

# EXPERIMENTING WITH PHASE-LOCKED LOOPS

*Four simple but useful circuits that will increase your understanding of these versatile 565 and 567 IC's.*

BY HERB COHEN

**W**HEN phase-locked-loop (PLL) integrated circuits began to appear on the hobby market, the experimenter was faced with the same problem always encountered with new devices: what to do with it. If he tried to understand the theory—usually available in abundance—he was clouted with terms like rads/second, capture ratio, lock range, and lag networks. Needless to say, there was an urge to slam shut the book and treat the IC as a "black box"—not really such a bad idea.

Although there have been a number of articles published in various magazines explaining the basics of PLL theory (see "How Phase-Locked Loops Work," February 1975), a "hands-on" session with these IC's will tell you more about them than all the reading you're likely to do. As an example, the 565 and 567 PLL's are so simple to work with and require so few external components that you don't

need a stage-by-stage understanding of what goes on inside them to put them to use.

In this article, we describe four simple projects you can build around a pair of commonly available PLL's to give a "feel" for how they perform. Each project illustrates a different aspect of phase-locked-loop technology, and each is a practical circuit you can put to immediate use. Before proceeding to the projects themselves, however, let us first discuss the specific PLL's used in our projects.

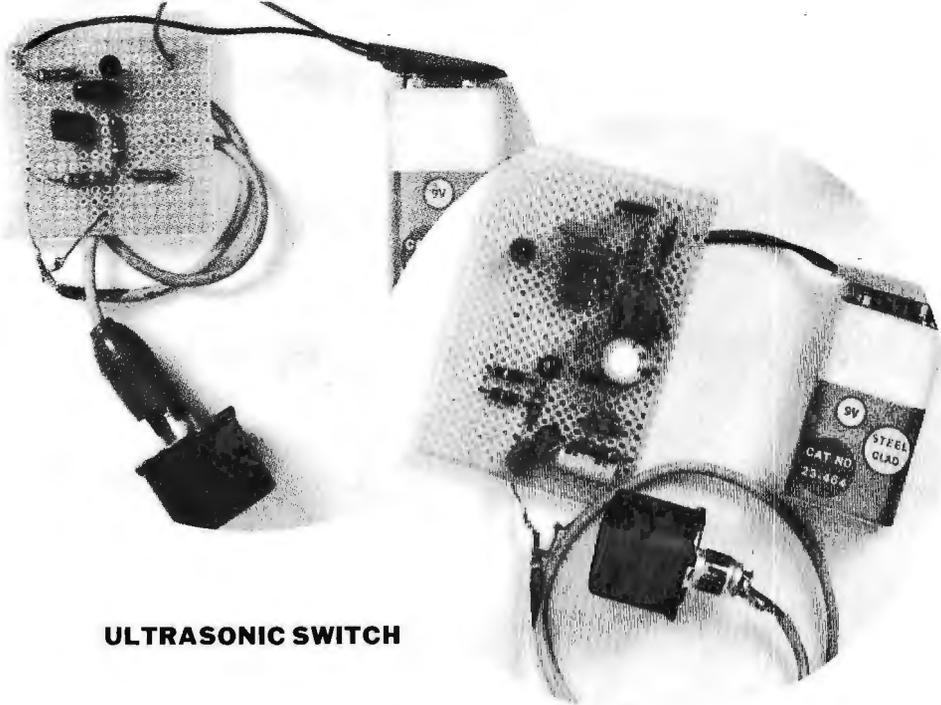
**Two PLL's.** Of the many phase-locked-loop IC's available, the 567 is the only one that is designed primarily for switching applications. When this PLL goes into lock, its output transistor, driven from a quadrature detector, is capable of passing 100 mA of current. This makes the 567 ideal as an SCR or relay driver.

Another unique feature of the 567

PLL is its ability to be driven from a low-voltage (4.5 to 10 volts) power supply at a nominal 10-mA drain. This means that the IC can be powered by a 9-volt transistor battery with good life expectancy. So, although it doesn't have the bandwidth or sensitivity of other PLL's, the 567 is ideal for hundreds of tone-decoder applications in the range from 1 Hz to 100 kHz.

The 565 is a general-purpose PLL IC and is by far the most popular now being used. It exhibits a very wide  $\pm 60\%$  locking range and a 1-mV input sensitivity. This PLL is ideal for use as an SCA decoder, which will let you receive the hidden subchannels on FM.

The following four projects are examples of the simplicity and versatility of the PLL IC. The first three are built around the 567, while the fourth—an SCA decoder—employs the 565 PLL. The circuits can be assembled easily on perforated boards or pc boards.



