Scott D. Prather, *KB9Y*
2776 S. Monroe Street
Denver, Colorado 80210

A UNIQUE APPROACH TO AM SYNCHRONOUS DETECTION

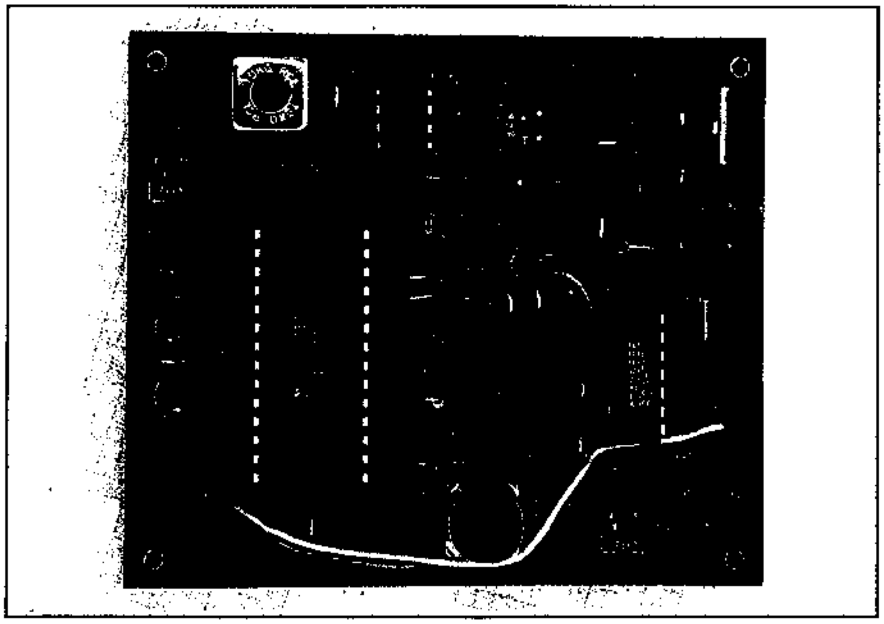
A simple way to enhance full-carrier AM reception

Amplitude modulation is almost as old as the radio art itself. Since the era of the radio-frequency alternator, AM has been used to convey intelligence throughout the RF spectrum. Even today, AM is hard at work in the standard broadcast band, the shortwave broadcast bands, and aviation communications.

For years now, the envelope detector has been the traditional method of demodulating AM. The envelope detector is a simple, low-cost device that provides relatively good performance under most conditions, but it is by no means a high-performance demodulator. For instance, the envelope detector suffers from extreme distortion during selective fading—a common occurrence on the medium and short wave bands.

Fortunately, there is a solution: synchronous detection. The synchronous detector (also known as a coherent detector) offers these advantages:

- Provides low-distortion audio during carrier fades when receiving skywave-propagated signals.



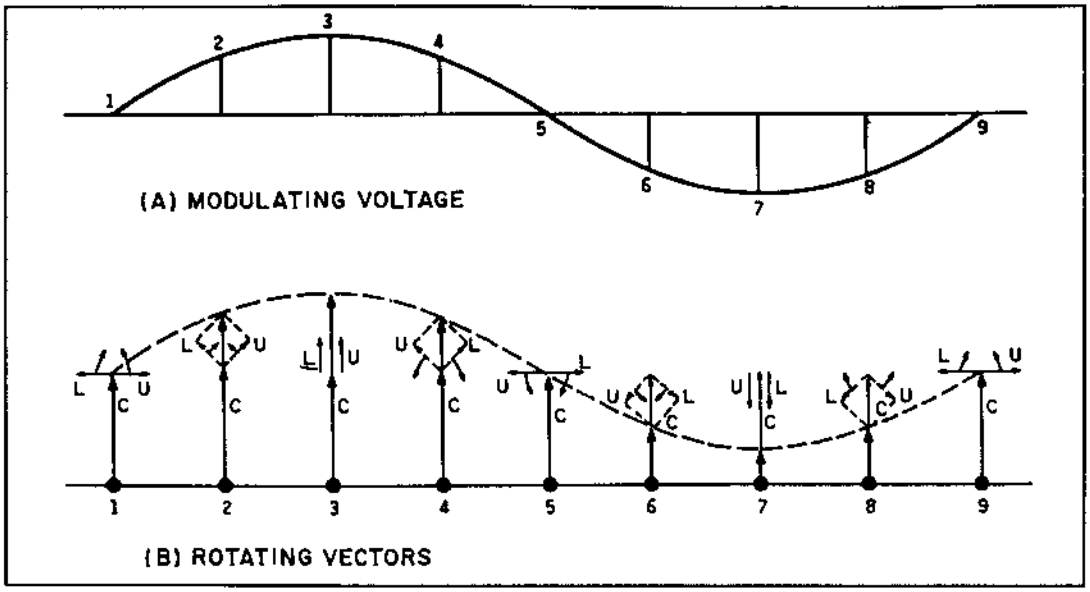


Figure 1. Rotating vectors are the easiest method of visualizing the phase relationships in amplitude modulation. Reprinted from Frederick Terman, *Electronic and Radio Engineering*, 1955, McGraw-Hill, permission of McGraw-Hill Books.

- Minimizes the effects of any quadrature components in the received signal caused by propagation anomalies, receiver mistuning, IF filter asymmetry, receiver phase noise, transmitter PM, etc.
- Provides a S/N ratio consistent with the actual S/N ratio of the incoming signal, regardless of its strength.

Until recently, most commercial receivers have not included a synchronous detector for AM, primarily because of its cost and complexity. The unique and simple circuit presented here was designed to offer the following features:

- Wide IF frequency range. Will work with any IF between 50 and 500 kHz, at any IF level between 10 mV and 1 volt RMS.
- Audio switching between an envelope detector and the synchronous detector is on-board, and is controlled by the presence of a ground signal.
- Audio distortion is less than 1.5 percent THD.
- An on-board notch filter with variable Q attenuates adjacent-channel heterodynes while providing high-frequency tone control. The notch filter can be set up to operate at 5, 9, or 10 kHz.
- An on-board LED driver is included to indicate detector phase lock.
- An on-board regulator permits the use of any input voltage between 7.3 and 35 volts DC, while eliminating the adverse effects of power supply ripple and VCO feedthrough.
- The board's small size (3.5 x 3 inches) allows its installation into almost any communications receiver.

Before we delve into the specifics of this circuit, let's spend some time looking at the AM demodulation process, and how a synchronous detector solves the problems associated with conventional envelope detection.

