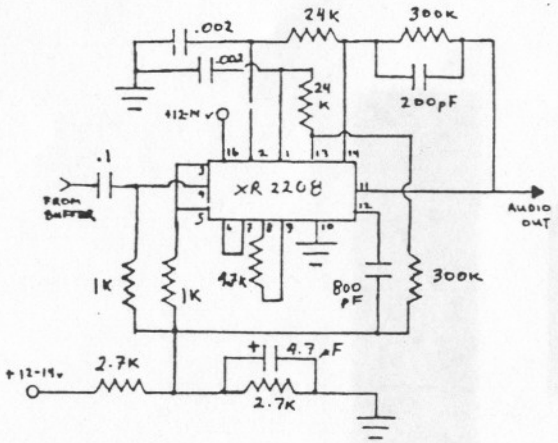
the irca technical column

MORE SYNCHRONOUS AM DETECTORS

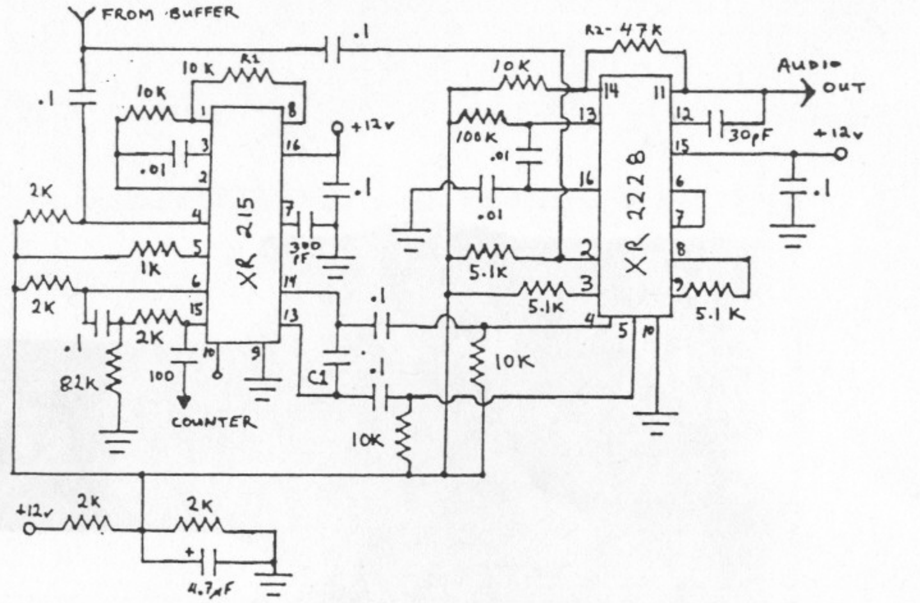
Some time back in this column (DXM #554, Aug 10/80; also reprinted in A DXer's Technical Guide, pp 85-87), a device known as a "Phase-locked loop (PLL) synchronous detector" was described. For the basics of synchronous detection, please refer to that article. Unfortunately, just as it was written, Signetics stopped producing the NE-561 IC that was used in the sample circuit. So far as I know, there is now no way to build a PLL synchronous detector using just one IC.* There is, however, another type of synchronous detector which uses just one IC, but it does not use a PLL.

Put simply, synchronous AM detection is the combining in a mixer of the desired AM signal with a waveform which is the same frequency and phase as the incoming AM carrier. Among the mixing products will be the audio with which the AM carrier was modulated back at the transmitter. After suitable filtering, this audio can then be fed to amplifiers to drive headphones or a speaker. In the first synchronous detector to be described here (see left), there is no external signal generated to simulate the AM carrier. Instead, the signal is developed within the IC, an XR2208 multiplier. In this IC, signal fed to either input can be amplified (amount of amplification is determined by external resistors for each channel), then combined. The AM signal from the IF amp is fed to both sections of the IC; one section is operated in the linear mode (determined by the 4.7 k resistor between pins 8 and 9), but the other section terminals (pins 6 and 7) are shorted together which causes the incoming AM signal to be amplified so much that it is limited (its peaks are chopped off). All this amplification results in a waveform which approximates the carrier in frequency and phase. The waveform is mixed with the AM signal to produce the desired audio. The IC also contains an op-amp, but its principal purpose is to convert the multiplier's differential output to the single ended output needed to drive most audio amps. Incidentally, this circuit is quite similar in principle to the "synchrophase" AM detector used in the Drake R7. Also, the XR2228 IC used below can be used instead of the XR2208 in this circuit; see the XR2228 data sheet for the different pin-out needed.