## ULTRASONIC SWITCH

**Ultrasonic Switch.** The simple transmit/receive system shown in Fig. 1 can receive a signal from distances of up to 40' (12 m) and more in hallways and enclosed areas where the acoustical properties are good. The transmitter is shown in B, while the receiver is shown in A.

Transducers *TR1* and *TR2* in the receiver and transmitter are 40-kHz barium-titanate ultrasonic transducers. Transducer *TR1* in the receiver picks up the sound waves from transmitter transducer *TR2* and passes them to the amplifier consisting of

transistors *Q1* and *Q2*. The PLL (*IC1*) then accepts the amplified signal and rejects any spurious responses and out-of-band noise pulses.

Light-emitting diode *LED1* and limiting resistor *R9* are installed in the circuit only temporarily to assist in tuning the system. Once the system has been properly tuned, these components are removed and replaced with the load to be driven (relay, lamp, etc.).

The transmitter shown in B is a Colpitts oscillator configuration that uses transducer *TR2* in the resonance cir-

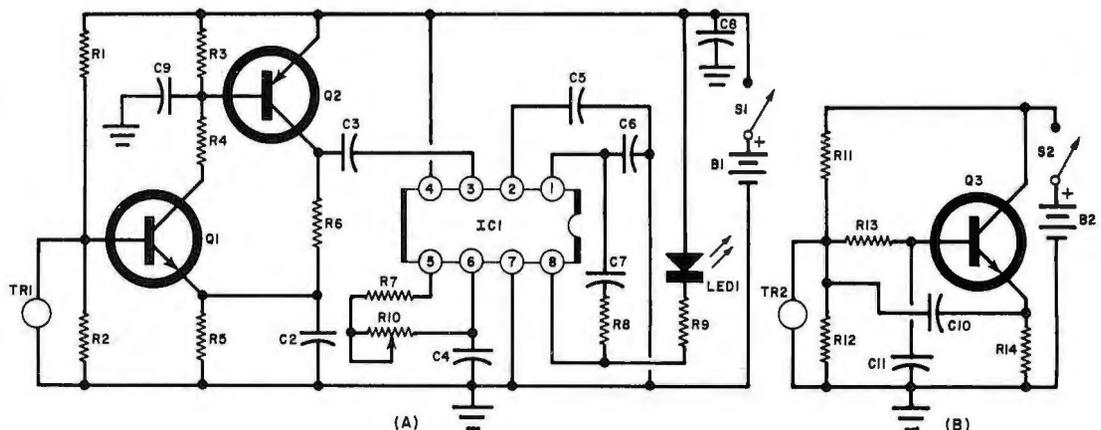
cuit. This circuit puts out a minimum of 2 volts rms across *TR2*, which develops more than enough sound power for the system.

To tune the receiver, place the transmitter about 5' (1.5 m) away from the receiver with both transducers facing each other. Adjust potentiometer *R10* until *LED1* comes on. Turn off the power to the transmitter; *LED1* should immediately extinguish. (Note *LED1* may light up when *R10* tunes the system to a submultiple or harmonic of the transducer frequency, so make sure you're tuned to the fundamental frequency.)

Once the receiver has been properly tuned, the range you can obtain with this system is dependent mainly on room acoustics. However, you should be able to obtain a minimum of 20' (6.1 m) of range.

The ultrasonic relay system can be used as an intruder alarm, garage door opener, or remote relay. It can even be made to operate as a simple motion detector. To do this, place the transmitter and receiver about 10' (3 m) apart and with their transducers facing the same wall in a room. The LED in the receiver should come on; if it doesn't, move the transmitter closer to the receiver until it does. Then, move it away until the LED just extinguishes. Now, walk along the side of the room that the transmitter and receiver are facing. As you move, the LED will blink on and off.

Fig. 1. A simple transmit/receive ultrasonic relay.

