The Basic Circuits Handbook for Electronics Experimenters

33 Bench-Tested Circuits

By the Editors of
POPULAR ELECTRONICS

A GERNSBACK PUBLICATION

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ABOUT THIS BOOKLET

As an old Turkish saying goes, "Show me an electronic engineer who has enough basic circuits on file and I'll show you an engineer who concentrates on playing checkers!" Well, maybe the saying is not that old and maybe it didn't come out of Istanbul. Nevertheless, the collection of circuits in this booklet are from "Circuit Circus" columns gleaned from *Popular Electronics* magazine and are the choice ones that raised the most interest measured by readers who wrote to the Editor.

The circuits given herein work! Limited to one or a few semiconductor devices per circuit, they perform well. What is interesting about them is that the circuit designer who uses them will either find them satisfactory for the purpose intended or he (or she) will be inspired to improve them thereby promoting the art of the engineer, or hobbyist, whatever the case may be. Good luck in your applications, and I hope you have as much fun with these circuits as I had.

Julian Martin, Editor Emeritus
Popular Electronics magazine

Circuit Circus

By Charles D. Rakes

USING SOUND FOR DETECTION AND MEASUREMENT

This month we're going to play around with a number of circuits that use audible and inaudible sound to detect objects, measure distance, and perform some other interesting experiments.

The velocity of sound traveling in air is slower than a snail on an incline when compared to the speed of light and electrical energy traveling through free space. Sound travels through the air at a rate of about 1100-feet-per-second—depending on the temperature, which effects the speed of sound by about 1-foot-per-second per degree Fahrenheit. Near freezing (0°C or 32°F) sound travels at a speed of about 1100-feet-per-second; and at a more sultry 100°F, sound speeds up to about 1175-feet-per-second.

In water sound travels at over 4000-feet-per-second; but through most metals and glass, its speed jumps to a rate of over 1-mile per second. Frequency has no affect on the speed at which sound travels; *i.e.*, two sounds of different frequencies traveling through the same medium will move at the same rate of speed.

Knowing the affect of various mediums on the movement of sound waves makes it possible to detect objects within a given area or measure distances. The simplified block diagram of a distance-measuring system—consisting of a pulse generator, an amplifier, and an oscilloscope—that allows you to use sound as an "electronic tape-measure" is shown in Fig. 1. In essence, what we are talking about is an extremely simple and limited-distance sonar system.

The pulse generator sends out a narrow pulse of energy to a transmitting transducer. The sound travels from the transducer to a solid object and is reflected back toward the receiver circuit. The reflected signal is then picked up by another transducer, sent to the amplifier, which in turn feeds the amplified signal to the vertical input of the oscilloscope.

The scope's horizontal sweep is triggered by the pulse generator, which is set up to start the sweep at the same time the sound leaves the transducer. The time it takes the sound to travel to the solid object and return to the receiver's pickup can be determined by simply measuring the distance between the two pulses that are displayed on the scope's screen.

The Transmitter. Figure 2 shows the transmitter portion of our measuring system. The transmitter, which is nothing more than a pulse-generator circuit feeding a piezo transducer, is capable of supplying enough output power to operate our simple distance-measuring system. In Fig. 2, a 555 timer (U1) is configured as a bistable multivibrator (flip-flop) and is placed between trigger-switch S1 and the pulse generator. The bistable circuit is used to prevent contact bounce from sending multiple trigger pulses to U2 and, thereby, causing erroneous output pulses.

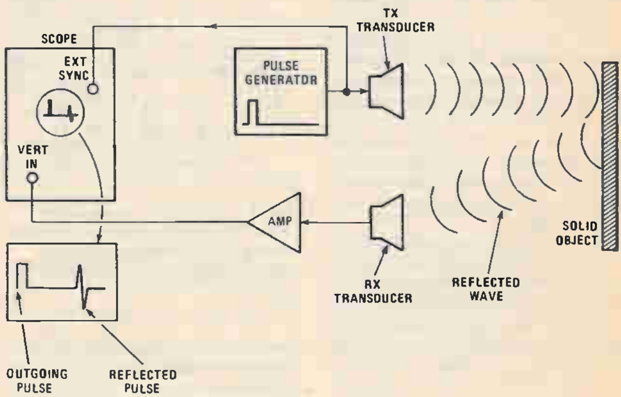


Fig. 1. Here's a simplified block diagram of a distance-measuring system—consisting of a pulse generator, an amplifier, and an oscilloscope—that allows you to use sound as an "electronic tape-measure"—in essence, it's an extremely simple radar system.

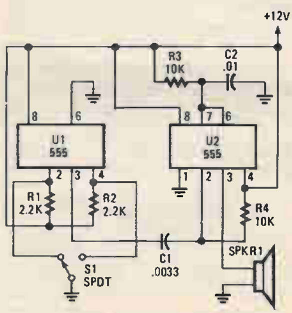


Fig. 2. The transmitter is nothing more than two 555 oscillator/timers; one is configured as a monostable multivibrator (U2) and the other is configured as a bistable multivibrator (U1).

A second 555 timer, U2, and its associated components make up a pulse-generator circuit that produces a single positive output pulse for each negative trigger received. The values of R3 and C2 set the pulsewidth of the output signal. The formula for setting pulsewidth is T = 1.1RC; where T is time in seconds, C is capacitance in microfarads, and R resistance in megohms. With the values shown in Fig. 2, the output pulsewidth is 0.00011 second or .11 millisecond.

It takes one second for sound to travel 1100 feet; 100 milliseconds (ms) for a trip of 110 feet; 10 ms for 11 feet; and only .909 ms to travel 1 foot. The formula for determining the time for sound to travel a given distance is T = D/1100;

PARTS LIST FOR THE TRANSMITTER

U1, U2—555 oscillator/timer, integrated circuit
R1, R2—2200-ohm, ¼-watt, 5% resistor
R3, R4—10,000-ohm, ¼-watt, 5% resistor
C1—0.0033-µF, ceramic-disc capacitor
C2—0.01-µF, ceramic-disc capacitor
BZ1—Piezo speaker (RS 40-1383 or 40-1397)
S1—SPDT toggle switch
Printed-circuit or perfboard materials, enclosure, 12-volt power source, wire, solder, hardware, etc.

where T is time in seconds and D is distance in feet. And if the time of travel is known, the distance can be determined by: D = T × 1100.

The circuit in Fig. 2 can be modified to automatically transmit pulses at a given rate by adding the low-frequency oscillator shown Fig. 3 (which, with the component values shown, has an output frequency of about 2 Hz) to the pulse-generator circuit shown in Fig. 2. That would eliminate the need to manually key the pulse generator for each output pulse.

Adding the low-frequency oscillator to the transmitter circuit is easy. Simply remove C1 from the circuit in Fig. 2, and connect C2 of Fig. 3 to pin 2 of U2 in Fig. 2. If you want to raise the pulse rate, just lower the value of R2; to lower the rate increase the value of R2.

The Receiver. Figure 4 shows the receiver section of the distance-measuring system. In that circuit, a single 741 op-amp (U1) is wired as an inverting amplifier and is used to boost the level of the incoming signal by a factor of about 100. That pushes the operating range of the receiver to well over 12

PARTS LIST FOR THE RECEIVER

U1—741 op amp, integrated circuit
R1—1000-ohm, ¼-watt, 5% resistor
R2, R3—10,000-ohm, ¼-watt, 5% resistor
R4—100,000-ohm, ¼-watt, 5% resistor
C1—0.01-µF, ceramic-disc capacitor
C2—0.1-µF, ceramic-disc capacitor
C3—47-µF, 16-WVDC, electrolytic capacitor
BZ1—Piezo speaker (RS 40-1383 or 40-1397)
Printed-circuit or perfboard materials, enclosure, 12-volt power source, etc.

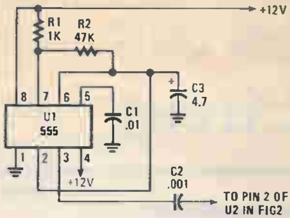


Fig. 3. By adding this low-frequency oscillator to the transmitter circuit in Fig. 2, the transmitter can be made to automatically transmit pulses at a given rate.

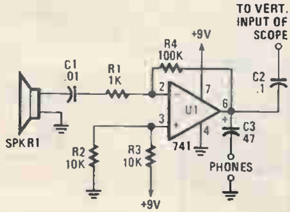


Fig. 4. In the receiver section of the distance-measuring system, a single 741 op-amp (U1) is wired as an inverting amplifier and is used to boost the level of the incoming signal by a factor of about 100.

feet. The output of the receiver is fed to the vertical input of an oscilloscope through a 0.1-µF capacitor (C2). Headphones can be connected to U1's output to monitor the return pulses.

The presence of fair-size objects can be detected from several feet away using that method, but will not give an indication of the actual distance between the transducers and the detected object. The system could be made portable to assist in night time navigation by sending out a pulse and listening for the return. Walls and other large objects would easily be detected. However, small items would likely be missed. That is an area that seems tailor-made for experimenting.

After assembling the two halves of the circuit, it must be checked for proper operation. Start by feeding several trigger pulses to the circuit, either by flipping S1 back and forth or by enabling the oscillator. As trigger pulses are received, a brief click should be heard coming from BZ1—one for each trigger pulse. If so, connect the scope's EXTERNAL-SYNC input to pin 3 of U2, and the vertical input across the receiving piezo transducer.

Set the vertical input of the scope for maximum gain and position the horizontal sweep for 1-ms-per-division. Place the two piezo transducers about one foot apart and facing each other. Activate S1 and a pulse should occur on the scope's screen about one millisecond (one division) after the trace begins. Separate the two transducers by two feet and the pulse will take about 2 milliseconds to make the trip.

Distances of over four feet can be measured with this simple set up. Place the two transducers side by side facing the same direction and directed away from any object or close by wall. Position a piece of solid material that's about 1-foot square parallel to and about one foot in front of the two transducers. Activate S1 and the reflected pulse should occur about 2 millise-

PARTS LIST FOR THE MOTION DETECTOR

SEMICONDUCTORS

U1—567 phase-locked loop, integrated circuit
U2—1496 balanced modulator/demodulator, integrated circuit
U3—386 low-voltage audio-power amplifier, integrated circuit
Q1, Q2—2N3904 general-purpose NPN silicon transistor

RESISTORS

(All resistors are ¼-watt, 5% units, unless otherwise noted.)
R1–R5—1000-ohm
R6–R10—10,000-ohm
R11–R13—2200-ohm
R14, R15—100-ohm
R16-R18—270-ohm
R19—10-ohm
R20—220,000-ohm
R21—50,000-ohm potentiometer
R22—25,000-ohm potentiometer
R23—5000-ohm potentiometer

CAPACITORS

C1–C8—0.1-µF, ceramic-disc
C9—0.0018-µF, 100-WVDC, mylar
C10, C11—0.05-µF, 100-WVDC, mylar
C12—47-µF, 16-WVDC, electrolytic
C13—220-µF, 16-WVDC, electrolytic
C14—470-µF, 16-WVDC, electrolytic
C15, C16—4.7-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

BZ1, BZ2—Piezo speaker (RS 40-1397 or similar)
SPKR1—8-ohm, 4-inch speaker
Perfboard materials, enclosure, 9-volt power source, wire, solder, hardware, etc.

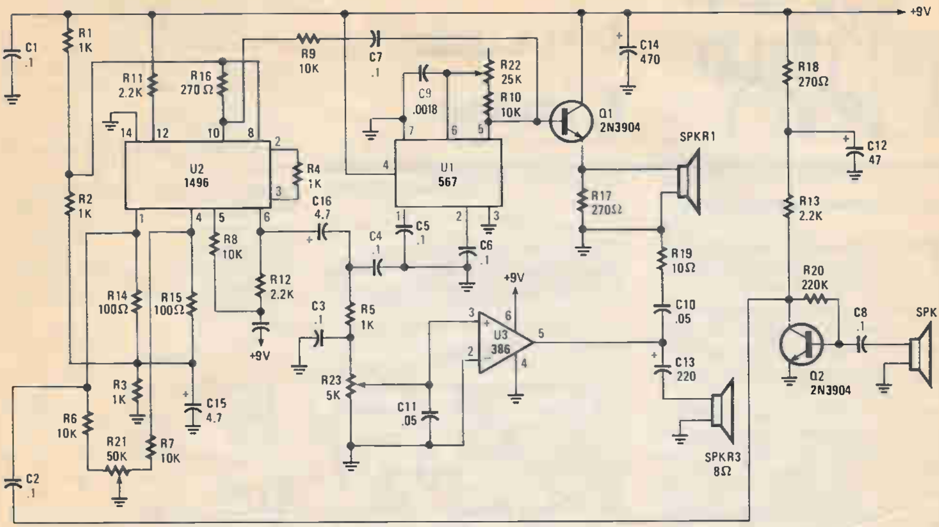


Fig. 5. The motion detector is based on the Doppler effect. If the sound source or the detected object is in motion, as they approach each other the sound increases in frequency and level; and as they pass, the frequency and level decrease.

conds after the start of the trace. That's 1 millisecond for the pulse to go from the transmitter's transducer to the solid object, and another 1 millisecond for the return trip, for a total distance of 2 feet.

Motion Detector. Another interesting characteristic of sound is the Doppler effect. The Doppler effect occurs when the source that's generating the sound is in motion. As the source approaches, the sound increases in frequency and level; and as it passes, the frequency and level decrease. If the sound source is stationary and you move toward or away from the source, the same Doppler effect occurs.

The circuit in Fig. 5 uses the Doppler effect to detect movement within a given area. A high-frequency sound source (15 to 25 kHz) is directed toward the desired area, and a sensitive transducer is positioned close to and aimed in the same direction as the transmitter's transducer. As long as there is no movement within the area, the reflected sound and transmitted sound are of the same frequency. Any movement will cause a slight frequency shift that will be detected by the receiver.

In Fig. 5, U1 (a 567 phase-locked loop) is configured as a tunable oscillator with an output-frequency range of 15 to 25 kHz. Potentiometer R22 is used to adjust the output frequency of the oscillator. The output of U1 is buffered by Q1 and fed to BZ1 (the transmitter transducer).

The reflected sound is picked up by BZ2 (in the receiver portion of the circuit) and applied to the base of Q2. The amplified output of Q2 is fed to U2 (a double balanced mixer) at pin 1. Another signal (taken from the output of U1) is fed to U2 at pin 10. Resistor R21 (a 50k potentiometer) which is used as a carrier-balance control that can be adjusted to keep the oscillator's signal from appearing in the mixer output at pin 6 of U2.

The mixer's output at pin 6 of U2 is fed through a low-pass filter to the input of U3 (a 386 low-voltage audio power amplifier). A speaker or headphones can be used to monitor the output of U3. Potentiometer R23 is used as a volume control.

Nothing about the circuit is critical. In fact, the circuit can be built on a section of perfboard. And if you follow a neat layout scheme (keeping all leads as short as possible), you should have no trouble. It would be a good idea to separate the receiver's input and the transmitter's output circuitry as much as possible in the layout, and to socket all IC's.

Once the circuit has been assembled, it will be necessary to check its operation. Start by positioning the two transducers about 4 inches apart, facing in the same direction, and away from any close objects. Set R21, R22, and R23 to mid position and apply power to the circuit. If you can hear the transmitter's output, the oscillator's frequency is set too low; adjust R22 to the point where you no longer hear it.

Adjust R21 for the quietest output in SPKR1. Wave your hand back and forth in front of the transducers and you should hear a varying low-frequency tone. The faster the movement, the higher the output frequency. For really slow moving objects, you might want to connect an analog DC meter to the output of U3 at pin 5. The meter's needle will vary up and down the scale as the slow-moving object passes in front of the transducers. ■

PARTS LIST FOR THE LOW-FREQUENCY OSCILLATOR

U1—555 oscillator/timer, integrated circuit
R1—1000-ohm, ¼-watt, 5% resistor
R2—47,000-ohm, ¼-watt, 5% resistor
C1—0.01-µF, ceramic-disc capacitor
C2—0.001-µF, ceramic-disc capacitor
C3—4.7-µF, 16-WVDC, electrolytic capacitor

Circuit Circus

By Charles D. Rakes

USEFUL AMPLIFIER CIRCUITS

This month we're going to play around with a number of unrelated circuits that can stand alone or be combined with circuits of your own design to complete a new or on-going project. In any case get out your junkbox, plug in your iron, and let the Circus begin.

How many times have you needed to speak to someone in another room, but couldn't without interrupting your work and making the journey in person to deliver the message? If that scenario fits your predicament then consider building our handy-dandy little intercom circuit, and send your messages at lightning speed electronically.

Two-Way Com-Link. Figure 1 shows a schematic diagram of a two-station intercom system. Not only is that intercom circuit simplicity itself, but it also offers features not found in some commercial units. There's only one IC per unit and a single inexpensive spring-return toggle switch takes care of the TALK/LISTEN function. When the intercom is in the normal listening position there's no current drain from the battery, and just about any two-wire cable can be used for the transmission line between units. Also, you can connect up to four units to the same two-wire circuit.

A miniature omni-directional electret-microphone element picks up the audio, eliminating the need for a matching transformer and additional switch contacts for switching a single pickup/output device between the input and output circuitry. In a typical intercom a single speaker and matching transformer is used for both sound pickup and output duties. Our approach works just as well and is less expensive and easier to build.

The input audio passes through C1 to the volume-control potentiometer, R2, and from there is fed to the input of the IC amplifier (U1, an LM386 low-voltage audio-power amplifier), where it is amplified about 200 times. The output of U1 is coupled through C4 to one contact of switch S1-b. From there the signal is routed to the other intercom speakers via the two-wire interconnecting cable. Each intercom is powered by a single inexpensive 9-volt battery.