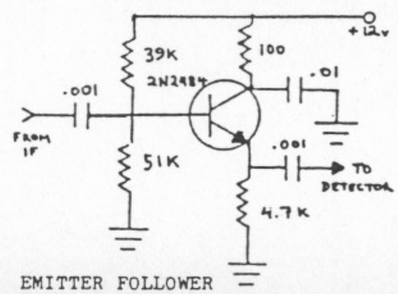


The next circuit (see below) is the XR215/XR2228 PLL synchronous detector from Exar data sheets, as built by E.H. Grossman some time ago. This uses the same principle as the NE561 circuit, and is quite a bit more forgiving of poor AGC in the receiver than the XR2208 circuit. The XR215 phase locked loop IC locks onto the signal carrier from the receiver's IF output. In this IC, the voltage controlled oscillator (VCO) free running frequency is determined by C1. A 470 pF capacitor will put the VCO pretty close to 455 kHz. If you need to decrease the free running frequency, add capacitance to C1 (use a trimmer in parallel). If you need to increase the frequency, put a 10 k trimpot between pin 10 and ground, and adjust this for the desired frequency. This circuit has quite a wide capture range, at least 420-480 kHz, so fine adjustment may not be necessary. On the other hand, you may find that fine-tuning the VCO frequency results in better handling of a wide range of signal strengths by this circuit; the PLL will be less likely to unlock on weak signals. If you have a frequency counter, the VCO's frequency of operation can be sampled at pin 15. Even without a counter however, you will probably know when the PLL locks up with the carrier, as the signal strength of the demodulated audio increases considerably and becomes clearer. FM demodulation is available (through a suitable low pass filter) at pin 8 if you're liable to be receiving such broadcasts, and R1 can be increased up to 100 k for greater audio output.

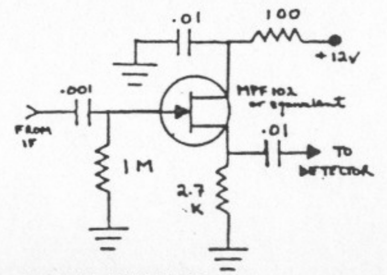
The output from the PLL is taken from across the timing capacitor C1 and applied to pins 4 and 5 of the XR2228 multiplier IC, while the desired AM signal is applied at pin 2. The signals are amplified and mixed and the resulting audio from pin 16 is filtered and amplified in an op-amp in the IC. R2 can be varied from 10-100 k to provide some audio gain control for the demodulated AM available at pin 11. The XR215, XR2228 and XR2208 are all available from Ancrona, P.O. Box 2208, Culver City, CA 90230. The prices are in the 3 to 5 dollar range each, and the company has a minimum $10 order with $2 shipping and handling.



The input signal to these detectors comes from the last transformer of your receiver's IF stage; note that your receiver must have a separate envelope detector and IF amplifier in order to use the detector circuits. If you are using a transistorized receiver, the secondary of the last IF transformer is usually untuned and could be connected directly to the input of the synchronous detector. It's better however to use a buffer amplifier between the two to avoid loading down the IF transformer, and to allow continued use of the receiver's envelope detector. An emitter follower, as shown below, will act fine as a buffer (circuit from Phil Bytheway). The buffer should be mounted close to the IF transformer, and could be powered from the receiver. In vacuum-tube type receivers, the final IF transformer usually has a tuned secondary and is of much higher impedance than the IF secondary of transistorized receivers. A source (FET) or cathode (tube) follower would be the circuit to use here to avoid loading down the IF transformer. A sample FET circuit is below.