Amplitude modulation—a tutorial

In order to understand synchronous detection, it's best to explain the physics of amplitude modulation. If we view an AM signal in the time domain using an oscilloscope, we can see the superpositioning of the modulating waveform on the carrier, resulting in modulation of the envelope of the wave. If we view the AM signal in the frequency domain using a spectrum analyzer set up with the appropriate resolution bandwidth and dispersion, we see the carrier and two identical sidebands spaced the distance of the modulating frequency from the carrier. If we vary the percentage of modulation, we would see the amplitude of the sidebands change relative to the carrier. Viewed this way, the AM process looks to be quite simple. However, there are phase relationships between the carrier and the sidebands that play an important part in the modulation process. We must be aware of these to understand how synchronous detection works.

Rotating vectors (see **Figure 1**) are the easiest method of visualizing the phase relationships in amplitude modulation. In **Figure 1**, the three vectors C, L, and U represent the amplitude and phase relationships of the carrier, lower sideband, and upper sideband, respectively. For clarity, the carrier vector C can be

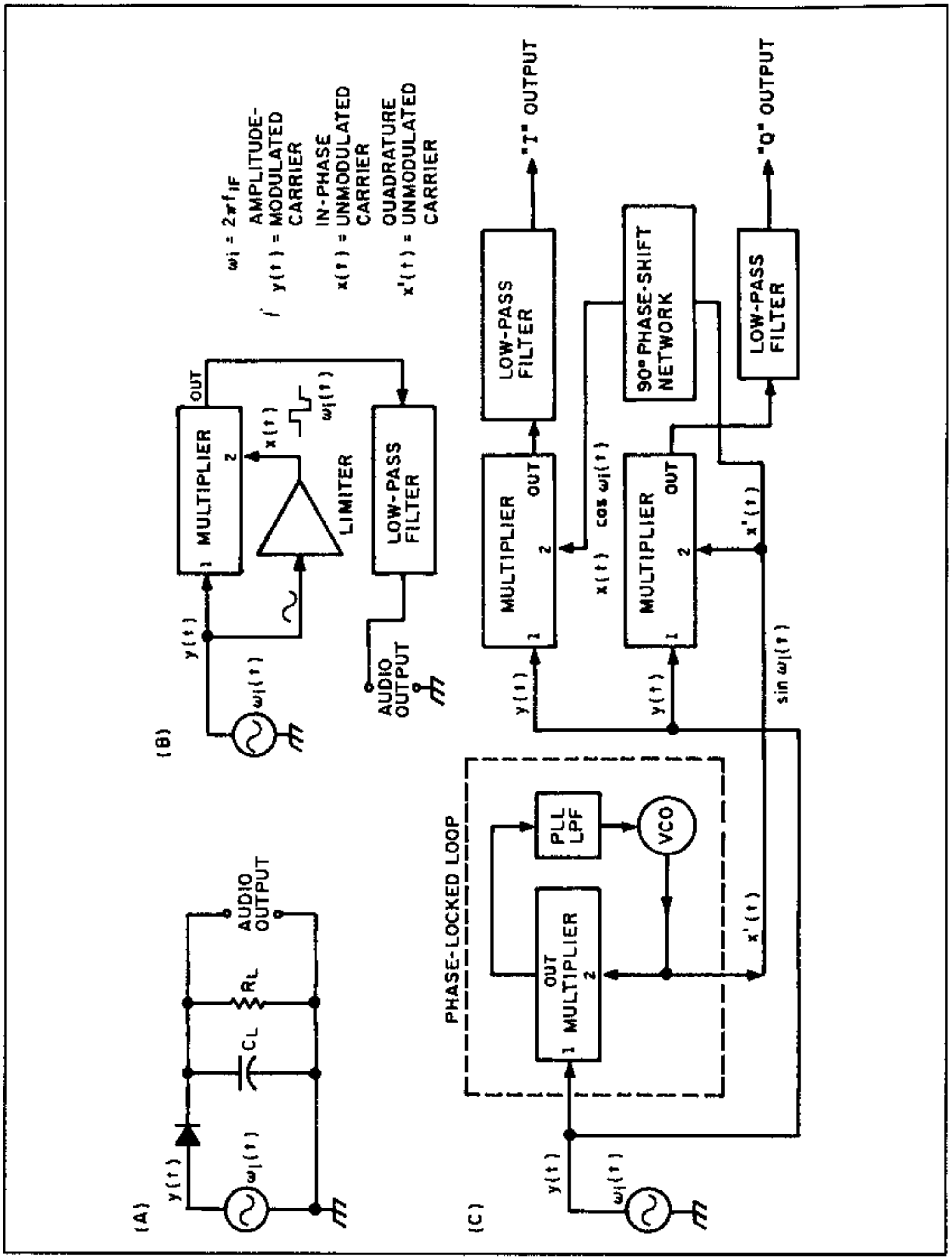


Figure 3. (A) Diode envelope detection. (B) Product detector. (C) True synchronous demodulation.

reduced in amplitude, the ratio of the magnitude of the L' and U' vectors and the C' vector during periods of maximum negative modulation (point 7) may create a modulation index that exceeds unity at the receiver causing extreme envelope distortion. In addition, rapid phase reversals occur as the modulating waveform crosses zero, causing a high degree of phase modulation.

AM demodulation

There are three basic types of AM demodulation: diode envelope detection, product detection (sometimes called quasi-synchronous detection),[2] and true synchronous detection. The differences between these three types are summarized below:

