  
 Voltage: 0 to 60 volts, one range.  
 Current: 0 to 2.5 amperes, one range.  
**Remote Programming:** Rear mounted terminals accept resistive value for control of output voltage at the rate of 100 ohms per volt.  
**Protection:** Output current limiter continuously adjustable from 100 ma to 2.2 amperes.  
**Cooling:** Forced air.  
**Power:** 115/230 volt  $\pm 10\%$ , 50 to 60 cps, 250 w max.  
**Dimensions:** 19 in. wide, 5 $\frac{1}{4}$  in. high, 12 in. deep.  
**Weight:** Net 25 lbs.  
**Price:** \$500.00.