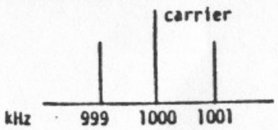
EMITTER FOLLOWER



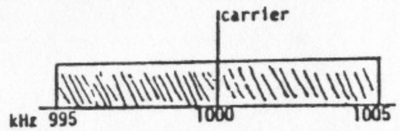
SOURCE FOLLOWER

E.H. Grossman has been comparing the common envelope detector (found in most receivers) with a circuit known as a synchronous AM detector. Before describing such a detector, let's run through a little background about AM signals and their detection.

An AM signal is composed of a number of different frequencies. The "carrier" is the central frequency, and is the one we refer to when we say that "station XXX is on 1000 kHz" 1000 kHz is what the station's carrier frequency is, but no information (music, voice, tones, etc.) is actually conveyed on this signal. The "sidebands" carry the station's programming, and for any sound more complex than a simple test tone, the sidebands are a group of signals symmetrically arranged on either side of the carrier frequency. These sidebands correspond in frequency and strength with the audio imposed onto the carrier signal at the AM transmitter. A simple example: a 1000 Hertz test tone will turn up as two signals, one which is one kilohertz higher than the carrier, and one which is one kilohertz lower.



--a 1 kHz TT on 1000 kHz



--complex sounds on 1000 kHz (sound has an upper limit of 5 kHz)

If the test tone is not pure, it may contain some weak energy at 2000 Hz. The 2000 Hz energy will show up as signals 2 kHz above and below the carrier, and so on.

To extract audio from an AM signal, one ordinarily uses a rectifier (in the form of a diode, a bipolar transistor or an FET) followed by a capacitor. This is an "envelope detector" and it needs the carrier and both sidebands of an AM signal in order to produce the least distorted audio.

A "product detector" is a more complex and efficient circuit most often used for reception of single sideband (SSB) and code signals. A signal from an oscillator known as a beat frequency oscillator (BFO) is injected into this sort of detector. This signal takes the place of the missing carrier of an SSB signal. The output of the product detector is approximately equal to the product of the BFO and the RF signal applied to it--and this output is at audio frequencies. AM signals can be heard with such a detector, but only if the BFO frequency is adjusted so that it has the same frequency as the incoming carrier; a beat note between the carrier and BFO frequencies will obliterate the audio otherwise.

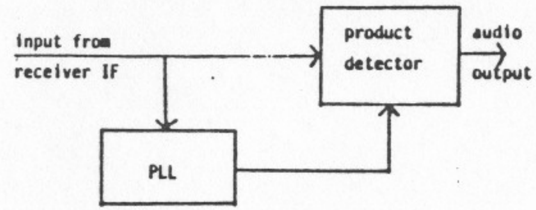
A distant AM signal can suffer from selective fading, i.e. its carrier and sidebands fade at different rates. But for the single diode or other envelope detector to yield undistorted audio, there must be a strong carrier present. If a selective fade weakens the carrier, you will be left with a jumble of noise, even though sidebands of the signal may still be present.

A carrier generated in the receiver can be substituted for the weak received carrier to allow better readability of a weak AM transmission as well as one with selective fades. This is known as the "exalted carrier" technique. SWL's with good quality receivers can zero-beat the BFO with the AM signal's carrier (usually in a product detector), using the BFO as a carrier rather as in listening to a SSB transmission. However, MW DXers' experimentation with exalted carrier techniques seems to have centered around using a Q-multiplier to peak the carrier in relation to the sidebands. See NRC reprint R2 "Single Sideband Reception of the BCB with Mechanical Filters" by Gordon Nelson or "Receiver Hot-Rodding Hints" by Ray Moore in the NRC Receiver Reference Manual for further information. Using this technique, one can hear reasonably undistorted audio using the carrier and only one sideband of an AM signal.