At rest, each intercom unit is in the LISTEN position with their speakers tied together through the two-wire cable. In that condition, no power is applied to either of the two stations. When any one of the intercom stations is switched to the TALK position, the battery is connected and the amplifier's output is fed to the intercom speaker at the other end of the com-link through the two wire cable.

Building the intercom is simple. Since the parts count is small and the circuit is

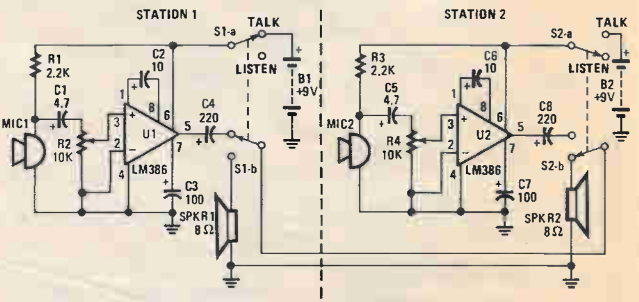


Fig. 1. The Two-Way Com-Link is a simple amplifier design, built around the LM386 low-voltage audio-power amplifier. A single-pole double-throw (SPDT) spring-return switch is used to toggle between the talk and listen modes at each station.

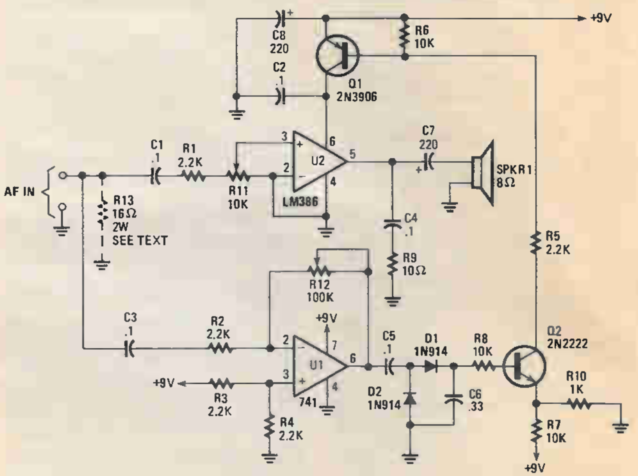


Fig. 2. The Audio-Squelch Circuit is designed to be connected between a receiver's audio output and a speaker to suppress the background noise that might be present between transmissions and during tuning. The circuit can also be used as a power amplifier (with built-in squelch) for a homebrew receiver designed for headphone use only.

PARTS LIST FOR THE TWO-WAY COM-LINK

CAPACITORS
C1, C5—4.7-µF, 16-WVDC, electrolytic
C2, C6—10-µF, 16-WVDC, electrolytic
C3, C7—100-µF, 16-WVDC, electrolytic
C4, C8—220-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS
U1, U2—LM386 low-voltage audio-power amplifier, integrated circuit
R1, R3—2200-ohm, ¼-watt, 5% resistor
R2, R4—10,000-ohm potentiometer
B1, B2—9-volt transistor-radio battery
M1, M2—Electret microphone element
S1, S2—DPDT spring-return toggle switch
SPKR1, SPKR2—3 to 4-inch 8-ohm speaker
Printed-circuit or perfboard materials, enclosure, knob, battery snap, battery holder, wire, solder, hardware, etc.

not critical, you can follow just about any construction scheme that suits your ability. This com-link is an ideal project for printed-circuit board construction and would be a good choice for your first attempt at laying out a printed-circuit board, or you can use perfboard and push-in pins. In any case it's a good idea to use IC sockets for the LM386 amplifiers.

The circuit can be housed in just about any enclosure, but plastic is usually cheaper and easier to work with. Mount the electret mike element(s), speaker(s), and switches to face the front of the cabinet. Since you'll probably only need to set the talk volume once, R2 can be located inside the project's enclosure. That will also discourage Murphy from cutting you off by turning the gain down to zero.

To test your homebrew com-link, simply connect the two stations together through a two-conductor run of wire—they should be separated by at least 10 feet to reduce acoustical feedback—and set R2 to its mid position. Place the switch of either (not both) stations in the "talk" position and speak into the mike and adjust R2 for the desired output level in the other unit's speaker. Then reverse the procedure using the other intercom.

PARTS LIST FOR THE AUDIO-SQUELCH CIRCUIT

SEMICONDUCTORS
U1—741 op-amp, integrated circuit
U2—LM386 low-voltage audio-power amplifier, integrated circuit
Q1—2N3906 general-purpose, PNP silicon transistor
Q2—2N2222 general-purpose, NPN silicon transistor
D1, D2—1N914 general-purpose, silicon diode

RESISTORS
(All resistors are ¼-watt, 5% units, unless otherwise noted.)
R1–R5—2200-ohm
R6–R8—10,000-ohm
R9—10-ohm
R10—1000-ohm
R11—10,000-ohm potentiometer
R12—100,000-ohm potentiometer
R13—16-ohm, 2-watt

CAPACITORS
C1–C5—0.1-µF, ceramic-disc
C6—0.33-µF, Mylar or similar
C7, C8—220-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS
SPKR1—8-ohm, 4-inch speaker
Perfboard materials, enclosure, knobs, DC power source (see text), wire, solder, hardware, etc.

Audio-Squelch Circuit. If you enjoy listening to a radio that is equipped with a squelch, then you'll love our next circuit. Figure 2 shows an audio-squelch circuit that can be connected between a receiver's audio output and a speaker to suppress the background noise that's present between transmissions and during tuning. The audio squelch can make an AM, CW, or SSB receiver sound like a squelched FM radio. The circuit can also be used as a power amplifier (with built-in squelch) for a homebrew receiver designed for headphone use only.

At the heart of the circuit are two IC's: an LM386 low-voltage audio amplifier and a 741 general-purpose op-amp. The LM386 supplies drive for the external speaker and the 741 op-amp controls the squelch's threshold level.

The receiver's audio is fed to the input of both IC amplifiers. The op-amp (U1) can amplify the audio presented to its input by up to 45 times, as determined by the setting of the threshold/gain control, R12. The output of the op-amp at pin 6 is converted to DC by D1 and D2, producing a positive DC signal. That signal is fed to the base of Q2, forward biasing it. The voltage at the junction of R7 and R10 sets the emitter of Q2 to about a 1-volt bias level. When the DC signal voltage at the base of Q2 rises above a 1.6-volt level, Q2 turns on.

Transistor Q2's collector pulls R5 to near ground potential, turning Q1 on and powering up the LM386 audio amplifier. The audio signal is amplified and fed to the speaker. As long as the average input-signal level remains fairly constant, U2 remains on, but if the audio drops sufficiently or stops altogether the procedure reverses and U2 is turned off. The values of C6 and R8 determine the time constant for the turn-off delay period.

The audio squelch circuit can be built on perfboard and mounted in a small metal or plastic enclosure, or located inside a receiver. Any 9- to 12-volt DC source that can supply up to 100 mA will power the circuit.

To use the squelch circuit, connect the squelch's audio input to the receiver's external-speaker output and add R13 (a 16-ohm, 2-watt resistor) between the positive signal input and ground, as shown in Fig. 2. That resistor (as indicated by the dashed line) is only needed when the squelch circuit is connected to an output designed to drive a speaker.

Set R12 for its maximum resistance and R11 to about mid range. With the squelch circuit disconnected, tune in a strong station and adjust the receiver's volume for a normal listening level. Reconnect the squelch circuit and readjust R11 for the desired volume. Turn R12 to its minimum resistance setting and the audio should turn off. Slowly increase R12's value until the audio returns. Now slowly tune the receiver to a new station and the audio should turn off between stations and return when the signal is strong and steady. Some experimenting with R12 will help in obtaining the desired squelch action.

To increase the time that the audio remains on between signals, increase the value of C6; to decrease the on time, decrease C6's value.

Audio Power Amp. Our next circuit might just turn out to be the very project you've been needing in your shack. How often have you needed a small, but powerful, portable audio amplifier that could be used to jack up an audio signal so it could be heard in a high-noise environment? Or to increase the anemic output of a mini transistor radio? Or to use as a miniature PA system in a pinch? If you've ever been in that predicament, take a look at the circuit shown in Fig. 3.

Thanks to National Semiconductor

(Continued on page 13)

Circuit Circus

By Charles D. Rakes

RF CIRCUITS FOR BETTER PERFORMANCE

This month we're going to explore a variety of RF enhancement circuits. Some of the circuits are designed to breath new life into older shortwave receivers, or to pull in a DX broadcast station from across the country on a generic AM radio.

Others are designed to electronically "stretch" a miniature antenna so that it acts like a long wire for the apartment dweller; another can be used to tune out what's not desired to be tuned in.

No matter what listening category you happen to occupy, it's my hope that at least one of the following circuits will enhance your next radio adventure. If you happen to live in an area where outside antennas are *taboo*, try one of the following "wire-stretcher" circuits.

Signal Grabber. The circuit in Fig. 1 takes a short pull-up antenna that has a high output impedance, and couples it to the receiver's low input impedance through a two-transistor impedance-matching network. Transistor Q1's high input impedance and high-frequency characteristics make it a good match for the short antenna, while Q2's low output impedance is a close match for the receiver's input.

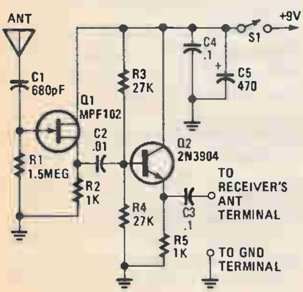


Fig. 1. The Signal-Grabber circuit is designed to make a short pull-up antenna perform like a long wire antenna, while offering no voltage gain. The circuit boosts the receiver's performance only if the signal at the antenna is of sufficient level to begin with.

The impedance-matching circuit allows a wide range of frequencies from below 100 kHz to over 30 MHz to enter the receiver. Even though the circuit offers no voltage gain, the receiver's performance is greatly enhanced. The matching circuit will boost the receiver's performance only if the signal reaching the antenna is of sufficient strength to begin with. If the desired signal isn't making it to the antenna, there's very little chance that any electronic wizardry will produce a usable signal at the receiver.

For the best low-noise performance, the matching circuit should be housed in a metal cabinet and powered from an internal 9-volt battery. But a well-filtered, noise-free external AC-derived power source can be used; or, if available, power can be supplied from the receiver.

The circuit can be assembled breadboard style on a piece of perfboard with push-in pins, or a simple circuit board can be produced; in either case, keep all leads short and follow a neat construction scheme. Just about any replacement pull-up antenna can be used or, if you have the available room, an old ¼-wavelength CB whip antenna would make a dandy signal grabber.

PARTS LIST FOR THE SIGNAL GRABBER

Q1—MPF102, general-purpose, N-channel FET
Q2—2N3904, general-purpose, NPN silicon transistor
R1—1.5-megohm, ¼-watt, 5% resistor
R2, R5—1000-ohm, ¼-watt, 5% resistor
R3, R4—27,000-ohm, ¼-watt, 5% resistor
C1—680-pF, ceramic-disc capacitor
C2—0.01-µF, ceramic-disc capacitor
C3, C4—0.1-µF, ceramic-disc capacitor
C5—470-µF, 16-WVDC, electrolytic capacitor
S1—SPST toggle switch
Perfboard materials, metal enclosure, telescoping antenna, wire, solder, hardware, etc.

Signal Booster. If your receiver needs a higher level RF-input signal than what the matching network can furnish, try the circuit in Fig. 2. The circuit, built around a few transistors and support components, offers an RF gain of about 12 to 18 dB from about 100 kHz to over 30 MHz, and is designed to complement the circuit in Fig. 1.

The RF signal is direct-coupled from Q1's source terminal to the base of Q2, which is configured as a voltage amplifier. The output of Q2 is then direct-coupled to the base of Q3 (configured as an emitter-follower amplifier). Transistor Q3 is used to match and isolate the gain stage from the receiver's RF-input circuitry.

Inductor L1 is used to keep any noise from the power source from reaching the FET (Q1) and any value of RF choke from 0.5 to 2.5 millihenrys will do. The value of R2 sets the bias for Q2 to about 2 volts. If the voltage is less than 2 volts, increase the value of R2 to 1.5k. To go below 100 kHz to the bottom of the RF spectrum, increase the value of C1 to .002 µF.

PARTS LIST FOR THE SIGNAL BOOSTER

Q1—MPF102, general-purpose, N-channel FET
Q2—2N3904, general-purpose, NPN silicon transistor
Q3—2N3906, general-purpose, PNP silicon transistor
R1—1.5-megohm, ¼-watt, 5% resistor
R2, R3, R5—1000-ohm, ¼-watt, 5% resistor
R4—2200-ohm, ¼-watt, 5% resistor
C1—680-pF, ceramic-disc capacitor
C2–C5—0.1-µF, ceramic-disc capacitor
C6—470-µF, 16-WVDC, electrolytic capacitor
L1—0.5–2.5-mH RF choke
S1—SPST toggle switch
Perfboard materials, metal enclosure, telescoping antenna, wire, solder, hardware, etc.

Tunable Trap. The add-on circuit, in Fig. 3, is a tunable trap that can be adjusted to extract undesirable AM signals and pass what is left to the receiver. Inductor L1 is a broadcast loopstick-antenna coil and C1 is a tuning capacitor, both of which were salvaged from an older AM transistor radio.

If the interfering signal originates from the lower frequency end of the broadcast band, set L1's slug about ¾ of the way into the coil and tune C1 for a minimum signal output at the interfer-

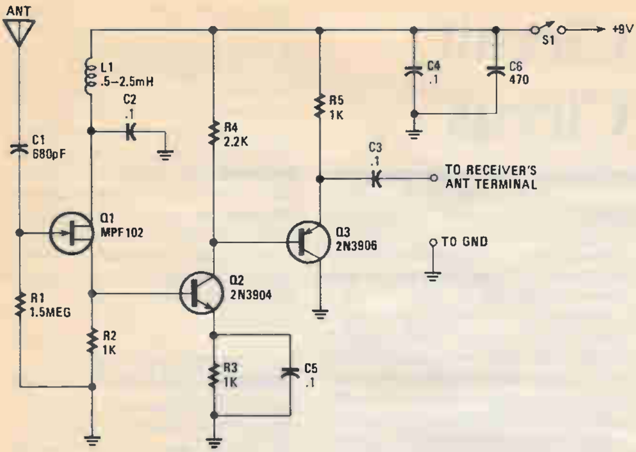


Fig. 2. The Signal Booster, built around a few transistors and support components, offers an RF gain of 12 to 18 dB from about 100 kHz to over 30 MHz, and is designed to complement the circuit in Fig. 1.

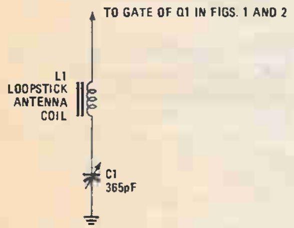


Fig. 3. The Tunable Trap can be adjusted to extract undesirable AM signals and pass what is left to the receiver.

ing frequency. And if the interfering station's frequency is near the upper end of the band, adjust the slug almost all the way out of the coil and tune C1 for a minimum signal.

It is possible that some transmitter other than a standard AM-broadcast type can get into the stretcher circuit. If

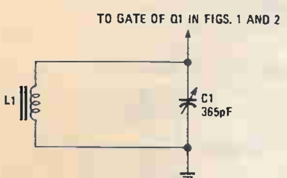


Fig. 4. The Signal Scrubber is a frequency-selective circuit for the wire stretcher. When a desired signal is receivable, but buried in noise, this circuit can pull it out of the mud, clean it up, and send it on to the receiver.

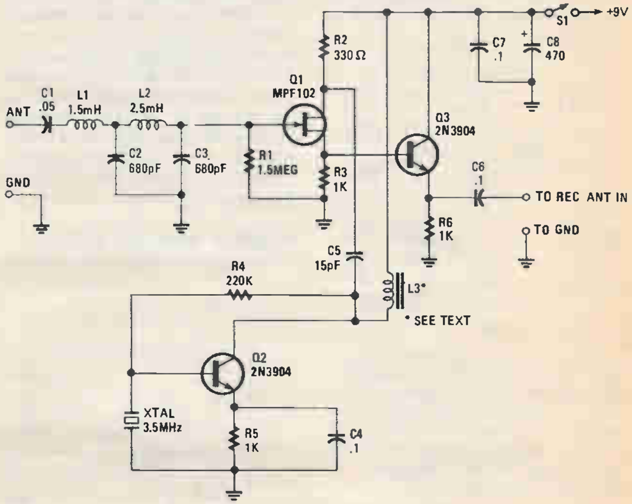


Fig. 5. The VLF Converter can be used to pick up signals for the general caverage of shortwave receivers. A number of unusual signals can be heard on frequencies below 15 kHz.

that does occur, determine the transmitter's frequency and select a coil/capacitor combination that will resonate at that frequency, and connect that combination to the circuit as shown in Fig. 3.

Signal Scrubber. A frequency-selective circuit for the wire stretcher is shown in Fig. 4. When a desired signal is receivable, but buried in noise, this circuit can pull it out of the mud, clean it up, and send it on through the stretcher to the receiver. At the same time that the tuner is increasing the level of the desired frequency, it's also attenuating all other signals outside its passband. The same combination of values for the coil and capocitor in Fig. 3 can be used in this circuit.

The input of the stretcher circuit is an ideal place to experiment with other types of antennas and selective circuits. A large tuned loop will give the circuit a directivity feature that can help in reducing an interfering signal coming from a different direction. If you don't have room for a large loop, you might try using a large, tuned ferrite coil in its place and retain the directivity feature.