• **Diode envelope detection**. This is the old-

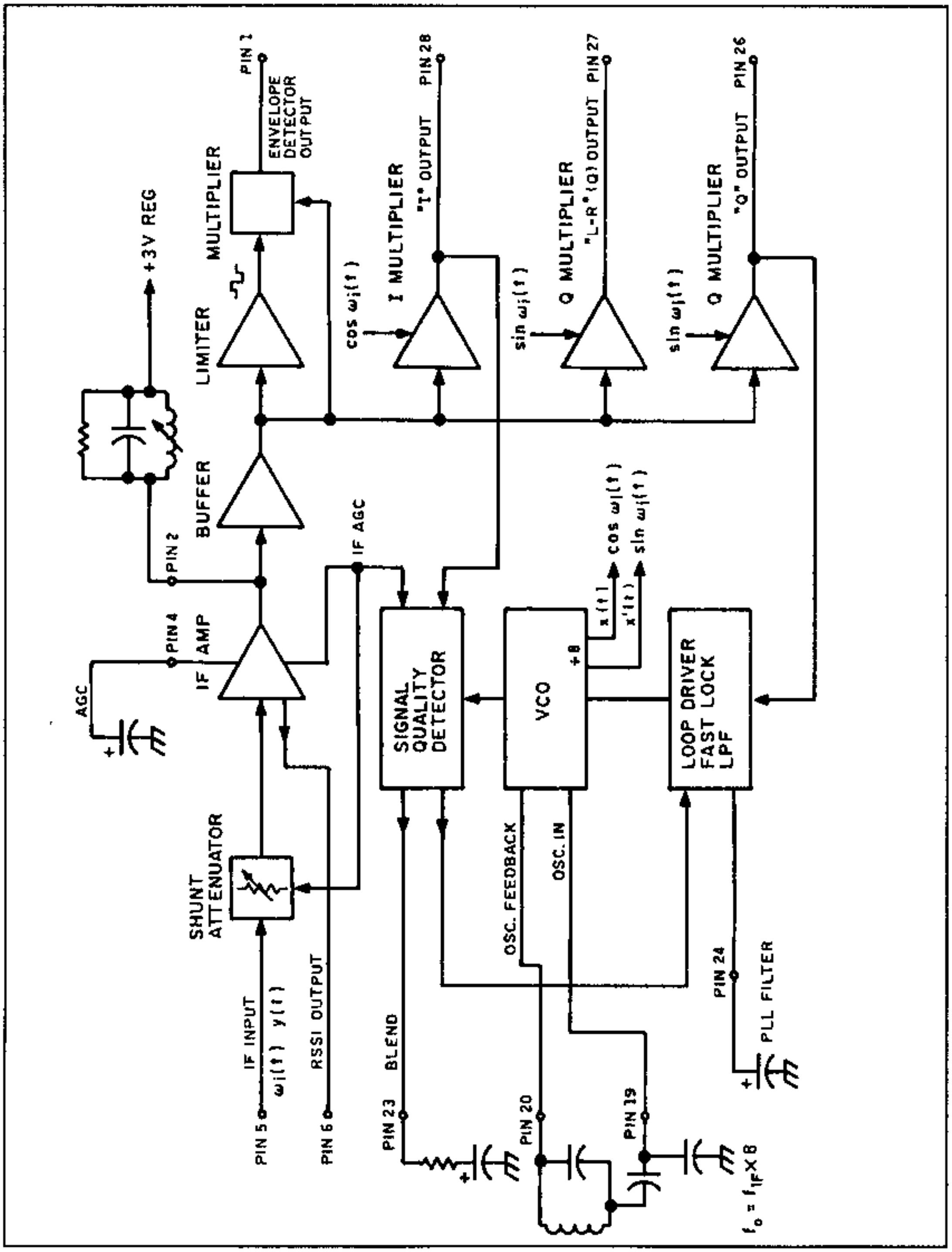


Figure 4. Motorola MC13022 internal circuitry.

est form of AM demodulation, in which a diode and capacitor produce an output voltage across a resistive load that corresponds to the envelope of the waveform (see **Figure 3A**). Although it's quite simple, the diode envelope detector has several disadvantages:

1) The diode is nonlinear, therefore creating distortion at certain levels of modulation.
2) The diode requires quite a bit of drive from the stages that precede it.
3) The diode demonstrates a threshold effect, where it will no longer demodulate when the input signal drops below a certain level.
4) The diode envelope detector creates severe distortion when the modulation index exceeds unity, as often happens during sky-wave propagation.

In spite of these disadvantages, the diode

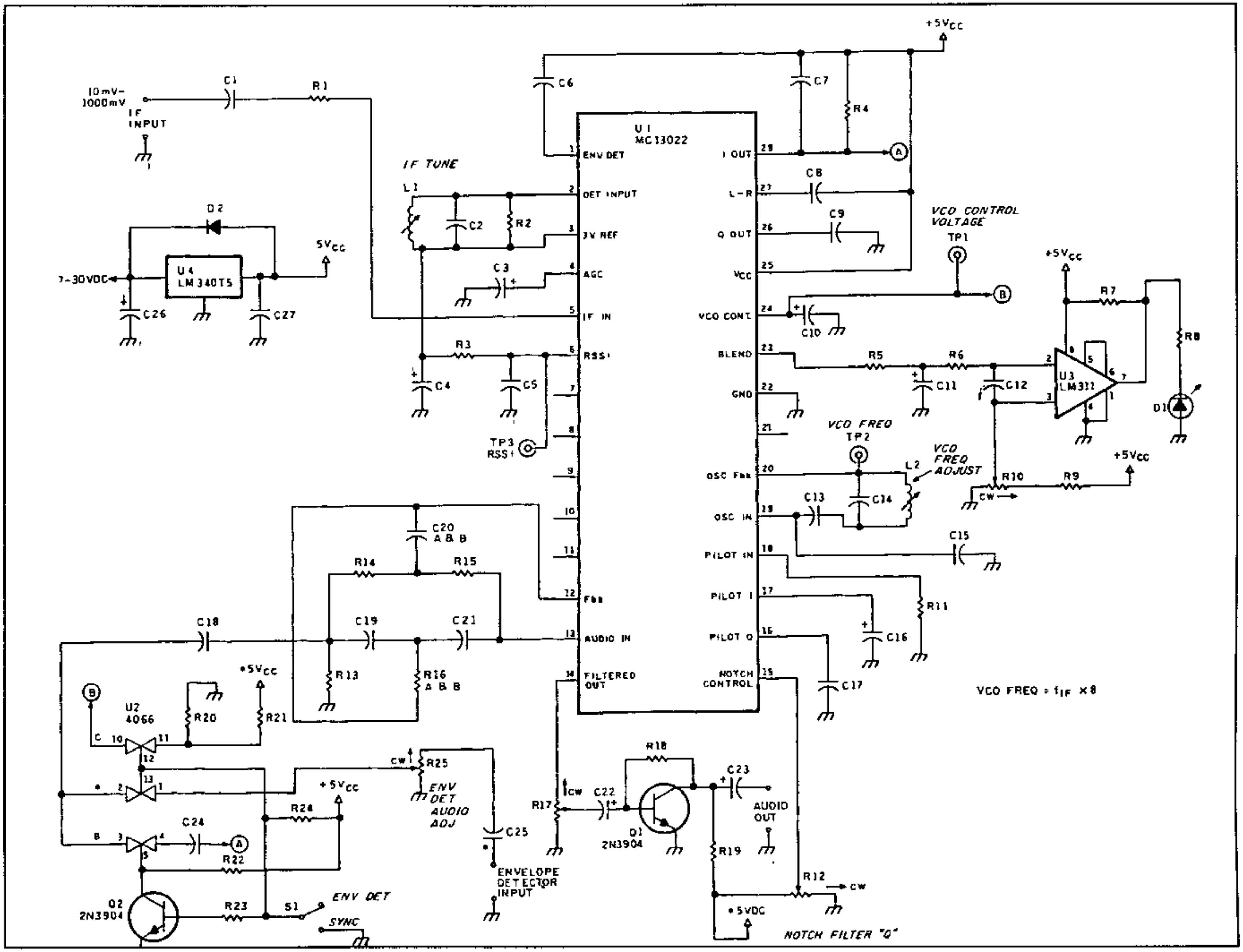


Figure 5. Synchronous detector circuit.

envelope detector has been used in communications receivers for decades, primarily because of its low cost. Today, however, the diode envelope detector has been replaced by product detection.