Exalted carrier reception sounds like a good idea, but the carrier generated in the receiver must be exactly the same frequency as the incoming carrier and it must stay that way while you're listening. This condition implies a great deal of stability in the local oscillator of the receiver as well as in the circuit supplying the internal carrier. Not only that, but one or the other of these circuits must have a control for some pretty fine tuning to get the internal carrier to the same frequency as the incoming carrier. Personally, I've not had a great deal of success using a Q-multiplier for exalted carrier reception due to these constraints and the limitations of my receiver.

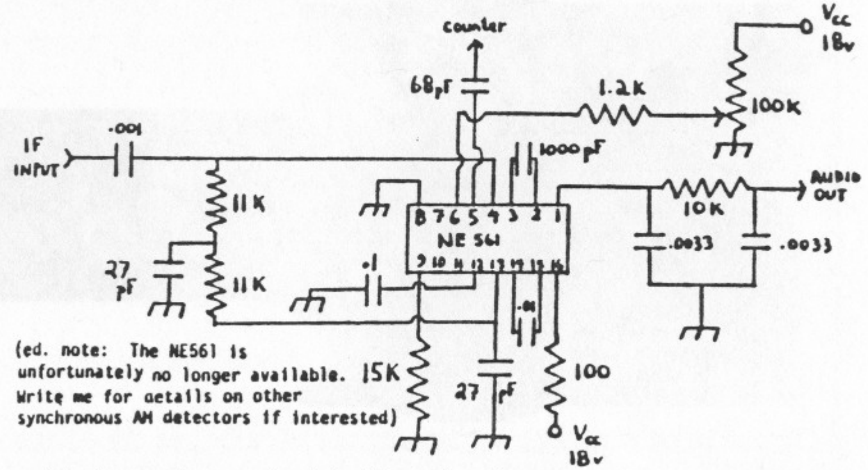
What one really needs is a circuit that will sample the weak carrier of a received signal and generate a strong steady signal which is in phase with that carrier. A circuit called a "phase-locked loop" (PLL) will do this very job and PLL integrated circuits are widely available.

After one obtains this strong steady signal from the PLL, it should be mixed with the desired DX signal. The desired signal will then beat with the output from the PLL (which matches exactly the carrier frequency of the desired signal) to yield audio. Such a circuit is known as a "phase-locked loop synchronous AM detector" and will allow detection if the carrier of the desired signal is strong enough to lock the PLL onto that frequency. In theory, a weaker signal can be copied with a synchronous detector than with an envelope detector, as noise does not affect the synchronous detector as much as it does the envelope detector. Audio from a weak noisy signal should theoretically be cleaner and more readable using a synchronous detector. A block diagram of such a detector might look like this:



The Signetics NE561 is an integrated circuit which combines both a PLL and a multiplier (used as a product detector) in one package. 100 uV of IF output is all that is needed to lock the PLL in phase with the carrier. The circuit uses this IC as a synchronous AM detector.

The 100 kΩ potentiometer adjusts the PLL output to the 455 kHz range so that it may lock onto an available carrier from the receiver IF stages. Once adjusted, it can be left alone. The frequency counter output does not have to be used, but if you have a counter available, it will let you know when the PLL is near the 455 kHz range before a signal is applied to the IC, and will let you know if the carrier of a DX signal has "locked up" the PLL. The same things can be done simply by adjusting the pot while listening to the output. If the receiver in use doesn't have an "IF output", some circuit will have to be put together to tap off signal from the receiver's IF strip and apply it to the 3 kΩ input of the NE561. A source follower or emitter follower should do the trick.