VLF Converter. The majority of the general-coverage shortwave receivers start with the AM-broadcast band and go up in frequency to about 10 meters, or 30 MHz. That common tuning arrangement leaves out a large number of interesting and unusual signals found below the standard broadcast band. Not to fret, for the circuit in Fig. 5 will take you there for a listening adventure.

A number of unusual signals can be heard on frequencies below 15 kHz.

(Continued on page 12)

Circuit Circus

By Charles D. Rakes

UNUSUAL CIRCUITS, AND DESIGN AIDS

Diode Matching Circuit. Our first test circuit came about when a number of matched silicon signal diodes were needed for a balanced modulator project. Since I wanted to match the diodes to within a few millivolts, the old "quick and dirty" method of using an ohmmeter to match the forward conduction of each unit was out. A 9-volt battery, two precision resistors, and a digital voltmeter, connected as shown in Fig. 1, proved to be a simple answer.

The two 2.2k resistors (R1 and R2) must be a matched pair—remember that at the rated value, a 5% unit can be off by as much as +/−110 ohms. Their actual resistance isn't critical as long as they are of equal value.

Finding two 2.2k resistors of the same value isn't too difficult. Take at least a dozen 2.2k units and carefully read each value using a digital ohmmeter. Pair the two closest values for R1 and R2. With any luck at all you should be able to find at least one set of twins without going through too many resistors.

Using the diode matching circuit is easy. Connect a diode to each pair of test terminals and set the DVM, if it's not an autoranging meter, to it's most sensitive DC-voltage range. The meter reading will indicate the difference in the forward voltage-drop of the two diodes in millivolts. Note: Each diode must be allowed to return to room temperature after handling before a reading is taken. To prove a point grab either diode and watch the meter change as the temperature rises.

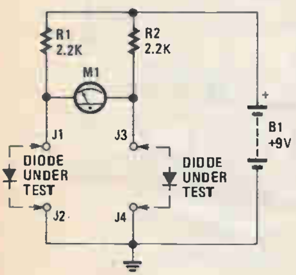


Fig. 1. This circuit can be used to match diodes for use in circuits where such a balance is necessary—a balanced modulator for instance. The Diode Matching Circuit will indicate the forward voltage drop of the two diodes in millivolts.

PARTS LIST FOR THE DIODE MATCHING CIRCUIT

B1—9-volt transistor-radio battery
R1, R2—2200-ohm, ¼-watt, 5% resistor (see text)
Digital voltmeter (see text)
Battery holder, alligator clips, wire, solder, etc.

Modified Matching Circuit. If a more-dynamic testing approach is desired, try the diode matching circuit shown in Fig. 2. The basic circuit is similar to the previous one; the main difference being the addition of a variable resistor, R4, which allows you to vary the current through the diodes.

That lets you compare the two diode's forward voltage-drop as the current flow is varied from less than 1 mA to over 7 mA. If the voltage changes very little over the current range, the two diodes are well matched in their forward voltage curve. Resistors R1 and R2 must be matched in the same manner as in the first circuit.

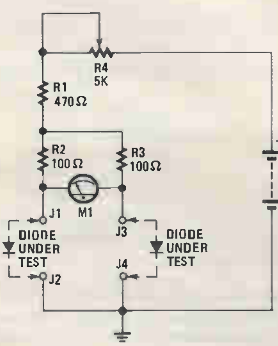


Fig. 2. If a more-dynamic testing approach is desired, try this modified version of the previous matching circuit. The main difference between the two circuits is the addition of a variable resistor, R4, which allows you to vary the current through the diodes.

PARTS LIST FOR THE MODIFIED MATCHING CIRCUIT

B1—9-volt transistor-radio battery
R1—470-ohm, ¼-watt, 5% resistor
R2, R3—100-ohm, ¼-watt, 5% resistor, see text
R4—5,000-ohm, potentiometer
Battery holder, alligator clips, wire, solder, etc.

Oscilloscope-Based Matching Circuit. Our last diode-matching circuit, see Fig. 3, allows you to look at the forward conduction curve of both diodes simultaneously on an oscilloscope. A 6-volt transformer (T1) and diode D1 sup-

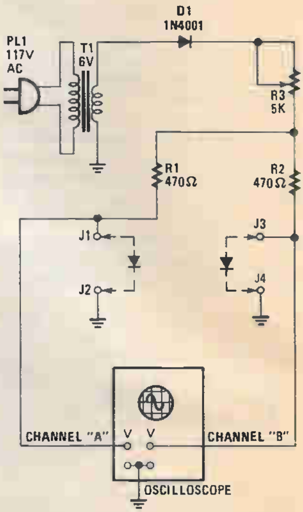


Fig. 3. The Oscilloscope-Based Matching Circuit allows you to look at the forward conduction curve of both diodes simultaneously on an oscilloscope.

PARTS LIST FOR THE OSCILLOSCOPE-BASED MATCHING CIRCUIT

D1—1N4001 1-amp, 50-PIV, rectifier diode
R1, R2—470-ohm, ¼-watt, 5% resistor
R3—5000-ohm potentiometer
T1—6.3-volt, 300-mA, step-down power transformer
Test terminals, scope, power cord, wire, solder, etc.

plies a pulsed positive voltage to the two diodes through a 5000-ohm potentiometer and two matched 470-ohm resistors.

The scope must have dual vertical inputs to connect to each of the diodes under test. The scope's vertical amplifiers can be used in either the alternate or chopped mode to display both waveforms together.

Here's how to set the scope up for the dual-waveform circuit. Set the gain of both vertical amplifiers to 0.2 volts per division. Place the vertical-mode switch to either the chopped or alternate setting. Set the horizontal sweep to 2 milliseconds-per-division. Set the scope's trigger to produce a horizontal line and adjust the trace of each vertical input to overlap and form a single line at the screen's center.

Connect the scope to the test circuit, re-adjust the trigger for a stable display, and if the diodes are alike the two waveforms will appear as a single trace. Resistor R3 sets the diode's forward current and can be adjusted during testing.

Crystal Tester. The next tester came about when our faithful old 75A-4 Collins amateur receiver failed to operate on the 20-meter band. A quick check of the receiver's schematic suggested that the crystal for the 20-meter band was sound asleep in its socket. Naturally our shop's crystal checker was nowhere to be found; so the circuit in Fig. 4 was quickly whipped together.

In that circuit, transistor Q1 is connected in a Pierce-oscillator configuration with the crystal supplying the feedback from Q1's collector to its base to produce and sustain oscillation. Actually that is what happens if the crystal under test happens to be good. A small variable capacitor, C4, allows the checker to cover a wide frequency range. Diodes D1 and D2 convert the RF to DC, lighting LED1 to indicate that the crystal is oscillating.

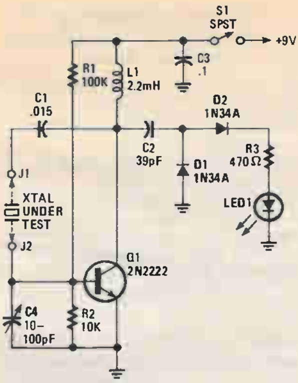


Fig. 4. In the Crystal Tester circuit, transistor Q1 is connected in a Pierce oscillator configuration with the crystal under test supplying the feedback from Q1's collector to its base to produce and sustain oscillation. If the circuit oscillates, the crystal under test is good.

PARTS LIST FOR THE CRYSTAL TESTER

Q1—2N2222 general-purpose NPN silicon transistor
D1, D2—1N34A general-purpose germanium diode
LED1—Jumbo light-emitting diode (any color)
R1—100,000-ohm, ¼-watt, 5% resistor
R2—10,000-ohm, ¼-watt, 5% resistor
R3—470-ohm, ¼-watt, 5% resistor
C1—0.015-µF, 100-WVDC, ceramic-disc capacitor
C2—39-pF, ceramic-disc, capacitor
C3—0.1-µF, 100-WVDC, ceramic-disc capacitor
C4—10-to-100-pF (or similar) tuning capacitor
L1—2.2-mH RF choke
S1—SPST toggle switch
Perfboard materials, alligator clips, battery and battery holder, wire, solder, hardware, etc.

The checker can be built breadboard style on perfboard and housed in a small plastic cabinet. Since there's such a wide range of crystal sizes used in electronics, two small mini alligator clips will serve fine as a universal crystal socket.

Using the crystal checker is simple. Connect the crystal to the tester and rotate capacitor C4, starting at its minimum capacitance value, until the LED lights. The circuit can also be used to check a number of the ceramic- and piezo-filter devices.

Magnetically Tunable Tone Generator. The next two circuits both use a permanent magnet to vary the inductance of a coil. The inductance value of a coil wound on a ferrite core is primarily determined by the number of turns of wire and the permeability of the core material. If a permanent magnet is moved toward a ferrite core, the permeability of the core will vary in relationship to the strength of the magnetic field and the inductance of a coil wound on the core will change accordingly.

The circuit in Fig. 5 uses an external horseshoe magnet to vary the frequency of an audio-tone generator. The tuning range of that circuit is about 2-to-1. Inductors L1 and L2 are wound on a ferrite core measuring ¼ inch in diameter and 4 inches in length. About any similar size ferrite rod will work in this circuit. A good source of ferrite material

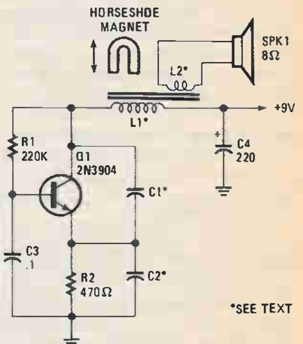


Fig. 5. This tunable tone generator uses a horseshoe magnet to vary the inductance of L1, thereby altering the output frequency of the circuit.

PARTS LIST FOR THE MAGNETICALLY TUNABLE TONE GENERATOR

Q1—2N3904, general-purpose NPN silicon transistor
R1—220,000-ohm, ¼-watt, 5% resistor
R2—470-ohm, ¼-watt, 5% resistor
C1, C2—See text
C3—0.1-µF, 100-WVDC, ceramic-disc capacitor
C4—220-µF, 25-WVDC, electrolytic capacitor
L1, L2—See text
SPKR1—4-inch, 8-ohm speaker
Perfboard materials, horseshoe magnet (with 1 to 2-inch pole spacing), 9-volt transistor-radio battery and battery holder, wire, solder, hardware, etc.

is Amidon Associates (12033 Otsego St., North Hollywood, CA 91607).

Inductor L1 consists of 70 feet of #26 copper wire wound on the ferrite rod from end to end. Inductor L2 is formed by winding 20 turns of #26 wire over the center of L1.

When a 1-µF, 100-WVDC Mylar capacitor is used for C1 and C2, the oscillator's frequency is near 1500 Hz. The frequency will increase to about 3400 Hz with the magnet touching the coil in a parallel position. The first effect of the magnet is noted at a distance of about 2½ inches.

The circuit can be used as a CW (code) oscillator and tuned for just the right sound with the magnet, or housed in a non-metallic cabinet and turned over to the kids as a fun noise maker.

By changing the values of C1, C2, and L1, the circuit in Fig. 5 can be turned into a variable-frequency RF generator. When a 2- by ½-inch, flat-bar, ferrite AM-broadcast antenna coil is used for L1 and two 680-pF capacitors are used for C1 and C2, the oscillator will tune from about 600 kHz to over 1.5 MHz with the same horseshoe magnet.

Magnetically Tuned Crystal Radio. Our next magnetically tuned circuit is by far the simplest of the lot and could be that first build-it-yourself project you've been looking for.

The crystal-radio circuit in Fig. 6 replaces the hard-to-locate broadcast tuning capacitor with a fixed capacitor and a horseshoe magnet. Just about any ferrite AM-broadcast antenna coil with a length of 2 inches or more will work in the circuit. Any small horse shoe magnet with a 1- to 2-inch gap between poles will do fine for tuning. The stronger the magnet the greater the tuning range.

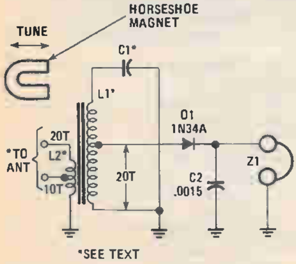


Fig. 6. In this unusual tunable crystal radio, the hard-to-locate broadcast-band tuning capacitor is replaced by a fixed capacitor and a horseshoe magnet.

PARTS LIST FOR THE MAGNETICALLY TUNED CRYSTAL RADIO

L1, L2—See text
C1—See text
D1—1N34A general-purpose germanium diode
C2—.0015-µF, 100-WVDC, Mylar or similar capacitor
Z1—2000-ohm (or similar) high-impedance headphones
Perfboard materials, horseshoe magnet (with 1 to 2-inch pole spacing), #26 coil wire, battery and battery holder, wire, solder, small knob, etc.

Take the selected ferrite coil and unwind twenty turns from either end and make a tap at that point and rewind the wire back in place. Over the same end of the coil (end where tap was made) wind 20 turns of #26 wire with a tap at the tenth turn. That winding will serve as the antenna and ground input for the receiver.

The receiver can be built breadboard style on a piece of wood or any non-metallic material. Use two plastic cable-mounting clips to secure the ferrite core solidly to the breadboard's base. Position the magnet, as shown in the schematic diagram, with each pole aimed at opposite ends of the ferrite core and at equal distances. If the magnet has a hole through the curved portion, a small knob can be attached to allow easier tuning of the circuit. Let the magnet lay flat on the breadboard's base and slide back and forth parallel to the coil.

Checking out the crystal set is easy. If a long wire antenna (50 or more feet) is available connect it to the tenth turn on L2; but if only a short wire is handy, connect it to the end of L2 farthest from ground. The receiver will perform best when the circuit ground is connected to a good earth ground.

It's unlikely that the receiver will tune the entire broadcast band with a single-value tuning capacitor, so try a 150 to 250 pF unit for C1, and see how much of the band can be covered. Without the influence of the magnet, the value of C1 will set the receiver to its lowest tuned frequency. As the magnet moves closer to the ferrite material, the frequency of the tuned circuit will increase toward the upper end of the broadcast band. ■

CIRCUIT CIRCUS

(Continued from page 9)

One unusual signal often received between 10 and 14 kHz, in our location (lower Midwest), is a slow two-tone, *dit-dah* signal that's strong enough to be received on a relatively short antenna. Electrical storms, with heavy lightning, can be received on those frequencies as crunching, crackling, and whistling sounds, long before the approaching storm strikes.

PARTS LIST FOR THE VLF CONVERTER

Q1—MPF102, general-purpose, N-channel FET
Q2, Q3—2N3904, general-purpose, NPN silicon transistor
R1—1.5-megohm, ¼-watt, 5% resistor
R2—330-ohm, ¼-watt, 5% resistor
R3, R5, R6—1000-ohm, ¼-watt, 5% resistor
R4—220,000-ohm ¼-watt, 5% resistor
C1—0.05-µF, ceramic-disc capacitor
C2, C3—680-pF, ceramic-disc capacitor
C4, C6, C7—0.1-µF, ceramic-disc capacitor
C5—15-pF, ceramic-disc capacitor
C8—470-µF, 16-WVDC, electrolytic capacitor
S1—SPST toggle switch
L1—1.5-mH choke
L2—2.5-mH choke
L3—See text
XTAL1—3.5-MHz (80-meter band) crystal
Perfboard, crystal socket, metal cabinet, antenna terminals, etc.

On frequencies above 15 kHz, you can expect to receive several of the following signals; Loran, Military, some foreign broadcasts, various CW signals, and in some areas a number of beacon and CW signals between 160 kHz and 190 kHz sent out by experimenters using 1-watt transmitters. Many of those legally operated transmitters have spanned the airways for several hundred miles to be received by other VLF'ers.

With the component values given in the Parts List, the circuit will cover all of the VLF frequencies from below 10 kHz to over 260 kHz. For the circuit to operate from 200 kHz to 500 kHz, a couple of input-filter component values will need to be changed. Remove C2 and C3, and replace C3 with a 150-pf, 100-WVDC ceramic-disc capacitor. Remove L2 and connect L1 to Q1's gate, or, if you are going to make only a temporary change, just place a jumper across L2. If you wanted a dual-band converter, a simple switching circuit could be added to do the above component swapping.

Even though the circuit's frequency range is on the low side, care should be taken in the circuit's construction. The components can be neatly mounted on a 2- × 3-inch piece of perfboard (as I did) or a circuit board can be used for an even more compact unit. Whatever scheme you use, keep the component and interconnecting leads short, and locate the crystal-oscillator circuit away from the front-end circuitry.

If you want to convert to a different frequency, use a socket for XTAL1. The converter will operate best when housed in a metal cabinet and since the circuit only draws a few milliamps of current, battery operation is suggested.

To use the VLF converter, connect the converter's RF output to the shortwave receiver's antenna input through a shielded cable or coax. Connect a good ground to the converter and receiver. Connect a long-wire antenna to the converter, tune the receiver to 3.5 MHz, and set the receiver's mode switch to CW.

The receiver should produce a loud audio tone. That audio tone is produced by the receiver's BFO (beat-frequency oscillator) heterodyning with the converter's 3.5-MHz crystal oscillator—that's normal. As the receiver is tuned beyond 3.5 MHz toward 4.0 MHz, the dial reading, starting at 3.5 MHz can be used to read out the converted frequency: 3.5 MHz = 0 Hz; 3.6 kHz = 100 kHz; and 4.0 MHz = 500 kHz.