• **Product detection (quasi-synchronous).** This term is actually a misnomer, as all demodulators produce an $x(t)\,y(t)$ product of the carrier and modulated carrier frequencies. However, the term has come into such common usage that it now denotes the use of a multiplier instead of a simple diode rectifier.[3] In the product detector, the IF signal is fed into a limiter stage, where the modulation is stripped from the waveform (see **Figure 3B**). The resulting square wave of frequency ω_I is fed into one port of a multiplier to serve as a carrier, $x(t)$, while the other input of the multiplier is fed with the original amplitude-modulated IF signal, $y(t)$. Product detection has the advantage of producing less distortion than a simple diode envelope detector under strong signal conditions, but it fails to offer any advantages as the signal strength decreases or the modulation index exceeds unity—as the $x(t)$ carrier level will drop as well. Product detectors typically require far less input signal to produce an output, so the drive requirements are reduced.

• **True Synchronous.** The premise of true synchronous demodulation is quite simple. Instead of depending upon the received carrier to maintain the proper carrier vector magnitude (and therefore a modulation index of unity or less), we will instead design the receiver so it generates its own carrier $x(t)$ of the proper magnitude in-phase with the received carrier. This carrier is injected as an LO signal into one port of an in-phase (I) multiplier, with the modulated IF signal $y(t)$ feeding the second multiplier input (see **Figure 3C**). The product that results from this process has several advantages over a simple diode envelope detector:

1) During periods of carrier fading, the receiver's synchronous carrier takes the place of the missing carrier for the duration of the fade. In so doing, the audio distortion from the detector is greatly minimized when the modulation index exceeds unity, unless the sideband amplitudes are altered severely.
2) The multiplier only responds to the in-phase or amplitude component of the signal, minimizing the detector's response to the phase component.
3) The synchronous detector continues to demodulate regardless of the level of the incoming signal, eliminating the threshold effect seen in diode envelope detectors
4) The phase-locked VCO can eliminate the frequency-modulation associated with two carriers near the same frequency (provided the carrier offset is outside the range of the lowpass filter in the PLL loop).
5) True synchronous detectors can also be used to demodulate single sideband reduced carrier transmissions, designated SSB–$_{12}$.

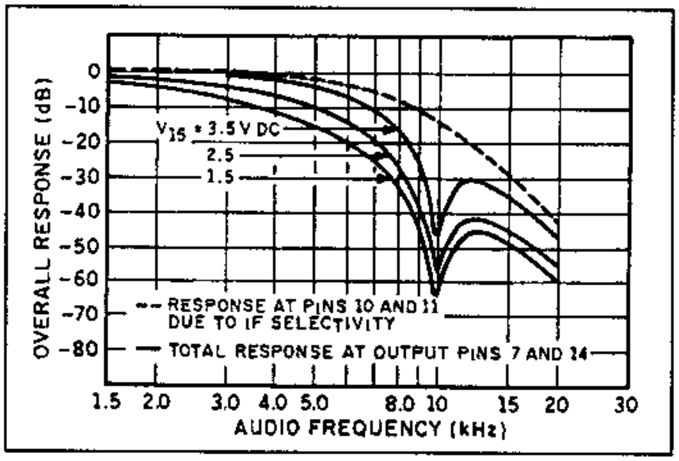


Figure 6. R3 and C5 provide the necessary R/C circuit for the RSSI line, who's output voltage varies according to the log of the input signal.

Overview of the Motorola MC13022 AM stereo decoder chip as a synchronous detector

Over the years, several means of providing synchronous detection have been developed, but in many cases the circuits were complicated and difficult to integrate into a wide range of receivers. Others were critical in their adjustment, and some required a very specific IF signal level. Still other circuits suffered from IF "breakthrough," where strong signals (such as local broadcast stations) would ride into the detector due to its high gain. I felt that there must be a simple way to provide synchronous AM detection in almost any receiver with an IF in the 50 to 500 kHz range without the problems associated with other designs. I found the answer in the Motorola MC13022 AM stereo decoder chip.

The real beauty of using the application-specific Motorola MC13022 as a synchronous detector is that a high percentage of the necessary components already reside on the chip. The MC13022 includes a low-distortion envelope detector, in-phase and quadrature multipliers, and an internal VCO. The chip also includes an AGC-controlled IF amplifier with 60 dB of dynamic range, and an audio notch filter to attenuate adjacent-channel heterodynes.[4] Although the chip was designed for an IF in the 260 to 455 kHz range, my tests indicate that it works just as well at any IF between 50 and 500 kHz—making it adaptable to a high percentage

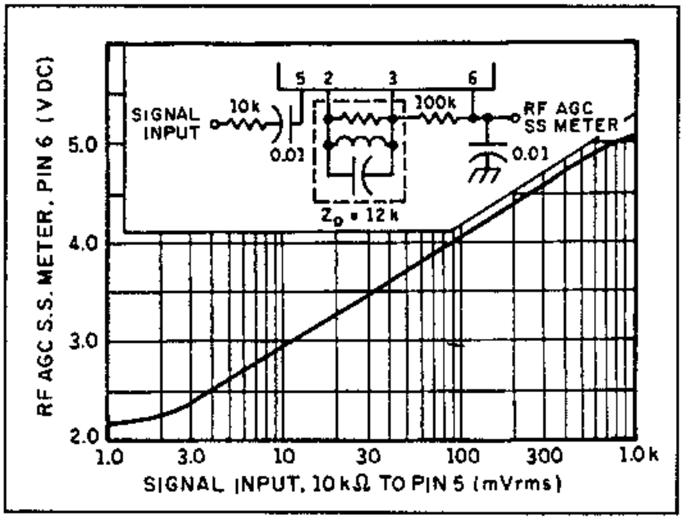


Figure 7. Notch depth/high frequency response versus pin 15 voltage.