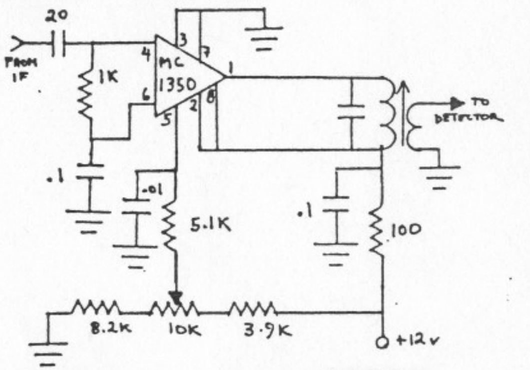


(ed. note: The NE561 is unfortunately no longer available. Write me for details on other synchronous AM detectors if interested)

E.H. Grossman has experimented with a number of synchronous AM detector circuits and found that most of them are an improvement over the envelope detector at least some of the time when listening to weak or fadey signals. He feels that a circuit using XR215 PLL and XR2228 multiplier IC's is the best so far. I can send anyone interested a schematic of this (it's quite a bit more complex than the NE561 circuit), though I feel it would be best if you have some knowledge of the IC's and of synchronous AM detectors before rushing off to build one! EHG has found that even the simple NE561 circuit can make a difference to a weak noise-plagued signal, however, and I hope that this article will stimulate some of the more technically oriented to some experimentation.

— Nick Hall-Patch

If you're not happy with the idea of adding another circuit to your receiver innards, simply attach a 20 pF capacitor between the top of the IF transformer secondary and a jack at the back of the receiver--use minimal distance between capacitor and transformer, shielded wire between the capacitor and jack. Then build an amplifier using the MC1350 IC as shown at left. This amplifier has plenty of gain (so wire it carefully) but it makes up for the weak signal available through the 20 pF cap. The output transformer in this circuit could be a J.W. Miller 8812, although Ambit International in the U.K. has similar transformers costing a lot less. The 10 k potentiometer is a gain control, as this amplifier will limit if run wide open. When the amp is connected between the receiver's IF and the synchronous detector, adjust this control for best sounding audio on weak signals. If your receiver has really good AGC action, then this control could be a trimpot, and just be set once. If your receiver AGC effect is mainly on stronger signals, then the gain control of this amp will have to be a front panel one, as some variation may be needed from signal to signal.



A word here about AGC. For best results with synchronous detectors I feel that a receiver should have a fast AGC (both attack and decay) that is effective on weak signals as well as strong. I suspect that many cheaper receivers don't really meet these standards. With the XR2208 detector, poor AGC action will be evidenced by sudden drops in signal strength during a fade, or disappearance of the signal altogether for brief periods (when the envelope detector would show a noise or splatter burst, for example). In the XR215/2228 circuit, bouts of reduced signal strength or a scratchy sounding het indicates that the PLL is not staying locked in. That would show that the receiver doesn't have a steady enough IF output signal strength due to poor AGC action. This is particularly annoying when trying to log a station with a fast strong SAH on it. The PLL could unlock every time the SAH bottoms out, reducing readability. Generally, fine tuning of the VCO free-running frequency in the XR215/2228 circuit will compensate for all but the poorest AGC systems, however. A possible solution to a weak AGC could be to use the MC1350 buffer amplifier above and apply AGC to it. I've read that the MC1330 detector IC can provide AGC for the MC1350, but don't know how effective it is, nor have I seen a sample circuit. If anyone knows of such a circuit, please let me know. There is an AGC circuit for the MC1350 in <u>Solid State Design for the Radio Amateur</u> from the ARRL, but it's fairly complex.

After all this, what sort of improvement can be expected in the readability of your DX signals? First, it must be noted that synchronous detectors are not a cure-all for receiver ills; they won't compensate for poor receiver sensitivity, signal handling or AGC; there may be an apparent selectivity improvement, but this is of the same order as a low-pass audio filter. However, a signal which is near the noise level can become more readable using these detectors. Signals suffering from phase distortion (which render distorted audio using envelope detectors) can also become clearer; on MW such signals are generally ones which arrive at your antenna via both skywave and groundwave. Phase distortion is much more common on SW, and though not a SW DXer, I have found that some SW broadcasts become less distorted when a synchronous detector is used. It seems that good receiver AGC is particularly important when demodulating phase distorted signals.