Inductor L3 was made by winding 30-turns of 26-gauge wire on a ¼-inch diameter ferrite core removed from an old AM-radio, loopstick antenna coil. The VLF converter can be used on other bands by changing the crystal's frequency and L1's inductance. To change from the 80-meter band (3.5 MHz) to the 40-meter band (7 MHz), both the crystal and L3 will need to be changed. Inductor L3 can be modified to operate in the 40-meter band by removing about 10 turns. ■

CIRCUIT CIRCUS

(Continued from page 7)

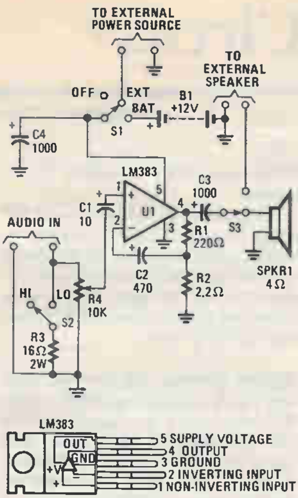


Fig. 3. This Audio Power Amp—built around an LM383 8-watt, audio power amplifier—can be used to boost an audio signal to a sufficient level so that it can be heard in a high-noise environment.

Corporation, the job of building our portable amp couldn't be easier. The very heart of the portable amp is their LM383 8-watt, audio power amplifier. The LM383 is designed to drive low-impedance loads—such as a 4-ohm speaker—with low distortion, powered from supply voltages ranging from 5 to 20 volts. Since the device is designed for automotive applications, 12 volts is an ideal operating voltage. The cost is also very modest at less than three dollars each in single quantities.

Our portable amp is designed to be a general-purpose universal amplifier that can be used for numerous applications. Switch S2 sets the amp's input impedance to a low of 16 ohms (as a speaker load for a transistor radio, etc.) and up to a high impedance of 10k. The amp's output can be switched from the internal 4-ohm speaker to an external speaker. A metal-horn paging speaker will really make the amplifier sound off like the big boys. The amp can be used in automotive applications, powered from the car's battery.

Building the amplifier is simple. The circuit can easily be built on a small piece of perfboard and housed in a metal or tough plastic cabinet. The LM383 should be mounted on a small heat sink with an area of at least 4 square inches. A simple heat sink can be made from scrap aluminum, or you

PARTS LIST FOR THE AUDIO POWER AMPLIFIER

RESISTORS

(All resistors are ¼-watt, 5% units, unless otherwise noted.)
R1—220-ohm
R2—2.2-ohm
R3—16-ohm, 2-watt
R4—10,000-ohm potentiometer

CAPACITORS

C1—10-µF, 25-WVDC, electrolytic
C2—470-µF, 25-WVDC, electrolytic
C3, C4—1000-µF, 25-WVDC, electrolytic

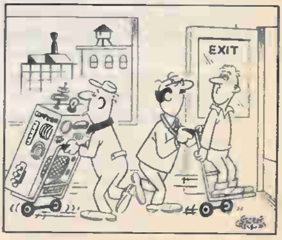
ADDITIONAL PARTS AND MATERIALS

U1—LM383 8-watt, audio-power amplifier, integrated circuit
B1—Eight C-cell batteries
S1—SP3T rotary switch
S2, S3—SPDT toggle switch
SPKR1—4-ohm, 10-watt speaker
Perfboard materials, enclosure, heat sink material, knobs, handle, battery holder and connector, wire, solder, hardware, etc.

can pick up a ready made one at a local electronic-supply house.

Mount the speaker, input/output jacks, switches, and the volume control (R4) at locations on the cabinet where they will work the best for you. Any arrangement that you are comfortable with will do, as long as you allow enough open area in front of the speaker for the sound to escape unrestricted.

Eight C-cell batteries can be used to power the circuit. A battery holder for the eight "C" cells will make the job of replacement a snap, and a handle mounted to the amp's top will add to its portability. ■



Circuit Circus

By Charles D. Rakes

ELECTRONIC DRUM CIRCUITS

This month the Circus starts of by following the "beat" of an electronic drummer. There are a number of similar noise makers on the market. Some of the low-end drum simulators use a piezo disc as the sensor to detect the drum stick's tap.

The piezo disc is attached to the bottom of a thin plastic membrane that serves as the drum head. Normally when the plastic drum sticks are used, the piezo sensor performs as designed, but if a wood or similar hard object is substituted, it's likely the sensor will be shattered and the beat will cease.

Not only will our first circuit overcome the problem of the fragile piezo sensor, but it will also replace it with a 10-cent super tough pick-up that's kid proof. If you take a common garden variety ceramic disc capacitor and bang away on it, a small, but detectable output will be produced.

The circuit in Fig. 1 takes advantage of that uncommon fact. A 0.1-µF, 100-WVDC disc ceramic capacitor is connected, through a length of shielded mike cable, directly to the input of op-amp U1-a.

The minute signal developed fron thumping on C1 is boosted several hundred times by U1-a and its output (at pin 1) is fed to the input of U1-b (which is configured as a voltage follower). A low voltage audio amp, U2, boasts the signal level sufficiently to produce a "bong" sound from the speaker for each tap on C1.

A number of various makes, shapes, sizes, and voltages of 0.1-µF ceramic-disc capacitors were tested for the sensor, and, like people, all were not alike. The capacitors that tested best for the task were the smaller (physical size) variety with a 100-volt or less voltage rating. Values greater than 0.1 µF will work too, but generally they're not as plentiful in most junkboxes as are the 0.1-µF or smaller units. The smaller capacitance values tested just didn't produce a sufficient output for the circuit. Although some 0.1-µF capacitors tested better than others, all worked fine as sensors.

The circuit in Fig. 1 makes a great test circuit because it lets you hear the results of each capacitor as it is being checked out. Some capacitors will produce a short "pinging" sound while others will actually produce a longer-lasting ringing sound.

Trigger Circuit. Our second circuit (see Fig. 2) uses the capacitor's amplified output pulse as a trigger signal to turn on a separate sound-generating circuit. The shape, duration, and level of the capacitor's output pulse is still important because it adds to the mix that determines the length and shape of the generated audio-output signal.

The circuitry surrounding U1-a is the same as in the previous circuit, but in this circuit U1-a's output is fed to a voltage-doubler/rectifier circuit, comprised of C2, D1, D2, and C7. The rectifier's output pulse supplies positive bias to the base of Q1.

Op-amp U1-b and its associated components make up a tone-generator circuit that remains inactive until triggered. The generator's output is fed to the input of U2 (an LM386 low power audio amplifier), which provides enough signal boast to drive the speaker, SPKR1.

Now here's how the circuit produces a drum-like sound. When C1 is tapped the signal is amplified by U1-a, and its output is converted to DC by the rectifier circuit. The DC output of the rectifier charges C7. At a given level, the charge on C7 is sufficient to turn on Q1 for a short time period. When Q1 turns on, it switches the junction of C4 and C5 to ground, causing the oscillator circuit to begin operation, producing a drum-like beat.

The timing of the output tone is controlled by the amplitude of the pulse coming from U1-a and the value of C7. Increase either or both and the "bong" lasts longer. Also the value of R7 can be decreased to shorten the tone time.

The generator's output frequency can be set to just about any audible tone by experimenting with the capacitor values of C4 and C5. Try 0.1 µF or larger values for the low end and 0.01 µF or smaller for the high end to produce just the right note.

For a different action and look, the sensor capacitor can be mounted inside a drum stick made out of a long plastic tube. Place the capacitor solidly against the inside edge of one end of the tubing and epoxy it in place. Connect the capacitor to the circuit through a length of shielded microphone cable and bang away on any hard surface.

Here's another sound application for the cheap sensor. If your home has one of those fancy, brass door knockers, epoxy one of the ceramic capacitor sensors to the inside area next to where the knocker makes contact. Connect the sensor to the circuit with a length of shielded cable and use an AC-operated power supply and you'll have a

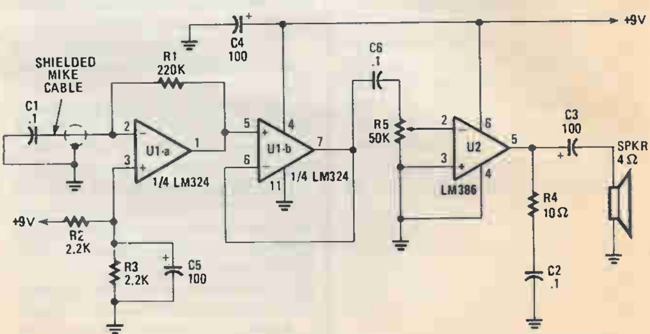


Fig. 1. Our drum simulator uses a capacitor to detect the tapping of the stick. The detected signal is then amplified, conditioned, and used to drive a 4-ohm speaker.

PARTS LIST FOR FIG. 1

U1—LM324 quad op-amp, integrated circuit
U2—LM386 low-power audio amplifier, integrated circuit
R1—220,000-ohm, ¼-watt, 5% resistor
R2, R3—2200-ohm, ¼-watt, 5% resistor
R4—10-ohm, ¼-watt, 5% resistor
R5—50,000-ohm, potentiometer
C1, C2, C6—0.1-µF, ceramic disc capacitor
C3–C5—100-µF, 16-WVDC electrolytic capacitor
SPKR1—4-ohm speaker
Printed-circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, shielded microphone cable, hook-up wire, solder, hardware, etc.

PARTS LIST FOR FIG. 2

U1—LM324 quad op-amp, integrated circuit
U2—LM386 low-power audio amplifier, integrated circuit
Q1—2N3904 general-purpose NPN silicon transistor
D1, D2—1N914 general-purpose small signal silicon diode
R1–R4—150,000-ohm, ¼-watt, 5% resistor
R5–R7—10,000-ohm, ¼-watt, 5% resistor
R8—10-ohm, ¼-watt, 5% resistor
R9—25,000-ohm potentiometer
C1, C3, C10—0.1-µF, ceramic-disc capacitor
C2—0.47-µF, ceramic-disc capacitor
C4, C5—0.01-µF, ceramic-disc capacitor
C6, C8, C9—100-µF, 16-WVDC, electrolytic capacitor
C7—4.7-µF, 16-WVDC, electrolytic capacitor
SPKR1—4-ohm speaker
Printed circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, shielded microphone cable, hook-up wire, solder, hardware, etc.

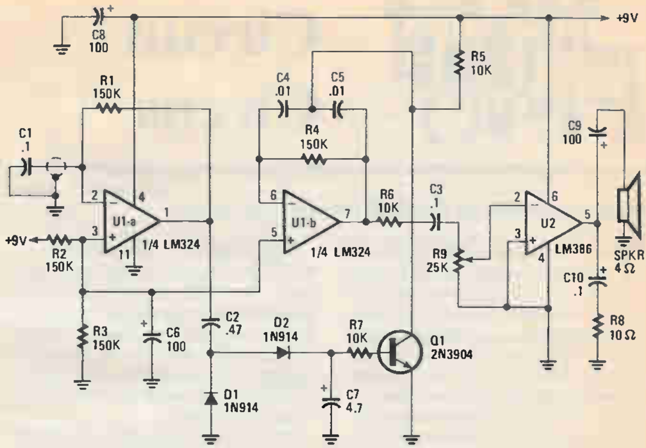


Fig. 2. This circuit is similar to the circuit in Fig. 1, except that the signal detected by the capacitor sensor is used to trigger the circuit.

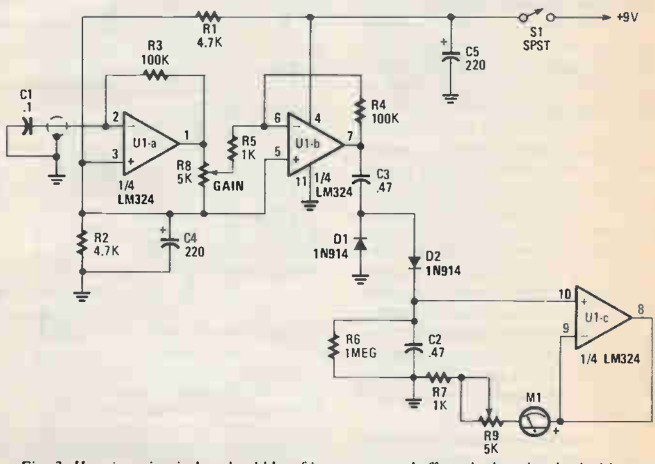


Fig. 3. Here is a circuit that should be of interest to car buffs and others involved with tracking down the source of strange knocking noises in electro-mechanical devices.

most unusual annunciator.

The third and last circuit using the ceramic sensor should find its way into every electronic detective's tool chest. If you have ever experienced the perplexing problem of tracking down the source of a knock or low frequency ping in a mechanical or electro-mechanical device, then by all means build and use the knock detector/locator.

Here's just a few area's where the circuit will certainly prove most valuable in locating and pinpointing an unusual sound problem: Locating the source of a knock or ping in an automobile or industrial internal-combustion engine; Detecting and locating the source of a similar noise in just about any mechanical or electro-mechanical manufacturing equipment, including robotic equipment, printing presses, office equipment, etc.

Knock Detector. Figure 3 shows the schematic diagram for the knock-detector circuit, in which capacitor C1 is used as a sensor. The sensor's output signal is amplified several thousand times by op-amps U1-a and U1-b. Potentiometer R8 serves as the sensitivity control. The amplified output of U1-b is rectified by the voltage-doubler circuit made up of C3, C2, D1, and D2. The doubler circuit's DC output is fed to the input of U1-c (which is configured as a voltage follower), and its output is fed to a 1-mA meter. Potentiometer, R9, sets the meter's maximum current level.

The value of R6 sets the discharge time for C2. If the value of R6 is made too large, the meter will require too

(Continued on page 30)

Circuit Circus

By Charles D. Rakes

SOME ADDITIONS TO THE WORKBENCH, AND MORE!

This month's Circus starts with a current-detection circuit that can be used to solve many printed-circuit board troubleshooting problems. When checking a breadboarded circuit, it's not too difficult to break a lead and check for current flow; but with a printed-circuit board, it's not quite as easy. Cutting a circuit board trace during troubleshooting is certainly not a good practice, and should *not* be performed except as a last-ditch effort.

High-Gain Current Sensor. Our first circuit, see Fig. 1, is a rather simple circuit built around a single op-amp. That circuit, a *High-Gain Current Sensor*, can be used to detect the presence of low-level current circulating through a printed-circuit board's copper traces. Two straight-pin probes are used to make contact with the circuit board's copper trace, diverting some small portion of the current in the circuit-under-test to the current-sensing circuit.

Voltage picked up by the probes is fed to both inputs of U1 (a 741 op-amp, configured as an inverting amplifier), which inverts the input signal and amplifies it by a factor of over 1000. The output of U1 is fed to two parallel-opposing LED's (LED1 and LED2), causing one to light to indicate current flow and polarity.

The op-amp's output (with zero input) is set to half the supply voltage via R5. The voltage at the junction formed by R3 and R4 is half the supply voltage. That arrangement makes up a simple bridge circuit with U1 being the variable element and the two LED's operating as output indicators. The resistance of R2 determines the op-amp's gain; for normal use, a 5-megohm resistor will suffice, but when it comes to ferreting out lower current levels, the value of R2 can be increased to 10 megohms for maximum sensitivity. Diodes D1 and D2 are used in the circuit to protect U1 from over-voltage inputs, while capacitor C1 is used to reduce the circuit's response to AC.

When assembling the circuit, mount the IC and all other components (except LED1, LED2, and R5) on a small piece of perfboard. The perfboard assembly can then be housed in a small plastic cabinet. The LED's and R5 (which is used in this circuit as a null adjust) should be mounted to one end of the project's enclosure.

The probes can be made of nothing more than a pair of finishing nails connected to the circuit board through short lengths of hook-up wire.

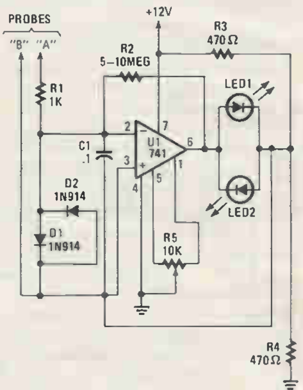


Fig. 1. The High-Gain Current Sensor is a rather simple circuit built around a 741 op-amp, which can be used to detect low-level current in a printed-circuit board's copper traces.

To use the circuit, first short the probes together and adjust R5 so that both LED's are off. Press the probes firmly on the circuit-board trace in question. If LED2 lights, the current flowing through the trace is in a direction that produces a positive voltage at probe "A" (relative to the voltage to probe "B"). A negative input at probe "A" (relative to probe "B") turns on LED1.

Inductive Current Sensor. Our second electronic detection circuit, an *Inductive Current Sensor*, is designed to seek out AC current flow in electrical wiring and electronic circuitry. The circuit, see Fig. 2, is designed to detect just about anything moving through a wire, or through a component lead with a frequency of from 60 Hz to over 10 kHz.

If you get stuck with the job of repairing a washer, dryer, or other appliance, the Inductive Current Sensor just might make you the hero of the day. The circuit can also be helpful in working on a car's electrical system.

The Inductive Current Sensor is built around a 1458 dual op-amp (U1). The signal input to the circuit is inductively coupled to the circuit through L1 (which is actually a 10K to 2K audio transformer; the 2K winding is not used). When L1 is brought near a conductor carrying a varying voltage, a voltage is induced in the coil. The voltage across L1 is fed to the inputs of U1-a, where it is amplified to provide a gain of approximately 100.

The output of U1-a is fed through potentiometer R7 (the GAIN control) to the inverting input of U1-b, which also provides a gain of 100. The output of U1-b is fed through a voltage-doubler/rectifier circuit made up of C3, C4, D1, and D2. The output of the doubler/rectifier is fed to the base of Q1, turning it on. That, in turn, applies a voltage to the anode of LED1 through R6, which is used to limit current through the LED.