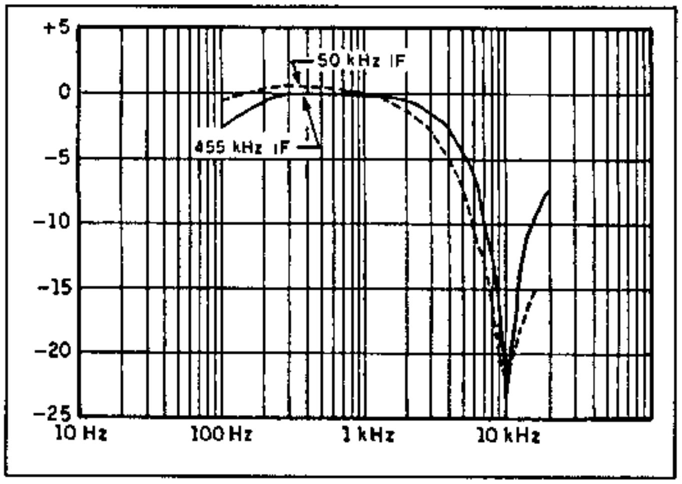


Figure 8. Frequency response.

of the communications receivers on the market. The high input impedance of the internal IF (>10 k), and low IF signal requirements (10 mV minimum) mean that the circuit is easily fed from almost any IF strip, or it can be used as an IF amplifier/synchronous detector in your next homebrew project.

Let's take a closer look at the circuit in **Figure 4**. The IF input of frequency ω_i from the receiver is fed in on pin 5. From there, the IF signal is amplified and appears on pin 2. An external L/C circuit resonates the IF amplifier output, and the IF signal is internally coupled to the envelope and I/Q phase detectors. AGC voltage developed in the IF amplifier is fed back to a shunt attenuator on pin 5 to maintain an optimum signal amplitude to the multipliers and PLL. This AGC circuitry also feeds an internal signal quality detector that provides an external logarithmic signal strength indication, in addition to providing a signal quality indication to be used in activating the PLL fast-lock circuitry[5].

The amplitude-modulated IF signal *y(t)* from pin 2 is fed into a buffer, and then into the multiplier/PLL input bus. The MC13022 uses multipliers for both the I/Q outputs and the envelope detector. By so doing, the envelope detector is actually a product detector (quasi-synchronous). The MC13022's I and Q multipliers are identical; the only difference between them is the LO signal injected into each from the VCO. Since the I multiplier demodulates the in-phase component, the VCO must supply it with an *x(t)* carrier of cos $\omega_i(t)$. The cos $\omega_i(t)$ carrier generates maximum voltage when cos $\theta=1$ ($\theta=0$ degrees). By the same token, the quadrature multipliers are fed with an *x'(t)* carrier of sin $\omega_i(t)$. With this carrier, the output voltage is maximum when sin $\theta=1$ ($\theta=90$ degrees).[6] These LO signals are developed in an internal phase-shift network on the output of the MC13022 VCO.

The VCO in the MC13022 operates at eight times the frequency of the IF and an internal divider brings the VCO down to the IF frequency. In the chip's original application, this was done to assure that the VCO would always be above the frequency of the standard broadcast band, even when the chip was used in an automobile receiver with a 260 kHz IF. In my application, this "feature" serves no purpose, other than to restrict the upper frequency limit of the IF input signal. The VCO employs a fast-lock circuit and an IF frequency discriminator that can sense whether the VCO is too high or too low in frequency and rapidly adjust the VCO lock voltage accordingly. Finally, VCO lock is fed back to the signal quality detector, where it provides an output voltage that I used to operate an LED to indicate PLL lock.

Circuit description

The support circuitry for the MC13022 is quite simple, and only minor modifications to the chip's standard configuration were necessary to allow its use as a synchronous detector (see **Figure 5**). The IF signal from the receiver is coupled through DC-block C1 and R1 to the IF input on pin 5. R1 raises the input impedance, since this is variable with the setting of U1's internal shunt attenuator. The amplified IF signal appears at pin 2, and is applied to the IF resonant circuit consisting of L1, C2, and R2. R2 is used to lower the "Q" of L1/C2, improving the frequency response of the IF.

Capacitor C3 provides internal AGC filtering, and C4 serves as a AC bypass for the 3 volt regulator on pin 3. R3 and C5 provide the necessary R/C circuit for the RSSI line, who's output voltage varies according to the log of the input signal (see **Figure 6**).

Moving on to the detector portion of the

Component	5 kHz notch	9 kHz notch	10 kHz notch
R14,15,16A,16B	68,000 ohms	47,000 ohms	43,000 ohms

Table 1. Component values for various notch-filter frequencies.

chip, capacitors C6, C7, C8, and C9 serve as bypass capacitors for the $2\omega_i(t)$ component present on these pins. The values of these capacitors vary according to the IF frequency, with a value of 0.01 µF for a 50 kHz IF and 0.001 µF for a 455 kHz IF. The values of these capacitors were carefully chosen to provide the necessary $2\omega_i(t)$ filtering while minimizing their effect on the audio frequency response. It's very important that the same value capacitor be used on all four multiplier outputs, as an imbalance can cause distortion and VCO locking problems. Resistor R4 is used to supply a small DC bias voltage to the internal voltage comparators that monitor the degree of negative modulation on the output of the I multiplier. During deep carrier fades the degree of negative modulation can be very high, triggering the MC13022's internal modulation comparators and causing a loss of VCO lock. The bias supplied by R4 minimizes this effect.

In the VCO section, C10 serves as the loop filter capacitor, and a value of 68 µF was chosen to maximize the ability to retain lock during deep carrier fades. For proper performance, C10 must be a low-leakage capacitor, preferably a tantalum. The VCO resonant circuit consists of L2 and C13-15. The values of these components can become quite critical, especially when the MC13022 is used at an IF frequency below its design limit of 260 kHz.

In order to provide a means of determining when the VCO is in lock, I modified the "Blend" circuit on pin 23. In U1's original application, this circuit was intended to slowly blend the left and right channels together during periods of poor signal quality, or to kill the stereo conversion process altogether when receiving a monaural station. It can also serve as an indicator of VCO lock, although it's effectiveness in this regard is minimized by the application of a DC bias voltage through R4 on the I multiplier output. The blend voltage goes low (around 0.5 to 0.6 volts) when the VCO is out-of-lock, and goes high (around 0.7 volts) when locked with a good signal. R5 and C11 provide a short R/C time constant, and the filtered blend voltage is fed into a simple voltage comparator consisting of R6-R10, C12, U3, and D1. C12 prevents oscillation in U3, and R10 is used to set the comparator level for proper sync light operation. Components R11, C16, and C17 are included to prevent the internal stereo decoding circuitry from interfering with my application of the MC13022.

The audio circuitry includes a Twin-Tee notch filter with variable feedback made up of C19, C21, R14-R16. This notch filter can be set for any notch frequency between 5 and 10 kHz as determined by the values of these components (see **Table 1**). R13 serves as a DC return for an internal capacitor on pin 13. The "Q" of the notch filter can be altered by changing the voltage on pin 15 via R12. Graphs showing the notch depth/high frequency response versus pin 15 voltage are shown in **Figure 7**. The output impedance of the MC13022 is very low, and will not provide an efficient match to the audio stage of most receivers. A simple self-biased audio amplifier stage consisting of C22, C23, R17-R19, and Q1 solves this problem.