However, if a weak or phase distorted signal suffers from noise bursts such as sideband splatter or electrical storm noise, the synchronous detector won't sound much better than an envelope detector. Unfortunately, my major interference on MW is splatter covering up DX signals, so the detector can't often work to best advantage. In some cases, sideband noise is dulled a bit by the detector, but generally bursts of splatter serve only to throw the PLL out of lock for a split second. I did once manage to dig out KIKI-830 from under some strong local electrical noise, while the envelope detector showed mostly noise. The synchronous detector seems to work best on continuous amplitude noise interference, preferably of a low level, such as background atmospheric noise, though it seems rare now that a weak signal has only the atmospheric noise level to contend with, without splatter or local electrical noise also.

I don't feel that everyone should replace the envelope detector in his receiver (though with decent AGC the synchronous detector does everything the envelope detector does), but for tight spots it may be useful to be able to switch in a synchronous detector to see if you can get enough extra readability for an ID on a weak DX signal. Running the envelope detector output to one channel, and the synchronous detector to another channel of a stereo amp yields quite a depth to the desired signal also.

Incidentally, Derek Claridge has tried using the XR215/2228 circuit tapped off the emitter of Q24 in his R1000 and feels that exalted carrier technique using the receiver's BFO gives as good a result if not better. With my homebrew equipment, I haven't found this to be the case however. In conclusion, if you're an avid experimenter with a reasonable receiver, try the synchronous AM detector and see what it can do for your DX, and let us know the results. Bi-aural reception (upper sideband to one audio channel, lower sideband to another) is possible with a more complex synchronous detector circuit, but I don't know when I'll find the time for that!

* from Sheldon Remington comes this late word: "Larry Magne announced 1-3-82 on R. Canada International that a new IC chip is expected shortly which will be a self-contained PLL synchronous detector designed specifically for AM signals. No other info was given, however."

---looks like the technical column has had another success in influencing IC manufacturers. Rule: anything said about IC's in the technical column will shortly be proved wrong by an IC manufacturer. Plenty more stuff on hand for the column--enough for another receiver issue at least, I would think. Wait for it.------------ ------73, NHP

Late word: Those who have seen Chuck Hutton's article on digital readout for the TRF in the Jan. 11/82 <u>DX News</u> may be wondering where to get the MM5430 chip. Jim Hill, 3801 Palos Verdes Drive North, Palos Verdes Estates, CA 90274 has found a source, but there's a minimum order of five IC's. The price is $7.50 plus sales tax and any postage needed for each chip. If you want to help Jim make up the necessary minimum, write to him at the above address. He says he can get the 2N3819 also needed in the circuit for 80¢ plus tax.

Synchronous detection may be quite promising for the MW DXer in more complex AM detector circuits. E.H. Grossman and Wayne Covington have uncovered articles on this method of detection which look quite challenging. Things like bi-aural listening (one sideband to one audio channel, and the other sideband to a different audio channel) are apparently possible without using two receivers.

These articles include:

"Synchronous detection" in <u>The New Sideband Handbook</u> by Don Stoner

"The synchronous detection process" in <u>73 Magazine</u>, Sept 1967. By William Nagle.

"A practical receiver design for SSB, ISB and AM medium frequency broadcasts" by Macario, Craine and Walters in <u>EBU Review</u> for June 1974

"Synchronous Detection in Radio Reception, Pt. 2" by Pat Hawker. <u>Wireless World</u>, November 1972

"Eliminating Adjacent Channel Interference" by P.L. Taylor in <u>Wireless World</u>, July 1977.

This last is a theoretical article and should provide food for thought for any engineers in the crowd.

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