The pickup coil, L1, was fabricated by removing the mounting frame from a 10K-to-2K miniature audio transformer and then removing the "E" and "I" laminations from the transformer core. The "I" sections were discarded and the leads to the 2K winding clipped close to the windings of the transformer. After that, all the "E" pieces were reinserted into the core opening (forming an open-loop core), and taped or glued in place. Doing so increases the sensitivity of the pick-up element.

The remaining circuit components were then mounted on perfboard or PC board and housed in a small plastic enclosure. The GAIN control, R7, the power switch, and the LED were on one side of the cabinet. Inductor L1 can either be mounted in one end of the cabinet with the winding flush and parallel with the cabinet's end, or for maximum sensitivity, it can be located on the outside end of the cabinet. The pickup's maximum sensitivity to an external field is realized when the conductor is parallel with L1.

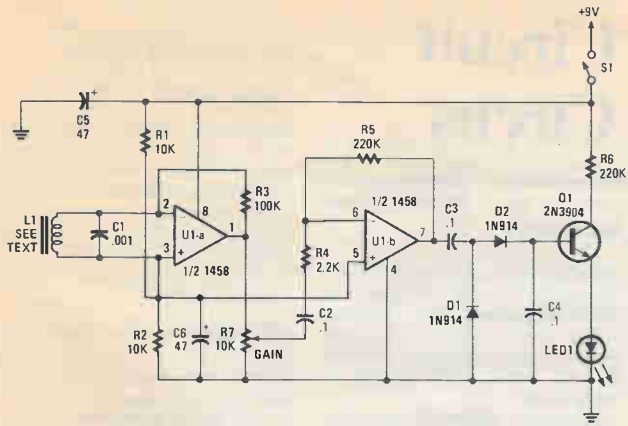


Fig. 2. The Inductive Current Sensor—built around a 1458 dual op-amp—is designed to seek out AC current flowing in electrical wiring and electronic circuitry.

PARTS LIST FOR THE HIGH-GAIN CURRENT SENSOR

SEMICONDUCTORS

U1—741 op-amp, integrated circuit
D1, D2—1N914 general-purpose silicon diode
LED1—Jumbo light-emitting diode

RESISTORS

(All resistors are ¼-watt, 5% units, unless otherwise noted.)
R1—1000-ohm
R2—5- to 10-megohm (see text)
R3, R4—470-ohm
R5—10,000-ohm potentiometer

ADDITIONAL PARTS AND MATERIALS

C1—0.1-µF, ceramic-disc capacitor
Printed-circuit or perfboard materials, probes, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

PARTS LIST FOR THE INDUCTIVE CURRENT SENSOR

SEMICONDUCTORS

U1—1458 dual op-amp, integrated circuit
Q1—2N3904 general-purpose silicon NPN transistor
D1, D2—1N914 general-purpose silicon diode
LED1—Jumbo light-emitting diode

RESISTORS

(All resistors are ¼-watt, 5% units, unless otherwise noted.)
R1, R2—10,000-ohm
R3—100,000-ohm
R4—2200-ohm
R5—220,000-ohm
R6—470-ohm
R7—10,000-ohm potentiometer

CAPACITORS

C1—.001-µF, ceramic-disc
C2–C4—0.1-µF, ceramic-disc
C5, C6—47-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

L1—10K to 2K miniature audio transformer (see text)
Printed-circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

Signal Conditioner. Our next offering, see Fig. 3, is a *Signal Conditioner* circuit that's ideal for cleaning up weak and noisy audio or Morse-code signals. The circuit can also be used to clean up digital tone signals (tones of the same frequency) in a remote-control extender circuit.

The audio signal is coupled through C1 and R9 to the input of U1—a 567 phase-locked loop (PLL)—at pin 3. The values of R1, R7, and C2 determine the detector's operating frequency. When a tone is detected, U1's output at pin 8 is pulled to ground for the duration of the input signal. If the tone is pulsed on and off, U1's output follows in step with the input signal.

The output of U1 is fed to the base of Q1 (a 2N3906 general-purpose PNP transistor), which is used to switch power to a second 567 PLL (U2) on and off. LED1 blinks on and off in step with the coded input signal. Integrated circuit U2 operates as a keyed oscillator, creating a new constant-amplitude output signal.

The rejuvenated tone need not be of the same frequency as the input, but can be set to a different frequency by way of R8. The circuit's output frequency is determined by the combined values of R4, R8, and C4. Transistor Q2 is used to isolate the output of U2 at pin 5 from external loading.

The actual values of frequency-determining components (as given in the Parts List) allow the two PLL's to tune from a low of a few hundred hertz to a high of several thousand hertz. The easiest way to raise or lower the tuning range is by increasing or decreasing the values of C2 and C4.

If you enjoy listening to CW (Morse code) and would like to clean up those weak and noisy signals, just connect the receiver's audio output to the input of

(Continued on page 31)

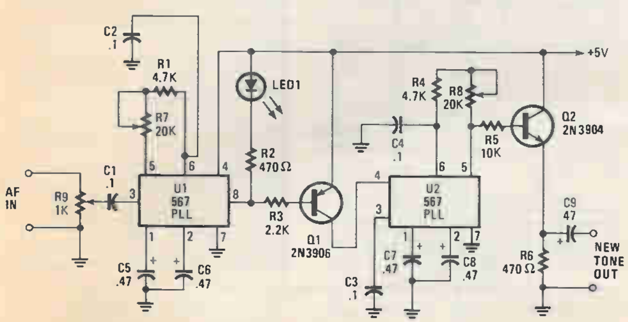


Fig. 3. The input to the Signal Conditioner (which is built around a pair of 567 PLL IC's) is coupled through C1 and R9 to the input of U1. The output of U1 is fed to the base of Q1, which is used to switch power to a second 567 PLL (U2) on and off.

Circuit Circus

By Charles D. Rakes

DIGITAL, PROGRAMMABLE TIMERS, AND MORE!

This month the Circus is off and running with a circuit using a most unusual and flexible programmable IC timer. The MC14541B (or 4541) can be had for about a buck and will make the old faithful 555 oscillator/timer stand in the corner. That CMOS timer consists of a 16-stage binary counter, an internal R/C-oscillator circuit, an automatic power-up reset circuit, and a choice of output logic.

The 16-stage counter divides the oscillator frequency into four available outputs of 2^8, 2^{10}, 2^{13}, and 2^{16}. The circuit counts 256 clock pulses for the shortest time interval (2^8), and 65,536 pulses for the longest time period (2^{16}). See the truth table in Fig. 1 for logic details.

By selecting the oscillator's frequency and the number of counter stages, the timing period can be set to just about any length you desire.

TABLE 1
COUNTER SELECTOR CHART

PIN 12	PIN 13	NUMBER OF COUNTER STAGES (N)	COUNT 2^N
0	0	13	8192
0	1	10	1024
1	0	8	256
1	1	16	65536

Fig. 1. The inputs at pins 12 and 13 of the MC14415 programmable counter determine the number of counter stages selected, and therefore the count.

Using the 14541. A get-acquainted timer circuit is shown in Fig. 2. When pin 5 of U1 is tied to a logic low (ground in our circuit) the counter circuit is automatically re-set when power is applied. The master reset at pin 6 requires a positive pulse to reset the internal counters and start the timing function.

Pin 9 sets the timer's output mode. Connecting pin 9 to ground keeps the timer's output voltage (pin 8) at ground potential until the timing cycle is completed and then switches positive. Connecting pin 9 to the V+ supply rail causes the opposite output conditions to occur: The output remains high until the timing cycle is completed and then goes low. Timing mode selection is made via S2.

The positions of S3 and S4 determine the timer's total count. With S3 in position 1 and S4 in position 0, the counter will total 256 before timing out. Match the positions of S3 and S4 to the truth table in Fig. 1 to set the desired count. The internal oscillator is set to the desired frequency with component values determined by the formula: $f = 1/(2.3 \times R4 \times C2)$. The value of resistor R3 should be about twice the value of R4.

Resistor R4's resistance is in megohms and C2's capacitance is in microfarads. For example, if R4 is 100k and C2 is 0.1 µF, then:

$$f = 1/(2.3 \times 10^5 \times 10^{-7}$$

$$f = 1/.023$$

$$f = 43.4 \text{ Hz}$$

Our frequency counter measured 41 Hz, which is close enough. With pin 10 (the mode control) tied to ground, as shown in Fig. 2, the timer operates in a single-cycle mode, but when pin 10 is connected to V+, the mode changes to a recycling condition that causes the timing cycle to repeat over and over as long as power is applied to the circuit. Potentiometer R4 is used to make obtaining an exact time delay easy. After the desired resistor value is determined, R4 can be replaced with a fixed 1% unit, or left as is for changing at a later date. Pressing S1 resets the circuit.

MC14536 Programmable Timer. Our second timer circuit is built around an MC14536B programmable timer, which contains a 24-stage, binary-ripple counter; 16 stages in that unit are selectable by a 4-bit binary code. The timer has a built-in RC oscillator (similar to the one in the previous IC), and a monostable-multivibrator output. Almost any timing period can be set by selecting the clock frequency and the proper counter stage for the desired time period.

In the Fig. 3 timer circuit, most of U1's options are selectable via individual switches. Pressing S1 supplies a positive pulse to the reset, or timer-start input, at pin 2 to initiate the timing cycle. Switch S2 selects the "8-bypass" option. Switches S3–S6 set the binary code for the counters.

Let's look into the IC in more depth; refer to Fig. 4 as we proceed. With pin 1

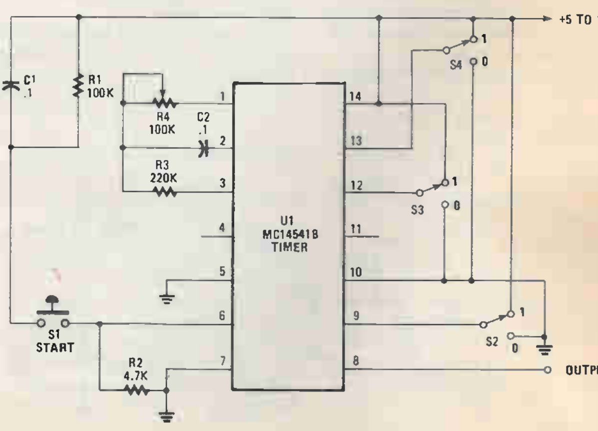


Fig. 2. The MC14541B (or 4541) programmable timer consists of a 16-stage binary counter, an internal R/C-oscillator circuit, an automatic power-up reset circuit, and a choice of output logic.

PARTS LIST FOR THE CIRCUIT IN FIG. 1

U1—MC14541B programmable timer, integrated circuit
R1—100,000-ohm, ¼-watt, 5% resistor
R2—4700-ohm, ¼-watt, 5% resistor
R3—220,000-ohm, ¼-watt, 5% resistor
R4—100,000-ohm potentiometer (see text)
C1, C2—0.1-µF, ceramic-disc capacitor
S1—Normally-open pushbutton switch
S2, S3, S4—SPST switch (any type)
Printed-circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

PARTS LIST FOR THE CIRCUIT IN FIGURE 3

U1—MC14536B programmable-timer, integrated circuit
R1, R2—100,000-ohm, ¼-watt, 5% resistor
R3—220,000-ohm, ¼-watt, 5% resistor
R4—4700-ohm, ¼-watt, 5% resistor
C1, C2—0.1-µF, ceramic-disc capacitor
Printed-circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

(set) tied high, the decode (out) pin (pin 13) is forced high and the internal oscillator is disabled. That places the circuit in the standby mode. Pin 1 must be tied low for the circuit to be placed into the timing mode. The reset input (pin 2) requires a positive pulse to activate the timer circuit by forcing the decode (out) terminal (pin 13) to go low, resetting all 24 flip-flop stages.

During the time that the pulse is positive, the chip's internal oscillator is inactive and the timing cycle remains in limbo until the negative-going edge of the input pulse starts the timing function. The in "1" terminal (pin 3) is the clock input. The internal counters advance on the negative-going edge of the clock input pulse. The clock input may be driven by the internal oscillator or from an external source.

If an external clock is used, both out "1" and out "2" (pins 4 and 5, respectively) may be left disconnected or used to drive other CMOS loads. When the 8-bypass terminal (pin 6) is tied high, the first 8 flip-flop stages are bypassed, making the device a 16-stage counter with each stage selectable from the 4-bit binary inputs.

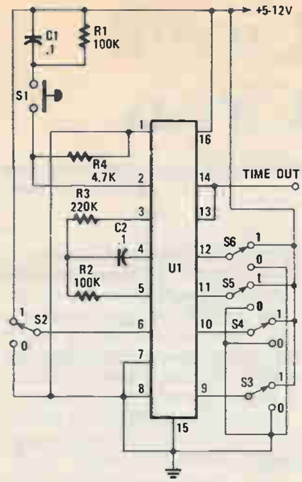


Fig. 3. This timer circuit is built around the MC14536 programmable timer, which contains a 24-stage, binary-ripple counter, a built-in RC oscillator, and a monostable-multivibrator output.

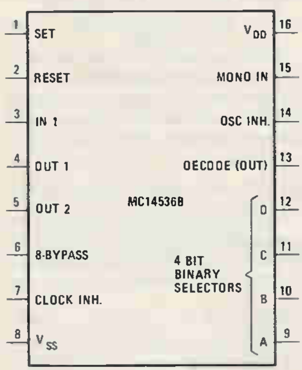


Fig. 4. Here's a pinout diagram of the MC14536. The chip can be programmed for the desired output frequency via its 4-bit binary-input selector (pins, 9, 10, 11, and 12).

With the 8-bypass pin tied to ground, all 24 flip-flop stages are used, with only the last 16 stages selected by the 4-bit binary inputs. Refer to the truth tables in Fig. 5 for selecting and setting the binary codes. The clock-inhibit terminal (pin 7) must be tied low for normal timing functions. If pin 7 (clock inhibit) is tied high, the first counter stage is disconnected from the clocking source. If the input is tied high during a timing interval, the current count will be kept on hold until the input goes negative.

BINARY CODE INPUT					
8 BYPASS PIN 6	D PIN 12	C PIN 11	B PIN 10	A PIN 9	SELECTED STAGE FOR OUTPUT
0	0	0	0	0	9
0	0	0	0	1	10
0	0	0	1	0	11
0	0	0	1	1	12
0	0	1	0	0	13
0	0	1	0	1	14
0	0	1	1	0	15
0	0	1	1	1	16
0	1	0	0	0	17
0	1	0	0	1	18
0	1	0	1	0	19
0	1	0	1	1	20
0	1	1	0	0	21
0	1	1	0	1	22
0	1	1	1	0	23
0	1	1	1	1	24

A

BINARY CODE INPUT					
8 BYPASS PIN 6	D PIN 12	C PIN 11	B PIN 10	A PIN 9	SELECTED STAGE FOR OUTPUT
1	0	0	0	0	1
1	0	0	0	1	2
1	0	0	1	0	3
1	0	0	1	1	4
1	0	1	0	0	5
1	0	1	0	1	6
1	0	1	1	0	7
1	0	1	1	1	8
1	1	0	0	0	9
1	1	0	0	1	10
1	1	0	1	0	11
1	1	0	1	1	12
1	1	1	0	0	13
1	1	1	0	1	14
1	1	1	1	0	15
1	1	1	1	1	16

B

Fig. 5. These truth tables can be used to set the desired output frequency. Refer to the text for details.

When pin 14 is tied high, the internal RC oscillator stops, reducing power consumption during the standby period. Pin 14 must be tied low for normal timing functions. The binary inputs (A, B, C, and D at pins 9–12, respectively) select the number of the counter stages needed to set the desired time delay (see the truth tables in Fig. 5). The mono-in terminal (pin 15) controls the operation of the internal monostable multivibrator. To disable the multivibrator, pin 15 is tied low.

The multivibrator is activated by connecting a resistor between pin 15 and the +V bus. The multivibrator's timing period is determined by the resistor's value and the internal circuit capacitance. The timing period can be increased by adding a capacitor between pin 15 and ground. Resistor values should range between 5k and

(Continued on page 30)

Circuit Circus

By Charles D. Rakes

ASTABLE MULTIVIBRATORS

This month we are going to spend our time together exploring a number of astable-multivibrators, more commonly known as oscillators. When it comes to picking the most often used circuit in electronics, the oscillator has got to be right up there near the top of the heap. And since the oscillator can do its own thing (in most cases) without support circuitry, it is a very popular "fun" circuit for the experimenter and project builder.

The most common type of oscillator starts off as an amplifier with a controlled amount of positive feedback from output to input to initiate and sustain oscillation. I'm sure most of you are familiar with the screeching sounds produced when a PA (public address) amplifier's gain is set too high.

The screeching sound is the result of positive feedback from the amp's speaker to the microphone. That type of oscillation is usually undesirable and in some instances difficult to overcome. Not all oscillators are welcome guests in the world of electronic circuitry.

Three-Transistor Oscillator. Our first entry, see Fig. 1, is a versatile oscillator circuit that will function at audio and low radio frequencies using just about any LC combination for the frequency-determining components. In our schematic diagram, the three transistors are connected in a Darlington/emitter-follower configuration, which presents a very high input impedance to the LC combination. That circuit arrangement reduces the loading effect on the frequency-determining components.

A simple way to determine the frequency of the LC tuned circuit is to follow this easy-to-use formula:

$$f = 5028/\sqrt{LC} \qquad (1)$$

where f is frequency in hertz, L is inductance in millihenrys, and C is capacitance in microfarads. Since C1 and C2 are connected in series the total capacitance (C_t) value must be calculated for the above formula using:

$$C_t = C1C2/(C1+C2) \qquad (2)$$

Here's an example of how to determine the resonant frequency of an LC combination, if L1 equals 10 mH, and C1 and C2 each equal 1 µF. Since C1 and C2 are in series, the total value is determined by:

$$C_t = 10^{-6} \times 10^{-6}/(10^{-6}+10^{-6}) = 0.5\ \mu F$$

The next step is to multiply the total capacitance (C_t) of 0.5 µF by the inductance value (10-mH) which gives us a value of 5. Now pull out your calculator and take the square root of 5 which is 2.236. Divide the number 5028 by 2.236, which works out to be 2248 Hz.