In order to make the detector simple to install into any receiver, on-board audio switching is provided through bilateral switch U2. Sections A and B of U2 allow the selection of either envelope detector or synchronous audio. A logic high at pin 13 selects envelope detector audio, while a high at pin 5 selects synchronous detector audio. Transistor Q2 serves as a logic inverter for the B section of U2. When envelope audio is selected, the audio can be derived from the receiver's internal envelope detector via C23 and R25. R25 allows balancing of the audio level between synchronous and envelope detector audio. Instead of using the receiver's envelope detector, audio can be derived from the envelope detector on pin 1 of U1, and R25 is not needed. However, C25 is necessary to serve as a DC block. When synchronous audio is selected, the output of the I multiplier in U1 feeds pin 4 of U2B via C24. Finally, section C of U2 was included to force the VCO to a center resting frequency when the envelope detector is in use. I found that the MC13022 has a propensity for pulling itself to an extreme of the control voltage range when first powered up, or when the receiver is tuned off of a strong station. Occasionally, it took some time and effort to pull the VCO back within the capture range of the PLL; consequently, R20 and R21 are switched in while the envelope detector is in use, pulling the VCO to a frequency within the PLL capture range.

Power for the synchronous detector board is supplied by regulator chip U4, a garden-variety 5-volt regulator. U4 serves two important func-

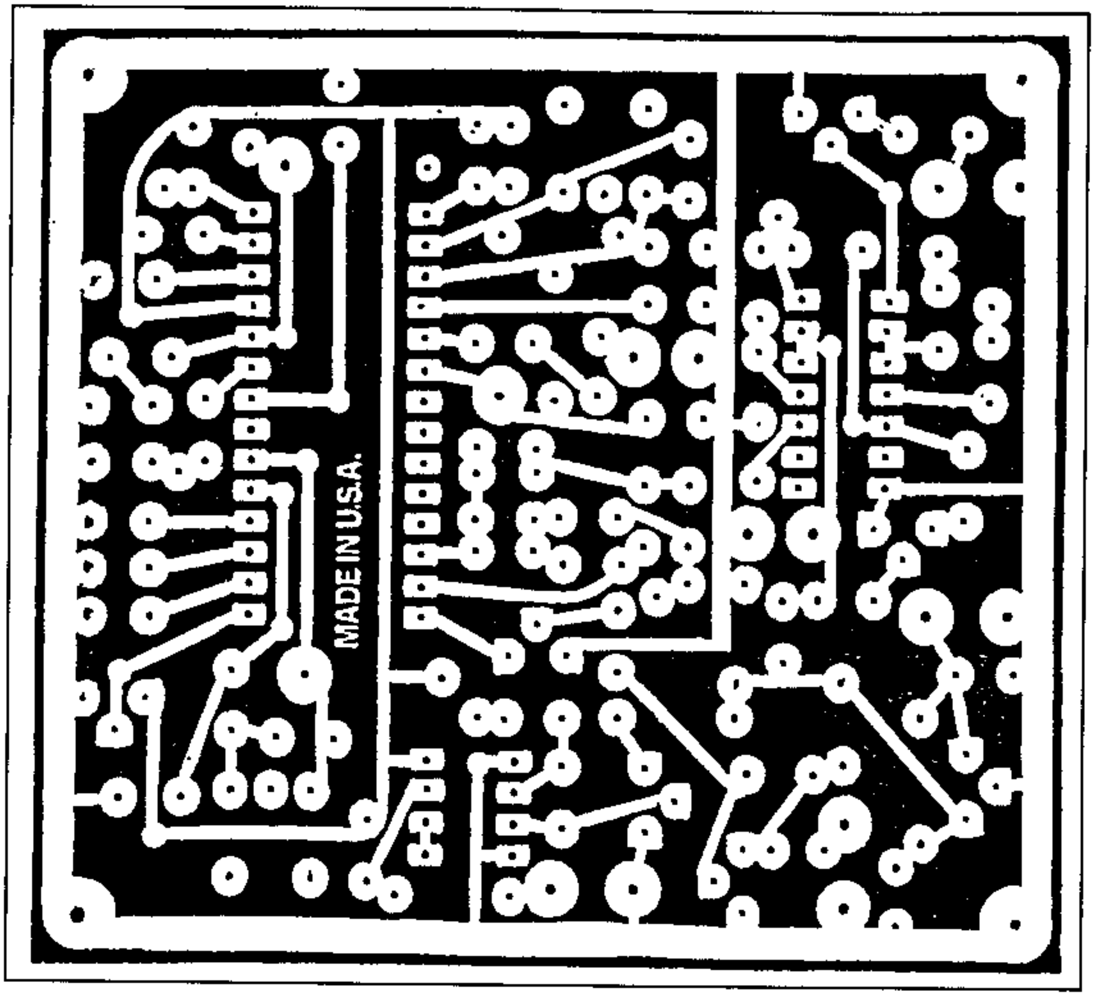


Figure 9. Synchronous detector board layout.

tions: 1) It supplies a low-ripple regulated voltage to the circuitry on the card, allowing it to operate from almost any DC power source in the 7.3 to 35 volt range, and 2) It greatly attenuates the fundamental and harmonics of the MC13022's internal VCO that would otherwise "ride out" on the power supply leads.

Pre-construction notes

Before constructing the synchronous detector described in this article, there are a few aspects of its design that you should be aware of:

- The receiver in which you plan to install the synchronous detector must be stable, with very low local oscillator FM. For instance, several consumer-grade shortwave receivers I tested tend to vary the local oscillator frequency according to the AVC voltage. While the degree of FM may be small (100 to 200 Hz), it may be enough to cause brief detector loss-of-lock during rapid changes in AVC voltage.
- Because the MC13022 is an application-specific chip, modifying it for use as a synchronous detector involves some compromises. One of these compromises is finding an effective manner in which to sense detector lock and operate an external indicator. The comparator included in this circuit (U3) works well in receivers with an AGC system, such as the Drake R-7 or SPR-4, but it does not work well in a receiver with a simple AVC circuit. U3 and its associated circuitry may be deleted if you don't need the sync indicator.
- The audio frequency response of this circuit has been tailored for communications use (200 Hz to 4 kHz). The detector will not provide a wideband audio output unless the notch filter is bypassed. Even then, the frequency response will be limited by the "Q" of the tuned circuit on pin 2 and the response of the IF stages preceding the detector (see **Figure 8**).
- I mentioned earlier that a synchronous detector can be used to demodulate SSB_{-12} transmissions. With SSB_{-12} only the upper sideband is transmitted and the carrier is reduced 12 dB below the sideband PEP. This provides just enough carrier for synchronous detection (although the phase modulation inherent in an SSB signal can make carrier-

lock difficult). SSB_{-12} is just now coming into use on the shortwave broadcast bands, and will become the standard for shortwave broadcasting by the year 2016. While my application for the MC13022 as a synchronous detector works well for full-carrier, DSB transmissions, the MC13022 may not reliably hold lock on SSB_{-12} transmissions because of its internal design. However, the primary design objective for this detector is to combat the effects of selective fading, and by so doing greatly minimize the listener fatigue associated with the reception of ionospherically propagated full-carrier AM signals.