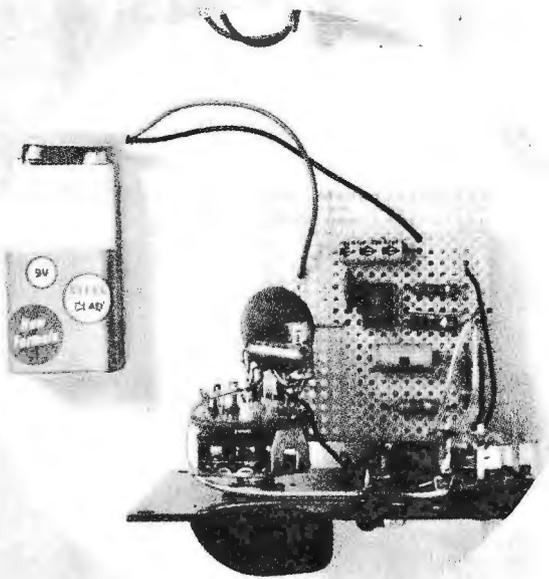


### PARTS LIST

B1, B2—9-volt battery  
 C1, C6—0.04- $\mu$ F disc capacitor  
 C2—5- $\mu$ F, 10-volt electrolytic capacitor  
 C3, C4—0.0047- $\mu$ F disc capacitor  
 C5—0.1- $\mu$ F disc capacitor  
 C7, C10—0.02- $\mu$ F disc capacitor  
 C8—100- $\mu$ F, 10-volt electrolytic capacitor  
 C9—0.001- $\mu$ F disc capacitor  
 C11—330-pF disc capacitor  
 IC1—567 PLL IC

LED1—Light-emitting diode  
 TR1, TR2—Ultrasonic transducer (Detector No. HCl)  
 Q1—2N4946 pnp transistor  
 Q2—2N4917 npn transistor  
 Q3—HEP S0007 npn transistor  
 The following are  $\frac{1}{4}$ -watt, 10% resistors:  
 R1—180,000 ohms  
 R2—43,000 ohms  
 R3, R4—2200 ohms

R5, R13, R14—1000 ohms  
 R8, R7—2700 ohms  
 R9—330 ohms  
 R11—22,000 ohms  
 R12—47,000 ohms  
 R10—10,000-ohm miniature potentiometer  
 S1, S2—Spst switch  
 Misc.—Battery clips; hookup wire; solder; etc.

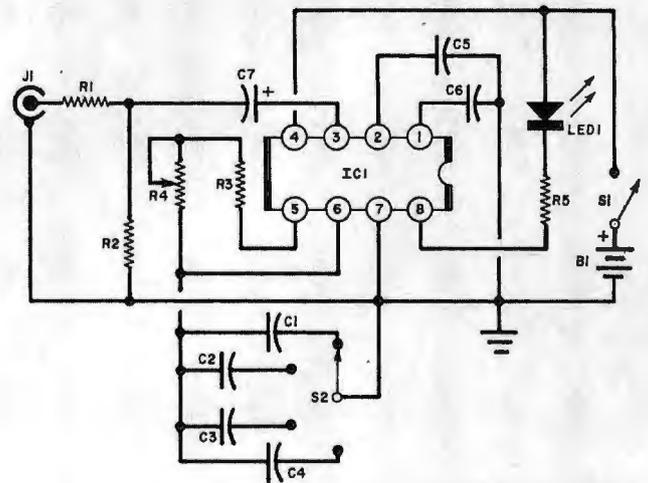


### TUNABLE FILTER

**Tunable Filter.** The circuit shown in Fig. 2 illustrates the use of the 567 PLL as a wideband (10-to-100-kHz) tunable filter. Potentiometer *R4* is the fine-tuning control. If its dial is accurately calibrated, the knob pointer can indicate to better than 5% accuracy, the frequency of any incoming signal within the filter's range. This circuit can be used for stereo tuning and tape bias oscillator adjustments. As a tone decoder, it would be hard to beat.

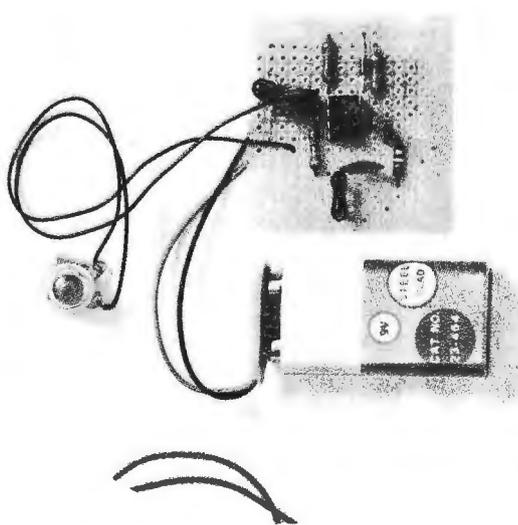
The circuit has several interesting features. First, the bandpass of the filter is proportional to the input voltage, from 1% to about 14% of the bandwidth. Second, when the PLL starts to lock onto the incoming signal, the