If you know the target frequency and have a specific coil on hand, the required capacitance value in microfarads can be determined by:

$$C = 5028^2/f^2L \qquad (3)$$

where C represents the combined value of the two series-connected capacitors. Just remember that the series value of C1 and C2 must equal the value determined by the formula. If C1 and C2 are of equal value, the actual value of the individual capacitors must be 2 times that calculated from the formula; *e.g.*, if the required capacitance is 2 µF and the capacitors are of equal value, then the individual capacitors must have a value of 4 µF. (Notice that capacitors in series divide like resistors in parallel.)

PARTS LIST FOR FIGURE 1

- Q1, Q2—2N3904 general-purpose NPN transistor
- R1, R2—1-megohm, ¼-watt, 5% resistor
- R3—470-ohm, ¼-watt, 5% resistor
- R4—500-ohm potentiometer
- C1, C2—See text
- C3, C4—4.7-µF, 35-WVDC, tantalum capacitor
- L1—See text
- Printed-circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

The LC tuned circuit best matches the transistor circuitry when C2 is larger than C1 by as much as 2 to 3 times. If you know the required frequency and have a capacitor on hand, the required inductance (L) can be determined by:

$$L = 5028^2/f^2C \qquad (4)$$

The receiver element from a telephone handset can be used for L1 and two 4.7-µF, 35-volt tantalum capacitors can be use for C1 and C2 (note polarization of C1 and C2 in Fig. 1) to produce a 700-Hz tone that can be heard coming from the inductor. The oscillator thrives on small inductors and very large capacitors. That feature is helpful in producing very low-frequency tones without the expense of a large inductor.

Potentiometer R4 sets the positive feedback and should be adjusted for the cleanest waveform. If an os-

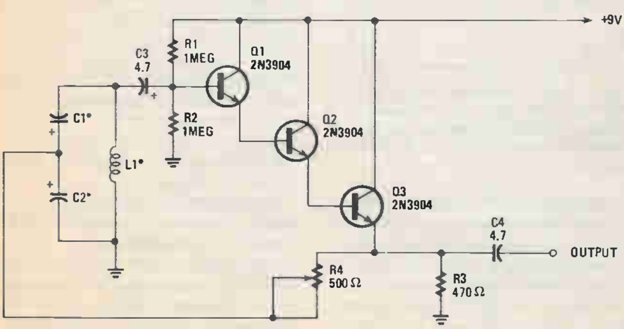


Fig. 1. In this circuit, three transistors are configured as a Darlington/emitter-follower, and will function at audio and low RF frequencies.

cilloscope is handy, monitor the output at C4 and decrease the value of R4, starting from its maximum resistance, until the circuit just starts to oscillate. Continue turning R4 in the same direction until the waveform just begins to show some distortion, and then back R4 off until the waveform appears symmetrical.

One-Transistor Oscillator. A similar oscillator circuit designed to operate at a much higher frequency is shown in Fig. 2. The upper frequency limit of that circuit is set primarily by the transistor. The L and C values are selected in the same way as for the oscillator in Fig. 1.

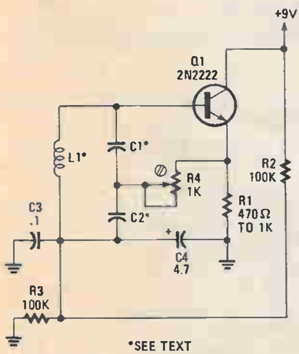


Fig. 2. This oscillator is designed to operate at a much higher frequency than the previous circuit, and its upper frequency limit is governed primarily by the transistor.

PARTS LIST FOR FIGURE 2

Q1—2N2222 or similar general-purpose NPN transistor
R1—470- to 1000-ohm, ¼-watt, 5%, resistor
R2, R3—100,000-ohm, ¼-watt, 5%, resistor
R4—1000-ohm trimmer potentiometer
C1, C2—See text
C3—0.1-µF, ceramic-disc capacitor
C4—4.7-µF, 16-WVDC, electrolytic capacitor
L1—See text
Printed-circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

The oscillator circuit in Fig. 3 is a good choice for a very low frequency, audio-tone generator. Tone frequencies below 10 Hz, and even less than 1 Hz, are obtainable with that oscillator circuit.

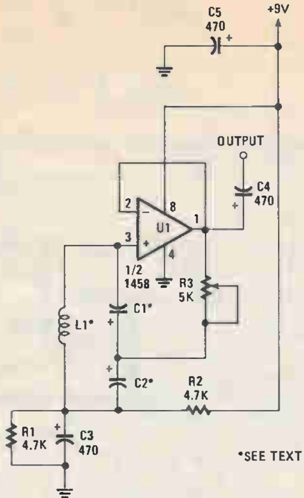


Fig. 3. The low-frequency audio-tone generator (built around a 1458 dual op-amp) can produce frequencies below 10 Hz, and contains an LC tuned circuit similar to those used in the previous two circuits.

PARTS LIST FOR FIGURE 3

U1—1458 dual-op-amp, integrated circuit
R1, R2—4700-ohm, ¼-watt, 5% resistor
R3—5000-ohm potentiometer (see text)
C1, C2—See text
C3–C5—470-µF, 16-WVDC, electrolytic capacitor
Printed-circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

One half of a 1458 dual op-amp serves as the active element and the LC tuned circuit is similar to those used in the previous two circuits.

When you start working with an LC tuned circuit that resonates at or below 10 Hz, you are dealing with very large inductors with values on the order of 10 henries (H) and up. Not only are large chokes hard to find, they are very expensive. But that's no problem for our circuit because it's happy to oscillate with just about any inductor that you choose to use.

With a little digging in the junkbox, you should be able to come up with a number of choices for the inductor portion of the tuned circuit. In fact, just about any power transformer's primary winding can be used for the inductor; the several tested ranged from a low of 3 to a high of over 10 henries. One of the best choices, if available, is a variable autotransformer that's made for 117-volts AC operation. Ham swap meets and surplus stores are good places to find that item.

Another very useful inductor that can be used for tuning the oscillator to a very low frequency range is the auto's high-voltage ignition transformer. Connect the high voltage output terminal and either of the primary terminals to the circuit and you can approach a frequency of 1 Hz.

In tuning the 10-henry coil to a frequency of 5 Hz, we find that by using formula 3 (above), a 100-µF capacitor is needed, and since C1 and C2 are in series, each capacitor value must be twice that size, or 200-µF each. Thanks to the circuit's versatility, electrolytic capacitors can be used for C1 and C2.

When using the formulas with large inductor values remember that 1 H = 1000 mH. Some LC combinations, especially those used to tune extremely low frequencies, require that R3 be set near the low-resistance end of its rotation. If you get erratic outputs under those conditions, substitute a 500-ohm potentiometer for R3. That arrangement makes controlling the circuit's feedback much smoother.

The "Q" of the large, inexpensive inductors is usually very low, requiring a greater circuit gain to sustain oscillation. Coils used for 100 Hz and up usually are higher in "Q" and require less feedback to maintain oscillation.

Wien-bridge Oscillator. Our next oscillator circuit—a Wien-bridge oscillator (see Fig. 4)—also generates nice low-frequency sine waves and does not require large inductors. The frequency-determining components for that oscillator circuit are two resistors and two capacitors.

The gain of the oscillator's active component, the popular 741 op-amp, is set by the values of R5, R6, R7, and the non-linear characteristic of diodes D1 and D2. The fine gain control, R7, sets the op-amp's gain to produce a clean sinusoidal output waveform. The oscillator's frequency is determined by the values of R1, R2, C1, and C2, when R1 = R2 and C1 = C2.

Setting the frequency of the Wien-bridge oscillator is slightly more difficult than tying your shoes. If a frequency of 1 kHz is desired and two 5% .005-µF capacitors are handy, the required resistance can be determined by:

$$R = .159/fC$$
$$R = .159/1000 \times .005$$
$$R = .0318 \text{ megohms or } 31{,}000 \text{ ohms}$$

The closest standard resistor values to that calculated would be 30k or 33k.

If you can locate a pair of 1-µF Mylar or polyester capacitors, or even make your own by paralleling two 0.5-µF units for C1 and C2, you can generate some truly low-frequency sine waves. Two 100,000-ohm resistors for R1 and R2 and the two 1-µF capacitors for C1 and C2 will cause the circuit to oscillate at about 1.6 Hz. Increase the resistor values to 1 megohm and the oscillator slows down to about 0.16 Hz.

Sinusoidal Oscillator. Our last oscillator circuit generates a sine wave by using three equal-value capacitors and resistors in a phase-shift configuration; see Fig. 5. A 741 op-amp supplies amplification to overcome the losses in the RC phase-shift network and one half of the phase shift needed to sustain oscillation.

The op-amp's gain is set by the values of R6, R7, and R1, or R6 + (R7/R1). With a gain of about 30, the oscillator will produce a good sine-wave output. Each time the values of R1–R3 are changed, the op-amp's gain must be re-adjusted.

Setting the frequency of the phase-shift oscillator is no more difficult than the previous circuit, but different formulas (derived from: $F = 1{,}000{,}000/2\pi \times \sqrt{6RC}$) are used to calculate values. To calculate frequency, use formula 5; for resistance, use formula 6; and for capacitance, use formula 7.

$$f = 65k/RC \quad (5)$$

$$R = 65k/fC \quad (6)$$

$$C = 65k/fR \quad (7)$$

Here's an example of how the simple frequency formula works. With three 10k resistors and three .068-µF capacitors, the oscillator frequency is:

$$f = 65k/RC$$
$$f = 65k/10k \times .068$$
$$f = 65k/680$$
$$f = 95.5 \text{ Hz}$$

It's a good idea to plug in your own component values, and experiment with those formulas to accustom yourself to them.

Well that's about all the space that has been allotted to us this month...but be sure to join us next time. ■

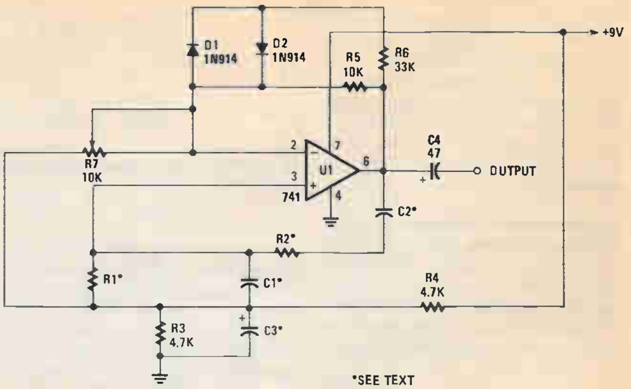


Fig. 4. The Wien-bridge oscillator generates low-frequency sine waves and does not require large inductors.

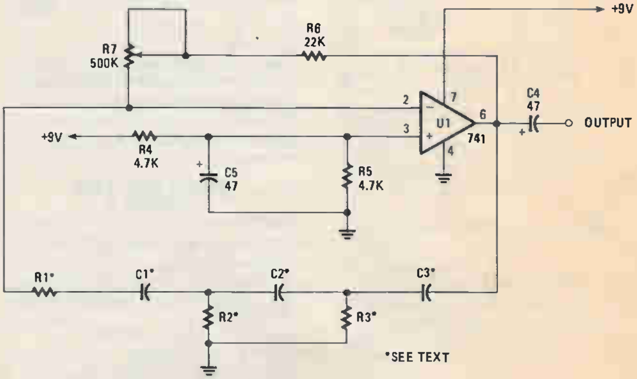


Fig. 5. The sinusoidal oscillator (built around a 741 op-amp) uses three equal value capacitors and resistors in a phase-shift configuration. Setting the frequency of this oscillator is no more difficult than the previous circuit.

PARTS LIST FOR FIGURE 4

U1—741 op-amp, integrated circuit
D1, D2—1N914 general-purpose small-signal silicon diode
R1, R2—See text
R3, R4—4700-ohm, ¼-watt, 5% resistor
R5—10,000-ohm, ¼-watt, 5% resistor
R6—33,000-ohm, ¼-watt, 5% resistor
R7—10,000-ohm potentiometer
C1, C2—See text
C3, C4—47-µF, 16-WVDC, electrolytic capacitor
Printed-circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, etc.

PARTS LIST FOR FIGURE 5

U1—741 op-amp, integrated circuit
R1–R3—See text
R4, R5—4700-ohm, ¼-watt, 5% resistor
R6—22,000, ¼-watt, 5% resistor
R7—500,000 potentiometer
C1–C3—See text
C4, C5—47-µF, 16-WVDC, electrolytic capacitor
Printed circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, etc.

Circuit Circus

By Charles D. Rakes

SIMPLE BUT USEFUL TEST GEAR, AND MORE!

This month's Circus offers a variety of circuits, some of which are suitable for full-fledged construction projects that should keep the soldering iron hot for many hours. We start off by featuring a circuit that's designed to make relative sound-level measurements. Intensity levels from less than 70 dB to over 115 dB are spread over four ranges and are easily read on a 10-segment, LED level indicator.

Sound-Level Meter. Figure 1 shows the schematic diagram of the Sound-Level Meter. Sound is picked up by MIC1 (an electret microphone element) and fed to the input of the first op-amp, U1-a (half of an LM1458N dual op-amp). The values of R3 and R4 set the op-amp's gain—which is equal to R4/R3—at 100; that's done using the values shown for those resistors. The signal is then fed to the input of the second op-amp (U1-b), where it is boosted again by a factor of between 1 and 33, depending upon the setting of the range switch, S1.

With the range switch set in the "A" position, R6 is 1K and R7 is 33K, so that stage has a gain of 33. In the "B" position, the gain is 10; in the "C" position, the gain is 2.2; and in the "D" position, the gain is 1.

Op-amp U1-b's output is converted to a varying DC signal by a voltage-doubler, rectifier circuit that's made up of components D1, D2, C3, and C4. Transistor Q1 is connected in an emitter-follower circuit to isolate the DC signal from the input circuitry of U2 (an LM3914 dot/bar display driver).

Transistor Q2, Zener doide D3, and resistor R13 make up a voltage-regulator circuit that reduces the 9-volt power source to a regulated 5-volt level and is used to power U2 (which is connected in the dot-display configuration).

As the signal voltage fed to the input of U2 at pin 5 varies, one of ten LED's will light to correspond with the input-voltage level. At the input's lowest operating level, U2 produces an output at pin 1, causing LED1 to light. The highest input level presented to the input of U2 (about 1.2 volts) causes LED10 to turn on.

Resistors R10 and R11 make up a simple voltage-divider network, which reduces Q1's output-signal voltage to an operating range that matches the input requirements of U2. Resistor R12 sets the LED's drive current. The light output of the LED's can be increased by reducing the value of R12 or decreased by increasing that resistor's value. The minimum value for R12 should not be less than 680 ohms.

Even though the circuit layout isn't critical, neatness and short interconnecting leads are a definite plus in the finished product. The circuit can be assembled on perfboard or (if you are well versed in printed-circuit fabrication) a printed-circuit board can be made. However, if the perfboard approach is taken, use sockets for the IC's. If you anticipate using the sound meter often, it would be worth your time to house the circuit in a small plastic cabinet with MIC1 mounted in one end and the LED's, and the range switch located on the top.

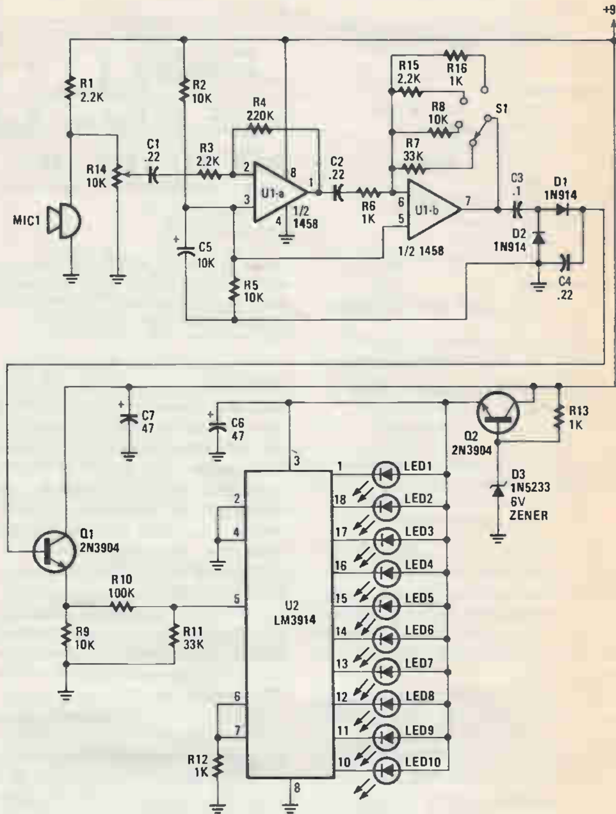


Fig. 1. The Sound-Level Meter is built around two integrated circuits—the LM1458N dual op-amp and the LM3914 dot/bar display driver—which are supported by two transistors and a handful of additional components.