Construction

Construction of the synchronous detector is noncritical. I highly recommend using the circuit board artwork included in this article (see **Figures 9** and **10**);* however, any method of construction may be used. The only sensitive portion of the circuit is the VCO L/C circuit on pins 19 and 20. These leads should be kept as short as possible to maximize stability and minimize microphonics. If you decide to make any component substitutions in this circuit, keep in mind that I spent quite a bit of time determining the values of inductors L1 and L2, as well as the associated capacitors. You may find that the VCO will not run if substitutions are made, especially when the MC13022 is used an IF frequency below 260 kHz. Also, be sure to use the same value of capacitor for C6-C9, as an imbalance in values will cause distortion or difficult VCO locking.[7] All of the remaining components may be substituted as your needs require.

Initial tests

Initial testing of the synchronous detector is quite simple. Begin by applying power to the card, and check for 5.0 ± 0.2 volts at the output of U4. Next, measure the voltage at pin 3 of U1, it should measure 3.0 ± 0.1 volts. Place the circuit in the envelope detector mode (pins 12/13 of U2 at logic high) and check the voltage at TP1 (pin 24 of U1). This should measure

*PC boards are available for $4.50 plus $1.50 shipping and handling from FAR Circuits, 18N640 Field Court, Dundee, Illinois 60118

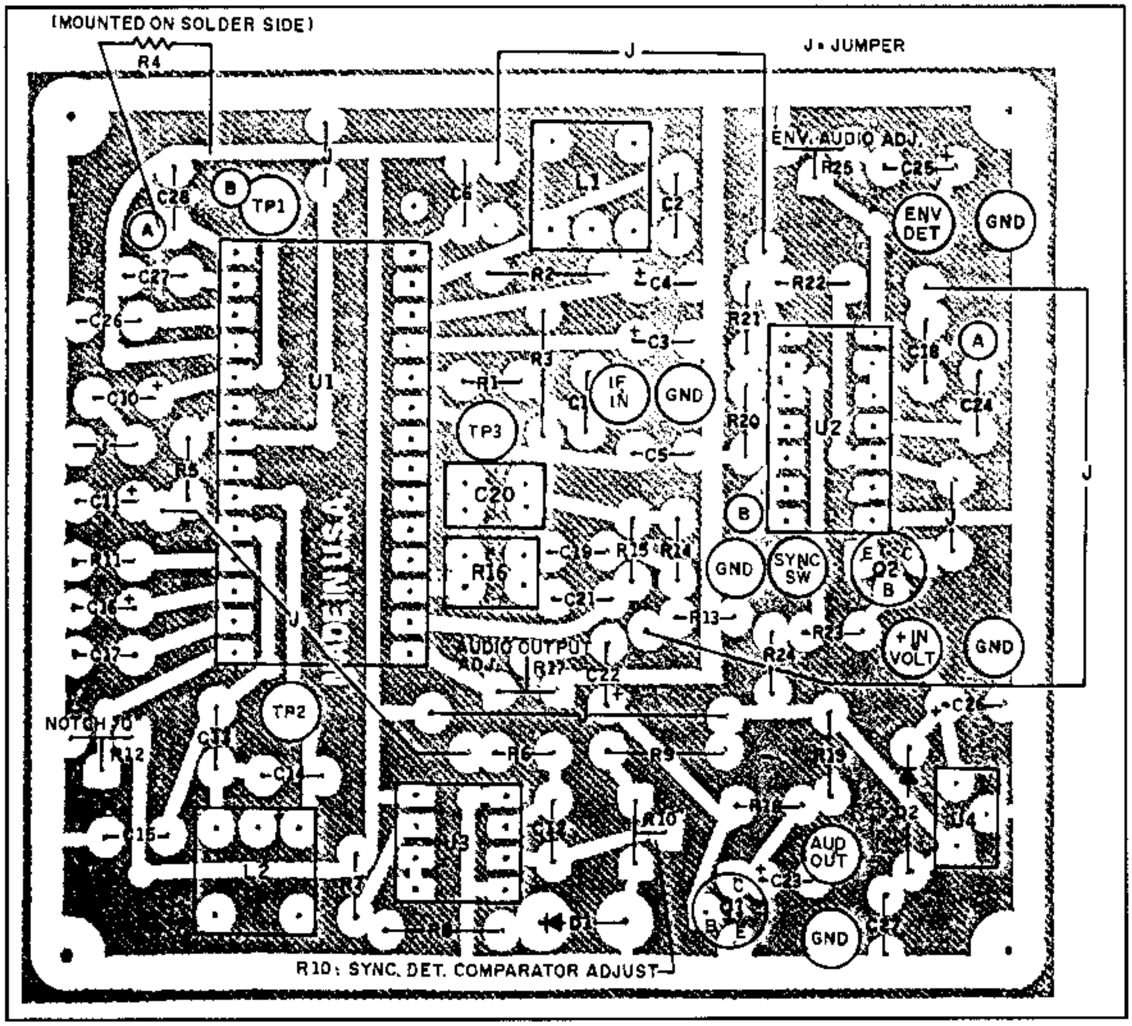


Figure 10. Parts placement.

about 2.8 to 3.1 volts. If all tests indicate proper operation so far, it's time to adjust the VCO resting frequency. To calculate the proper VCO operating frequency, multiply the IF frequency by eight. Attach a frequency counter to TP2 (pin 20 of U1) and adjust L2 until the frequency of the VCO is within 100 Hz of the calculated operating frequency. Next, adjust potentiometer R12 (notch filter Q) for 2.9 volts at pin 15 of U1 and adjust pot R10 (voltage comparator) to supply 0.72 volts to pin 3 of U3. You are now ready to install the card into your receiver.

Installation

This synchronous detector was designed to be easily installed into almost any receiver. The AGC circuit in the IF amplifier allows the circuit to function quite well down to 10 mV of IF signal. Therefore, the IF sample can be taken from any convenient point in the receiver after any IF filters. For example, the IF sample can be taken from an unbypassed cathode bias resistor in the last stage of IF amplification. In some receivers, this level may be too high for the detector (the IF level must be kept below 1 volt RMS). If this is the case, simply substitute the existing cathode bias resistor with two resistors in a series voltage-divider configuration. Choose a division ratio that provides between 100 and 200 mV with a strong input signal (receiver AGC on). In a solid-state receiver, the IF sample can be taken from the input to the diode envelope or product detector. As with a vacuum tube receiver, a voltage-divider may be necessary if the IF level at this point is too high.