*Fig. 2. Tunable filter circuit can be used as a tone decoder.*



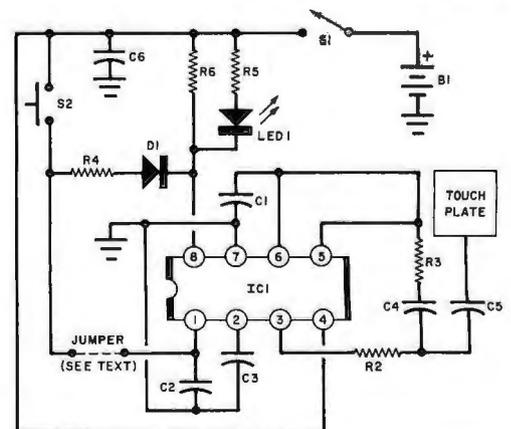
### PARTS LIST

- |   |   |
|---|---|
| B1—9-volt battery                                 | LED1—Light-emitting diode                     |
| C1—0.01- $\mu$ F disc capacitor                   | R1—4700-ohm, 1/4-watt resistor                |
| C2—0.1- $\mu$ F disc capacitor                    | R2—2200-ohm, 1/4-watt resistor                |
| C3—1- $\mu$ F, 15-volt electrolytic capacitor     | R3—1000-ohm, 1/4-watt resistor                |
| C4—10- $\mu$ F, 10-volt electrolytic capacitor    | R4—10,000-ohm, linear-taper potentiometer     |
| C5—0.05- $\mu$ F disc capacitor                   | R5—330-ohm, 1/4-watt resistor                 |
| C6, C7—5- $\mu$ F, 15-volt electrolytic capacitor | S1—Spst switch                                |
| C8—100- $\mu$ F, 15-volt electrolytic capacitor   | S2—4-position non-shorting rotary switch      |
| IC1—567K PLL IC                                   | Misc.—Battery clip; hookup wire; solder; etc. |
| J1—Phono jack                                     |   |



### TOUCH SWITCH

*Fig. 3. Touch switch can be made to latch in by adding the jumper.*



### PARTS LIST

- |   |   |
|---|---|
| B1—9-volt battery                       | C6—30- $\mu$ F, 10-volt electrolytic capacitor                            |
| C1—0.005- $\mu$ F disc capacitor        | D1—1N914 diode  |
| C2, C3, C4—0.04- $\mu$ F disc capacitor | IC1—567 PLL IC  |
| C5—33-pF disc capacitor                 | S1—Spst normally open, momentary-action switch                            |
|   | Misc.—3" x 3" solderable metal for touch plate; hookup wire; solder; etc. |

**Touch Switch.** As a convenience feature in a home, the touch switch,

shown in Fig. 3, is hard to beat. Just by touching the plate, body capacitance unbalances the circuit and pulls IC1 into lock. An external signal is normally fed into the PLL (IC1) via pin 3 and C1 and R1 are used to tune the voltage-controlled oscillator to the input frequency. When lock occurs,

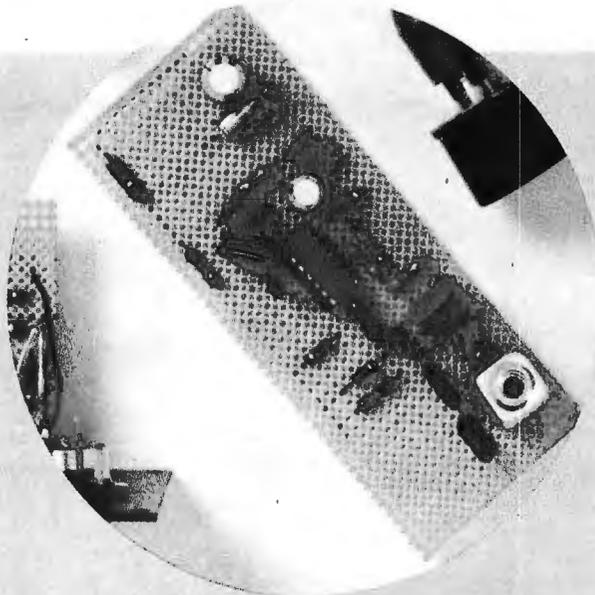
the vco adjusts itself to be 90° out-of-phase with the input signal.

With the input signal at pin 3 coming from the output of the vco (pin 5 of IC1) through C4, R2, and R3, the two signals are in-phase with each other and the circuit cannot lock. However, when the touch plate is approached,

enough capacitive phase shift is introduced to allow the circuit to lock.

Wiring the jumper into the circuit as shown allows the system to latch in the on position even after your hand is removed from the touch plate. To reset the system to off requires S1 to be closed momentarily.