PARTS LIST FOR THE SOUND-LEVEL METER

SEMICONDUCTORS

U1—LM1458N dual op-amp, integrated circuit
U2—LM3914 dot/bar-display driver, integrated circuit
Q1, Q2—2N3904, general-purpose, NPN silicon transistor
D1, D2—1N914, general-purpose silicon diode
D3—1N5233, 6-volt ½-watt Zener diode
LED1–LED10—Jumbo light-emitting diode

RESISTORS

(All resistors are ¼-watt, 5% units, unless otherwise noted.)
R1, R3, R15—2200-ohm
R2, R5, R8, R9—10,000-ohm
R4—220,000-ohm
R6, R12, R13, R16—1000-ohm
R7, R11—33,000-ohm
R10—100,000-ohm
R14—10,000-ohm potentometer

CAPACITORS

C1, C2, C4—0.22-µF, mylar or ceramic disc
C3—0.1-muF, ceramic disc
C5–C7—47-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

MIC1—Electret microphone element
S1—Single-pole, 4-position rotary switch
Printed-circuit or perfboard materials, enclosure, IC sockets, 9-volt transistor-radio battery and battery holder, wire, solder, hardware, etc.

The easiest way to calibrate the Sound-Level Meter is with a commercial sound-level meter. However, if one is not available, the following method will do fine, especially if the circuit is to be used in making relative sound-level comparisons.

A number of low-cost piezo sounders—for which the manufacturers have specified a dB output-sound level at a fixed distance—are available from several suppliers. To calibrate the circuit using sounders, take a sounder for which the output dB level is specified. Let's say that the unit chosen is rated for 100 dB at a distance of one inch.

Place MIC1 about one inch from the sounder, then set range-switch S1 to the "C" position and adjust R14 so that the fifth LED turns on to indicate 100 dB.

Now with the simple calibration procedure completed the approximate range of each switch position is as follows: Position "A" = 65 dB to 85 dB; position "B" = 80 dB to 96 dB; position "C" = 94 dB to 105 dB; and position "D" = 100 dB to over 115 dB.

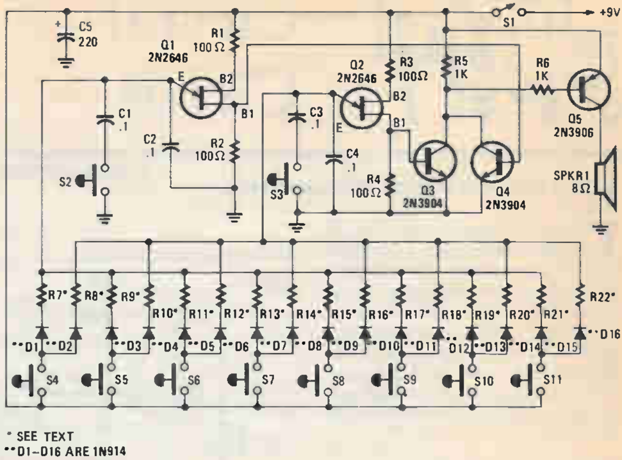


Fig. 2. The Electronic Bagpipe is made up of two oscillator circuits that are built around unijunction transistors (UJT's). Q1 and Q2. The outputs of the oscillators are fed to an audio mixer (consisting of Q3 and Q4), the output of which is the fed to the base of Q5, which is used to drive speaker SPKR1.

A jet airplane flying directly overhead, and at close range, can produce sound levels greater than 120 dB, which is near the threshold level that can actually cause pain. The ambient noise level found in many manufacturing facilities can vary from a low of 65 dB to levels over 80 dB. A normal conversation between two people in a quiet room will average between 75 and 80 dB at a measured distance of 1 foot from the speakers. For a quick circuit check, you can position the microphone about one foot away from, and directed toward you, and speak in a normal manner and adjust R14 so that LED5 lights on the "A" range.

Of course, our simple Sound-Level Meter won't match the performance of the professional high-cost units, but for the time and money spent, it can be a handy test instrument to have around the shop.

Electronic Bagpipe. Our next circuit, see Fig. 2, is my version of a simple Electronic Bagpipe that's not only fun to build, but can be a neat gift for that special child. The circuit mimics the dual-tone drone sound that's produced by the unusual wind instrument.

Here's how the sounds are made. Unijunction transistors Q1 and Q2 are connected in similar audio-oscillator circuits. Each of the oscillator frequencies is determined by one of the two resistors selected by one of the pushbutton switches, S4 through S11. Odd-numbered resistors, R7–R21, determine the frequency for the Q1 oscillator circuit and the even-numbered resistors, R8–R22, determine the frequency for Q2's circuit.

PARTS LIST FOR THE ELECTRONIC BAGPIPE

SEMICONDUCTORS

Q1, Q2—2N2646 N-channel unijunction transistor
Q3, Q4—2N3904 general-purpose silicon NPN transistor
Q5—2N3906 general-purpose silicon PNP transistor
D1–D16—1N914 general-purpose diode

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1–R4—100-ohm
R5, R6—1000-ohm
R7–R22—3300-ohm

CAPACITORS

C1–C4—0.1-muF, ceramic-disc
C5—220-muF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

SPKR1—8-ohm, 4-inch speaker
S1—SPST toggle switch
S2–S11—Normally open pushbutton switch
Printed-circuit or perfboard materials, enclosure, IC sockets, 9-volt, transistor-radio battery and battery holder, speaker grille, wire, solder, hardware, etc.

When S4 is pressed, the positive supply is connected to both R7 and R8 through isolation diodes D1 and D2, causing both oscillators to operate. A narrow, fast-rising positive pulse is developed at B1 of both Q1 and Q2 for each cycle of operation. Transistors Q3 and Q4 serve as a simple audio mixer, which is used to combine the pulses from each oscillator. The mixed signal at the collectors of Q3 and Q4 is coupled through R6 to the base of Q5, which amplifies and drives an 8-ohm speaker, SPKR1.

The resistor values (R7–R22) for determining the oscillator's operating frequency should be selected in pairs to generate the dual-tone drone of the bagpipe, and should be values ranging between 3.3k and 33k. A good musical ear or frequency counter will be helpful in selecting the resistors and tuning the instrument. The sixteen resistors, R7–R22, can be replaced with the same number of miniature trimmer potentiometers to simplify the tuning.

Switches, S2 and S3 are used to reduce the oscillator's frequency by about one-half, when closed, to produce a new group of tones. The circuit is not critical and can be assembled on perfboard or a printed-circuit board of your own design and housed in a suitable plastic or wood enclosure. The selection or building of a special enclosure can turn this simple circuit into a very special project of which you can be proud.

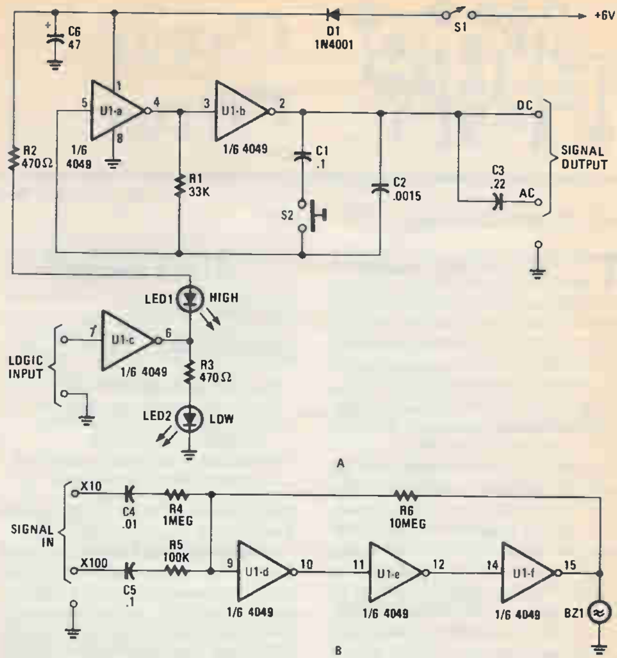


Fig. 4. The 3-in-1 Test Set combines three of the most useful test instruments—a signal injector, a logic probe, and an audio signal tracer. The signal tracer has two inputs that allow it to accept two signal levels; the one you use depends upon the magnitude of the signal injected into the circuit.

PARTS LIST FOR THE 3-IN-1 TEST SET

SEMICONDUCTORS

U1—4049 hex inverting buffer, integrated circuit
D1—1N4001 silicon diode
LED1, LED2—any color LED

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1—33-ohm
R2, R3—470-ohm
R4—1-megohm
R5—100,000-ohm
R6—10-megohm

CAPACITORS

C1, C5—0.1-µF, ceramic-disc
C2—.0015-µF, ceramic-disc
C3—0.22-µF, mylar or similar
C4—.01-µF, ceramic-disc
C6—47-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

S1—toggle or slide power switch
S2—normally open push-button switch
BZ1—Piezo sounder element without internal driver.
Printed-circuit or perfboard materials, enclosure, IC sockets, 4 "AAA" batteries and battery holder, wire, solder, hardware, etc.

3-in-1 Test Set. Our third circuit is actually a three-in-one Test Set designed around a 4049 hex inverter/buffer. See Fig. 3. Two inverters (from that six-inverter unit) are used in a dual-frequency signal-injector circuit, another inverter is used as a logic probe, and the remaining three inverters are used as a sensitive dual-input, audio-signal tracer.

The signal-injector portion of the Three-in-One Test Set consists of gates U1-a and U1-b, which are configured as a two-frequency, pulse-generator circuit. Under normal conditions, the generator's output frequency is around 10 kHz, but when S2 is closed, the output frequency drops to about 100 Hz. For higher frequencies decrease the values of C1 and C2 and for lower frequencies increase the capacitor values. Both AC and DC outputs are offered.

The logic-probe portion of the circuit is made up of U1-c, and a couple of LED's, which are used to indicate the "high" or "low" logic state by turning on an LED. When a logic high is applied to the input of U1-c, the output of the inverter goes low. The low output of U1-c reverse biases LED2, so it remains off. That low output also forward biases LED1, causing it to light. But when a logic low is presented U1-c's input, the situation is reversed, so that LED2 lights and LED1 goes dark. Resistors R2 and R3 limit the current flow through the LED's to about 10 mA.

The audio-signal tracer portion of the circuit is made up of U1's three remaining inverters (U1-d through U1-f), which

(Continued on page 32)

Circuit Circus

By Charles D. Rakes

HEXFET APPLICATIONS

This month we're placing a power hexFET at center stage, performing in a number of interesting and useful tasks. The IRF511 N-channel power MOSFET is one of the least expensive of the hexFET devices that International Rectifier (IR) produces, and is available from at least two **Popular Electronics** advertisers: Digi-Key Electronics and Radio Shack.

The IRF511 has a maximum on-state resistance of 0.6 ohm, input/output capacitance of less than 150 picofarads (pF), a gate threshold voltage (voltage level needed to turn on the device) of between 2 and 4 volts, a maximum drain-to-source voltage of 60 volts, and a maximum drain current of 3 amperes. In addition, its maximum power dissipation is 20 watts, and it comes in the handy TO-220 plastic package.

Inverters, choppers, switching power-supplies, motor controls, audio amplifiers, and high-energy pulse circuits are but a few of the applications where that semiconductor device can be pressed into service. But enough about the unit's characteristics. Let's get to the point of this column—to teach as well as entertain.

Class A Amplifier. Our first act places the IRF511 (Q1) in a simple class-A audio-amplifier circuit. See Fig. 1. With zero gate bias applied, Q1 is like a switch in the off state, so no current flows through the load resistor, R2.

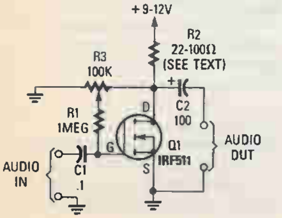


Fig. 1. In this circuit the IRF511 is configured as a class A amplifier. Ideally, for class-A operation, the voltage across Q1 and the load resistor should be equal.

PARTS LIST FOR THE CLASS A AMPLIFIER

Q1—IRF511 hexFET
R1—1-megohm, ¼-watt, 5% resistor
R2—22–100-ohm, ¼-watt, 5% resistor (see text)
R3—100,000-ohm potentiometer
C1—0.1-µF, ceramic-disc capacitor
C2—100-µF, 25-WVDC, electrolytic capacitor
Printed-circuit or perfboard materials, 9–12 volt power source, wire, solder, etc.

Ideally speaking, the voltage across Q1 and the load resistor should be equal for class-A operation. A 100K potentiometer (R3) and a 1-megohm fixed resistor (R1) make up a simple adjustable gate-bias circuit. Place a voltmeter between the drain of Q1 and the circuit ground, and adjust R3 for a meter reading of half the power-supply voltage.

Almost any resistor value can be used for R2 as long as the maximum current and power ratings of the FET are not exceeded. A resistor value of between 22 and 100 ohms is a good choice for experimenting. At high currents, a suitable heat sink should be used.

Relay Controller. The second circuit, shown in Fig. 2, has the power FET (Q1) controlling a relay. With zero gate-bias applied, Q1 acts like an open switch, but when a DC voltage greater than 5 volts is applied to the input of the circuit, Q1 turns on, completing the relay circuit and thereby activating the relay coil.

PARTS LIST FOR THE RELAY CONTROLLER

Q1—IRF511 hexFET
D1—1N4001 silicon rectifier diode
R1—100,000-ohm, ¼-watt, 5% resistor
R2—1-megohm ¼-watt, 5% resistor
K1—12-volt DC relay
Printed-circuit or perfboard materials, 12-volt power source, wire, solder, etc.

The input bias current required to turn on Q1 and operate the relay is less than 10 microamperes (µA), which is about 1/1,000,000 of the current required to bias the popular 2N3055 power transistor to operate the same relay.

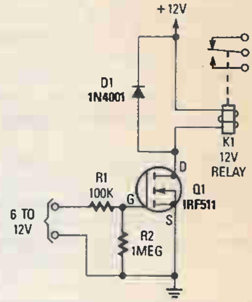


Fig. 2. With zero gate-bias applied, Q1 acts like an open switch, but when a DC voltage greater than 5 volts is applied to the input of the circuit, Q1 turns on, completing the relay circuit, and thereby activating the relay.

Proximity Switch. The next circuit (see Fig. 3) takes advantage of the ultra-high input impedance and power-handling capabilities of the FET to make a simple, but sensitive, proximity sensor and alarm-driver circuit.

A 3 × 3-inch piece of circuit board (or similar size metal object), which functions as the pick-up sensor, is connected to the gate of Q1. A 100-megohm resistor, R2, isolates Q1's gate from R1, allowing the input impedance to remain very high. If a 100-megohm

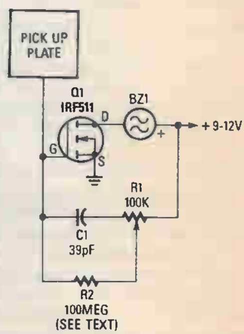


Fig. 3. The sensitivity of this Proximity Switch can be varied by adjusting R1. Note that R2 is specified as a 100-megohm unit, if that value cannot be located tie five 22-megohm resistors in series and use that combination for R2.

PARTS LIST FOR THE PROXIMITY SWITCH

Q1—IRF511 hexFET
R1—100,000-ohm potentiometer
R2—100-megohm, ¼-watt, 5% resistor (see text)
C1—39-pF, ceramic-disc capacitor
BZ1—piezo electric buzzer
Printed-circuit or perfboard materials, enclosure, 9–12-volt power source, wire, solder, etc.

resistor cannot be located, just tie five 22-megohm resistors in series and use that combination for R2. In fact, R2 can be made even higher in value for added sensitivity.

Potentiometer R1 is adjusted to a point where the piezo buzzer just begins to sound off and then carefully backed off to the point where the sound ceases. Experimenting with the setting of R1 will help in obtaining the best sensitivity adjustment for the circuit. Resistor R1 may be set to a point where the pick-up must be contacted to set off the alarm sounder. A relay or other current-hungry component can take the place of the piezo sounder to control most any external circuit.

Lamp Flasher. The circuit in Fig. 4 is built around two power FET's, which are configured as a simple astable multivibrator to alternately switch the two lamps on and off. The R/C values given in the Parts List sets the flash rate to about ⅓ Hz. By varying either the resistor or capacitor values almost any

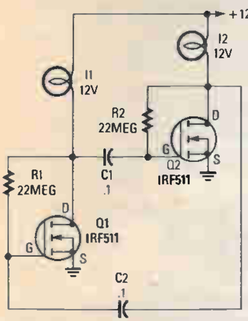


Fig. 4. In this circuit, two hexFETs are configured as a simple astable multivibrator to alternately switch the two lamps, I1 and I2, on and off.

flash rate can be obtained. Increase either C1 and C2, or R1 and R2, and the flash rate slows. Decrease them and the rate increases.

Unlike most semiconductor devices, the power MOSFET can be paralleled, without special current-sharing components, to control larger load currents. That can be an important feature when the device is used to turn on incandescent lamps, because the lamp's cold resistance is much lower than the normal operating resistance.

A typical #1815 12- to 14-volt lamp measures 6 ohms cold. When 12 volts is applied, the initial current drawn is 2 amps. The same lamp, when operating at 12 volts, requires only 200 mA. The hot resistance figures out to be ten times its cold resistance, or 60 ohms. That tidbit should be considered when picking any semiconductor device to control an incandescent lamp.

PARTS LIST FOR THE LAMP FLASHER

Q1, Q2—IRF511 hexFET
R1, R2—22-megohm, ¼-watt, 5% resistor
C1, C2—0.1-µF, mylar capacitor
I1, I2—12-volt incandescent lamp
Printed-circuit or perfboard materials, 12-volt power source, wire, etc.

Audio Oscillator. The next circuit places the power FET in the output stage of an audio variable frequency oscillator (VFO) circuit (see Fig. 5). That simple VFO circuit can be used for audible-tone testing, driving someone nuts, or transformed into a simple electronic musical instrument. For instance, several might be wired parallel to each other with each tuned for different frequencies, with pushbutton switches added to control the power circuit, thereby producing a simple electronic organ.