Power for the circuit can be taken from any point capable of supplying a minimum of 7.3 volts at about 30 mA. Make certain that you do not exceed the regulator's maximum input of 35 volts. In a vacuum tube receiver, you can derive the necessary power from the 6.3 or 12.6 volt filament circuit. Simply install a power supply consisting of a half-wave rectifier and a 500 µF filter capacitor on the filament bus.

The only critical part of the installation of this card comes in determining its placement within the receiver. You must choose a location that will minimize the coupling of radiated energy from the VCO into the receiver front end. The easiest way to find a location for the card is to provide it with power and try placing it in potential locations within the receiver. Then tune the receiver to the VCO fundamental frequency as well as several harmonics, and note any presence of the VCO signal.

The board can be installed so that it uses either the on-board envelope detector for non-sync audio or the receiver's envelope detector. The choice is primarily dictated by the receiver design and your personal preference. This decision will also be influenced by your desire to route either all audio through the notch filter, or only synchronous detector audio. If the receiver mode switch selects detected audio from two separate points when switching between AM and SSB, you can use either the receiver's envelope detector as an input to R25, or you can use the envelope detector on pin 1 of U1. However, if the receiver mode switch selects AM and SSB audio from the same point, you must feed receiver audio into R25.

Finally, you will need a means for switching between sync and non-sync audio from the front panel. Because the board requires nothing more than a ground to switch sources, this should be simple to do. If you don't want any additional holes in the front panel, look for unused switches. A prime candidate on many receivers would be the receive/standby switch. I used the calibrator switch on the Drake SPR-4, and the "Spkr" switch on the Drake R-7. In any event, make sure you disconnect and normalize any existing wiring to the switch you select prior to connecting the sync audio control line. If you would like specific information concerning the installation of this board into the Drake R-7, Drake SPR-4, or Hallicrafters SX-42, please send me an SASE at the address listed at the beginning of this article.

Alignment

Connect a signal generator tuned to your receiver's IF frequency and to the input of the synchronous detector card. Set the generator for 30 percent modulation at 100 mV output. Connect a DVM to TP3 (pin 6 of U1) and measure the RSSI voltage. With 100 mV input, this test point should measure about 4.0 volts DC. If necessary, tune L1 for maximum RSSI voltage. This completes the alignment of the card in the non-sync mode.

To align the synchronous detector, you need only adjust the VCO frequency. Begin by connecting a signal generator to your receiver at any convenient frequency. Place the receiver in the narrowest bandwidth you would use for voice communication, and center the signal from the generator in the IF passband. Next, connect the synchronous detector card to the IF sample point. Check for proper RSSI voltage as before. Using a scope, also check for a sine wave at pin 1 of U1. Place the synchronous detector in the sync mode, and measure the voltage at TP2. Adjust L2 until this voltage reads 2.9 ± 0.1 volts. Connect a scope to pin 28 of U1. You should now see a sine wave identical to that present on pin 1 of U1. Finally, with the detector locked on your test signal, adjust R10 until the sync light goes out, then back again until just slightly past the point where it comes back on. This sets the comparator threshold for your particular MC13022 blend line. The only remaining alignment is the setting of audio levels.

If you have wired the detector so you will use the on-board envelope detector in the non-sync mode, the only audio adjustment you need to make is to R17. This pot should be adjusted so the audio level from the card matches the level of the detector the card replaced. However, if you plan to use the receiver's envelope detector, there are a couple of additional steps. Connect the signal generator to the receiver, and tune both to a convenient frequency with 30 percent modulation of the carrier. Next, with the card in the sync mode, measure the audio output voltage from the board. Place the board in the envelope-detector mode, and adjust R25 for the same audio level at the output of the board as you had in the sync mode. Alignment of the card is now complete.

Operation

Operating your receiver with the synchronous detector installed is quite simple. Begin by powering up the receiver with the detector in the envelope detector mode. Once the desired station has been selected, center the station in the receiver's passband and select the synchronous mode. If the station was properly centered, the sync LED will illuminate and the audio should be normal. If there is an audible heterodyne, retune the receiver towards zero-beat. The VCO should come into lock and the sync LED should illuminate. You may find that getting the detector into sync may be difficult on very weak stations, or stations with strong adjacent channel interference. However, careful tuning will bring these stations into lock. I highly recommend that you "browse" through the band with the synchronous detector turned off, as the heterodynes created prior to VCO capture tend to become very annoying. Also, occasionally you may find that you cannot achieve VCO lock, even on strong signals. This often happens when tuning through the band with the synchronous detector turned on. This rapid tuning may cause the VCO control voltage to sit at its lower limit. To correct this, place the detector in the envelope-detector mode, then switch back to synchronous. This will re-establish a favorable VCO control voltage, and the detector will come right into sync.

When you should use the synchronous detector is totally a matter of personal preference. I use the sync mode almost all the time, as its audio consistently sounds better than that of a conventional envelope detector. If you use the on-board envelope detector, there may be times on strong signals when you notice no difference between sync and non-sync audio, primarily because the on-board envelope detector is actually quasi-synchronous.

Finally, if you decide to use R12 as a variable tone control, it's important that you do not allow the voltage to pin 15 of U1 to exceed 2.9 volts. The MC13022 generates high-frequency transients when the VCO locks up, causing an annoying "pop" in the audio. The high-frequency roll-off at this setting of R12 is sufficient to attenuate these transients.

Conclusion

The synchronous detector presented in this article provides a simple means of greatly enhancing full-carrier AM reception. As with any unique application of a custom-designed chip, it has its drawbacks. For example, the circuit may not demodulate SSB–12 transmissions, but this is of minimal consequence, as the vast majority of stations utilize full-carrier DSB, and will continue to do so for some time. I feel that this circuit meets the synchronous detection needs of most short and medium-wave listeners. I have installed this board in a Drake R-7, Drake, SPR-4, and Hallicrafters SX-42—all with equally impressive results. The significant reduction in listener fatigue during selective fading was this circuit's primary design intent, and it meets that objective quite satisfactorily.

I hope that by presenting this implementation of synchronous detection, we can begin to bring circuits of this type into common use, and spur others to design even more flexible circuits than what I have presented here. In addition, I look forward to hearing from readers who have designed other applications for this circuit. For instance, the output from the quadrature multiplier could be used to indicate the degree of phase modulation in a signal, which may be useful for some types of propagation measurements or in measuring phase noise. The quadrature output could also be used with a noise blanker or any circuit that could benefit from the lack of an in-phase modulation component.

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