## SCA DECODER



**SCA Decoder.** Our final PLL project is an SCA decoder built around the 565 phase-locked-loop IC. This is es-

entially a 67-kHz FM detector. However, a PLL is a better detector for FM than any of the traditional detector de-

signs because it has the ability to dive 6 dB below the noise level and still lock onto a signal.

In the case of an SCA subchannel where the information is only 10% of the total program power (most of that lost in the audio filtering), the 565 IC's ability to reject noise is an important factor in building a simple and effective SCA decoder.

Capacitors C1, C2, and C3 and coil L1 (Fig. 4) form a bandpass filter that peaks at 67 kHz and rejects all low-frequency components of the audio signal in an FM tuner. Transistor Q1 amplifies this signal and passes it to IC1. The PLL IC is tuned by C7, R6, and R10. Since the tuning frequency is also a function of the supply voltage, the IC should be zener-diode regulated.

The demodulated audio signal comes out of the decoder at a 50-mV level. It has a 7,000-Hz audio bandwidth that can hardly be considered hi-fi. This bandwidth, however, is more than sufficient for background music.

The tuning procedure is simple. Connect the output of your FM tuner to the input of the SCA decoder and the output of the decoder to your audio amplifier. Set R10 to the center of rotation. Scan the FM dial; all you should be able to hear at this point is noise and no stations. An SCA subchannel will appear as a sharp drop in the noise level, accompanied by a distorted music program. Now, adjust R10 for the best signal-to-noise (S/N) ratio and highest fidelity.

Tune to the weakest SCA subchannel you can find. Adjust L1 for the lowest possible noise level. The SCA decoder is now ready to use.

**Closing Comment.** The preceding four projects illustrate only a small portion of the possible applications to which the versatile phase-locked-loop IC can be put. A couple of the projects should be able to suggest other projects of your own.

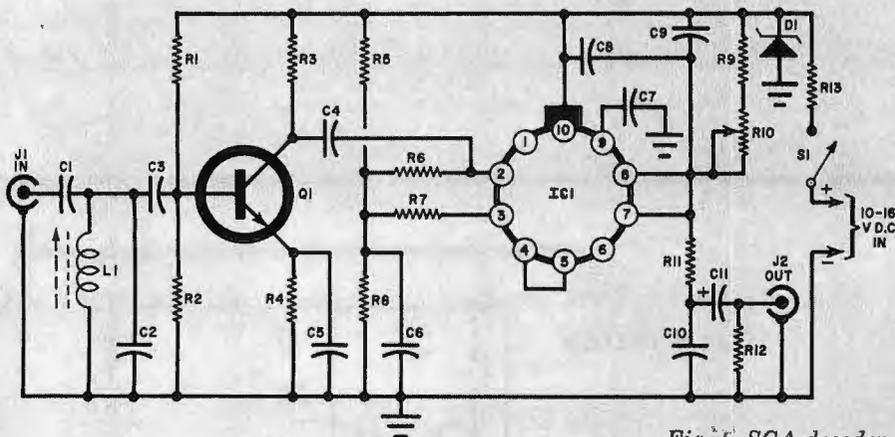


Fig. 4. SCA decoder.

### PARTS LIST

C1—220-pF disc capacitor  
 C2—0.002- $\mu$ F disc capacitor  
 C3—330-pF disc capacitor  
 C4—560-pF disc capacitor  
 C5, C9, C10—0.04- $\mu$ F disc capacitor  
 C6—0.1- $\mu$ F disc capacitor  
 C7—0.001- $\mu$ F disc capacitor  
 C8—0.001- $\mu$ F disc capacitor  
 C11—30- $\mu$ F, 15-volt electrolytic capacitor  
 D1—12-volt zener diode  
 IC1—565 PLL IC  
 J1, J2—Phono jack  
 L1—10-mH slug-tuned inductor (Miller No. 9060)  
 Q1—2N2926 npn transistor

The following are  $\frac{1}{4}$ -watt, 10% resistors:  
 R1—100,000 ohms  
 R2—22,000 ohms  
 R3—8200 ohms  
 R4—1500 ohms  
 R5—15,000 ohms  
 R6, R7, R11—4700 ohms  
 R8—6800 ohms  
 R9—1000 ohms  
 R12—47,000 ohms  
 R10—10,000-ohm, linear-taper potentiometer  
 R13—47,000-ohm,  $\frac{1}{2}$ -watt, 10% resistor  
 S1—Spst switch  
 Misc.—Battery clip; hookup wire; solder; etc.