Two gates, U1-a and U1-b (⅓ of a 4049 hex inverter), are connected in a VFO circuit. Components R1, R3, and C1 set the frequency range of the VFO.

PARTS LIST FOR THE AUDIO OSCILLATOR

U1—4049 hex inverter, integrated circuit
Q1—IRF511 hexFET
R1—47,000-ohm, ¼-watt, 5% resistor
R2—1-megohm, ¼-watt, 5% resistor
R3—1-megohm potentiometer
C1—.0036-µF, mylar capacitor
C2—.056-µF, mylar capacitor
SPKR1—45-ohm speaker (2 or 3 inch diameter)
Printed-circuit or perfboard materials, enclosure, wire, solder, etc.

With the values given, the circuit's output can range from a few hundred hertz to over several thousand hertz by adjusting R3.

The simplest way to change the frequency range of the oscillator is to use different capacitance values for C1. A rotary switch, teamed up with a number of capacitors, can be used to select the desired frequency range.

Cassette Interface. In our next circuit (Fig. 6) two power FET's (Q1 and Q2) are used to form the basis of an interface circuit for attaching a cassette recorder to the phone line. If you're fed up with your answering machine, because the incoming tape always fills up with sales pitches so that when a really important message comes through, there's no more room, then this circuit could be for you. Of course your machine must be able to continue to operate when the incoming tape is full.

With the Interface circuit installed, place a long-play tape in your cassette recorder, press the record switch, and get all of the incoming messages. Or the circuit can become a 24-hour automatic secretary to record all incoming phone calls.

The circuit does not require a power supply because operating power is drawn from the telephone line itself.

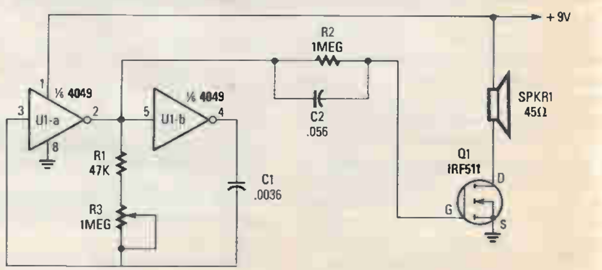


Fig. 5. This simple VFO circuit can be used for audible-tone testing, driving someone nuts, or it can be transformed into a simple electronic musical instrument—an electronic organ, for example.

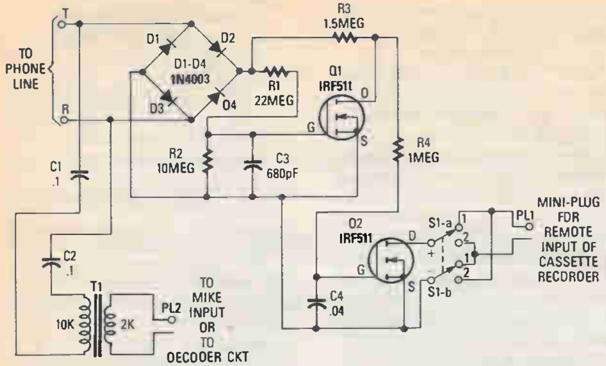


Fig. 6. The Cassette Interface does not require its own power supply, but instead rectifies a portion of the incoming audio signal to provide power for the circuit.

The incoming signal is fed across a bridge-rectifier circuit, consisting of diodes D1 through D4. If your are familiar with the operation of bridge rectifiers, you'll realize that the bridge ensures that no matter how the circuit is connected to the phone lines, the voltage at the junction of R1 and R3 will always be positive.

When the phone is on hook the voltage at the output of the bridge (at R1/R3 junction) is near 48 volts. That voltage is fed across a voltage divider consisting of R1 and R2. The voltage at the junction formed by R1 and R2 is fed to the gate of Q1, turning it on. That pulls the drain of Q1 low. Since the gate of Q2 is connected to the drain of Q1, the bias applied to the gate of Q2 is low, holding it in the off state.

When the answering machine respondes to a call or a phone is taken off hook, the voltage across the phone lines drops below 10 volts, causing Q1 to turn off. At that point, the voltage at Q1's drain rises, turning Q2 on. The remote input of the cassette is connected to Q2's drain and source through S1 and a miniature plug selected to mate with the remote input jack.

Switch S1 must be in a position so that the positive lead of the recorder's remote input connects (through switch position 1) to Q2's drain and the negative input to Q2's source. Switch S1 provides a convenient way to reverse the circuit's trigger output without having to unsolder and resolder leads. The phone's audio is coupled through C1, C2, and T1 to the microphone input of the cassette recorder.

PARTS LIST FOR THE CASSETTE INTERFACE

SEMICONDUCTORS
Q1, Q2—IRF511 hexFET
D1–D4—1N4003 silicon diode

RESISTORS
(All resistors are ¼-watt, 5% units.)
R1—22-megohm
R2—10-megohm
R3—1.5-megohm
R4—1-megohm

CAPACITORS
C1, C2—0.1-µF, mylar
C3—680-pF, ceramic disc
C4—.04-µF, mylar

ADDITIONAL PARTS AND MATERIALS
T1—miniature audio transformer (10K to 2K)
S1—DPDT toggle switch
PL1, PL2—See text
Printed-circuit or perfboard materials, modular telephone plug, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

PARTS LIST FOR THE SOUND-ACTIVATED SWITCH

SEMICONDUCTORS
U1—LF353 dual op-amp, integrated circuit
Q1—IRF511 hexFET
D1, D2—1N914 general-purpose silicon diode

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1, R7—2200-ohm
R2, R3—10,000-ohm
R4, R9—1000-ohm
R5—100,000-ohm
R6—10,000-ohm potentiometer
R8, R11—220,000-ohm
R10—100-ohm
R12—1-megohm

CAPACITORS
C1, C3, C6—0.47-µF, 16-WVDC, electrolytic
C2—47-µF, 16-WVDC, electrolytic
C4, C5—0.1-µF, 100-WVDC, ceramic disc

ADDITIONAL PARTS AND MATERIALS
MIC1—Electret condenser microphone
Perfboard material, enclosure, IC sockets, 9-volt battery and battery holder, wire, solder, hardware, etc.

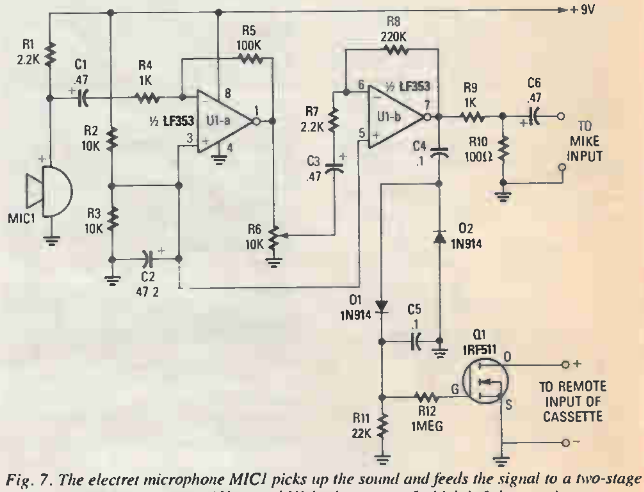


Fig. 7. The electret microphone MIC1 picks up the sound and feeds the signal to a two-stage amplifier circuit, consisting of U1-a and U1-b, the output of which is fed to a voltage-doubler circuit (made up of D1, D2, C4, and C5).

Sound-Activated Switch. In our final circuit, the power FET is used as a switch in a sound-activated cassette-recorder circuit; see Fig. 7. Such a circuit might find application in a project for recording intermittent noise or wildlife sounds automatically without having the recorder running constantly.

A sensitive electret microphone picks up the sound and feeds the signal to a two-stage amplifier circuit, consisting of U1-a and U1-b. The amplified output of U1-b is fed to a voltage-doubler circuit (made up of D1, D2, C4, and C5). The output of the doubler is input to the gate of Q1. When the DC voltage reaches the gate's threshold level, Q1 switches on, starting the recorder.

The cassette's internal or external microphone can be used to record normal sound levels, but for picking up weak sounds use the amplified output for a boosted level. Resistor R6 sets the circuit's sensitivity and should be experimented with to obtain the optimum adjustment.

On MOSFETS. There's one important area that we didn't cover and that's where the power MOSFET really shines. It's an ideal device to use in high voltage circuits because it doesn't suffer from the dreaded secondary-voltage breakdown that plagues the common power transistor. And any number of MOSFET's can be paralleled without requiring a special high-wattage, current-equalizing resistor.

Our shop's treasure chest of spare parts contained a number of IRF731 hexFET's with a V_{DS} (drain-to-source voltage) rating of 350-volts; a 1-ohm R_{DS} (on-state resistance); a maximum I_D (drain current) of 3.5 amps; and a maximum power-dissipation rating of 75 watts. There are a number of similar hexFET's that are available for less than $3.00 that will work just as well in a high voltage circuit. I'd suggest obtaining a copy of Digi-Key's (701 Brooks Ave. South, PO Box 677, Theif River Falls, MN 56701; Tel. 800/344-4539) catalog, which lists two full pages of hexFET's.

PARTS LIST FOR FIGURE 8

U1—4049 inverting hex buffer, integrated circuit
Q1—IRF731, or similar hexFET
R1—2.2-megohm ¼-watt, 5% resistor
R2—10,000-ohm ¼-watt, 5% resistor
C1—.0036-µF, mylar-capacitor
C2—680-pF, ceramic disc capacitor
C3—220-µF, 16-WVDC, electrolytic capacitor
T1—Automobile-ignition coil (any type)
Printed-circuit or perfboard materials, heat-sink material, 12-volt 2-amp power source, IC socket, wire, solder, hardware, etc.

Flip the Switch. Our first application (see Fig. 8) has an IRF731 hexFET operating as a high-current switch in a high-voltage generator circuit. Two gates of a 4049 hex inverting buffer (U1-a and U1-b) are configured as a simple squarewave-generator circuit. The output of the squarewave generator (a narrow positive pulse) at pin 2 of U1-b is fed to the gate (G) of Q1 through an R/C combination (consisting of R2 and C2), causing it to switch on and off at the same rate.

The fast switching current through the primary of T1, an automobile-ignition coil, is transformed into a high-voltage at T1's secondary. Caution! Keep all attached body parts away from the output of T1. The high-voltage output of T1 is great enough to jump from the output terminal to one or both of the primary terminals.

If the high voltage circuit is to be operated for any length of time, a heat sink with a minimum area of 9 square inches should be attached to Q1. A piece of scrap aluminum will do just fine. The circuit can be operated with an input voltage as high as 16 volts for short periods of time for even greater output voltages.

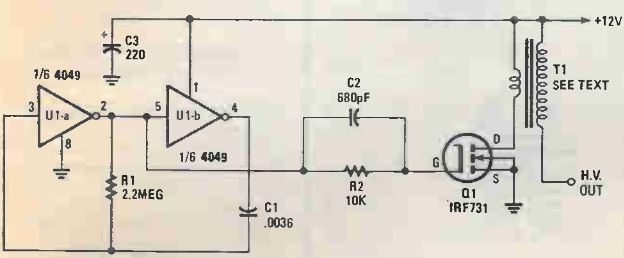


Fig. 8. In this circuit, an IRF731 hexFET and two gates of a 4049 hex inverting buffer are configured as a squarewave-generator circuit, with Q1 operating as a switch.

Non-Integrated Inverter. Have you ever needed just one more gate or inverter stage to finish that special circuit design? Or do you sometimes find that an inverter or gate is lacking in output drive? If so, why not consider one of the following simple add-on circuits, built around discrete transistors, to fill that void.

The circuit shown in Fig. 9 is a simple inverting amplifier that can be driven from most CMOS or TTL IC's. The truth table for that circuit is the same as what might be expected from an ordinary integrated-circuit inverter: *i.e.*, high in, low out; low in, high out.

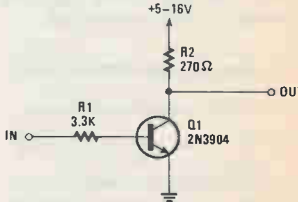


Fig. 9. This simple inverting amplifier, built around discrete components, can be driven from most CMOS or TTL IC's.

PARTS LIST FOR FIGURE 9

Q1—2N3904, 2N2222, or similar NPN silicon transistor
R1—3300-ohm, ¼-watt, 5% resistor
R2—270- to 1000-ohm, ¼-watt, 5% resistor (see text)
Printed-circuit or perfboard materials, 5- to 16-volt power source, wire, solder, etc.

When the inverter's output is high, it will supply drive current, limited by the value of R2 and the transistor, to whatever circuitry is connected to its output. When the inverter's output is low, the circuit connected to its output will be pulled to ground. The amount of current the transistor can sink depends on its gain and power handling capabilities.

Non-Integrated Buffers. The circuit in Fig. 10 is a non-inverting amplifier that can be used to increase output drive current. Like its integrated counterparts, its truth table says that a high

(Continued on page 32)

CIRCUIT CIRCUS
(Continued from page 15)

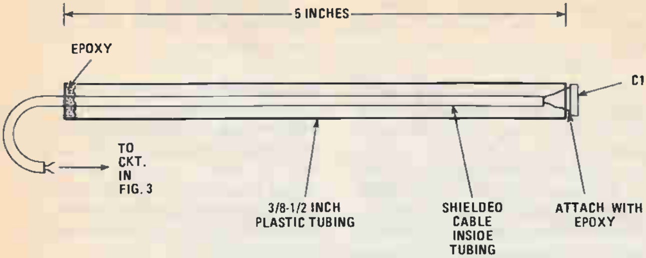


Fig. 4. Shown here are construction details for the probe unit used with the knock-detector circuit.

much time to fully recover and return to a zero reading between input signals. And if the value is too small the meter's needle will not have sufficient time to climb to its peak reading before the voltage across C2 is discharged.

PARTS LIST FOR FIG. 3

- U1—LM324 quad op-amp, integrated circuit
- D1, D2—1N914 general-purpose, small signal diode
- R1, R2—4700-ohm, ¼-watt, 5% resistor
- R3, R4, R7—100,000-ohm, ¼-watt, 5% resistor
- R5—1000-ohm, ¼-watt, 5% resistor
- R6—1-megohm, ¼-watt, 5% resistor
- R8, R9—5000-ohm, potentiometer
- C1—0.1-µF, ceramic-disc capacitor
- C2, C3—0.47-µF, ceramic-disc capacitor
- C4, C5—100-µF, 16-WVDC electrolytic capacitor
- M1—0–1-mA, DC milliammeter
- Printed-circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, shielded microphone cable, hook-up wire, solder, hardware, etc.

A 1-megohm resistor proved to be a good compromise value for R6; but if an intermitant knock ensues, the value can be increased to 10 megohms and the meter will retain the reading for a period of time to make tracing the noise to its source much easier.

The circuit can be built on perfboard and mounted in a small plastic case allowing enough room for the meter, battery, R8, R9, and the OFF/ON switch (S1). Use a socket for the IC. Keep the component leads short and the wiring neat, and with any luck old Murphy will stay far away.

The pick-up probe can be a copy of the one in Fig. 4, or one of your own design. But in any case make sure that C1 can be placed flat against the object being checked to ensure its maximum sensitivity to the shock wave created by the ping or knock. At least a three foot length of shielded cable should be used to connect the probe to the circuit so that it can be maneuvered into hard-to-get places.

Using the instrument is easy. First set the gain control for maximum gain and tap the sensor end of the probe on a hard object and adjust R9 for a full-scale meter reading. Place the probe flat against the object to be checked and note the meter's reading each time the knock occurs and move the probe in the direction that causes the meter's reading to increase. The gain setting may need to be reduced somewhat when the probe is near the source of the knock. ■

CIRCUIT CIRCUS
(Continued from page 19)

100k, and the capacitor should be no larger than 1000 pF.

The out "1" and out "2" terminals at pins 4 and 5 are used with the in "1" terminal to form an RC-oscillator circuit. The decode (out) terminal at pin 13 is the timer's output. For the circuit shown in Fig. 3, the frequency of U1's internal RC oscillator is determined by the same formula used in our first timer circuit. Set S2 and S3 to the 1 position, and switches S4, S5, and S6 to 0.

Figure 5B shows that we've selected the binary code for a divide-by-4 function. Note that S2 is set to bypass the first 8-counter stages. So after 4 clock pulses, the timer gives a positive output at pin 13. For a much longer time period, set S2 to the 0 position and S3, S4, S5, and S6 to 1. The oscillator will have to cycle through all 24 flip-flop stages for a count of 16,777,216 before the timer circuit will produce an output.

If the clock is running at 1 Hz, the timing cycle would take 16,777,216 seconds, or 279620.26 minutes, or 4660.33 hours, or 194 days to produce an output. To reduce the time delay by a factor of 10 just increase the oscillator's frequency to 10 Hz, or by a factor of 100 to 100 Hz, and so o.

The decode (out) terminal at pin 13 is tied back to the oscillator inhibit termi-

PARTS LIST FOR THE CIRCUIT IN FIGURE 6

- U1—4011 quad 2-input NAND-gate, integrated circuit
- R1, R2—10,000-ohm, ¼-watt, 5% resistor
- S1—SPDT momentary spring-return toggle switch
- Printed-circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

PARTS LIST FOR THE CIRCUIT IN FIGURE 7

- U1—4049 hex inverting buffer, integrated circuit
- R1—10,000-ohm, ¼-watt, 5% resistor
- R2—100,000-ohm potentiometer
- C1—4.7-µF, 25-WVDC, electrolytic capacitor
- Printed-circuit or perfboard materials, enclosure, IC sockets, battery and battery holder, wire, solder, hardware, etc.

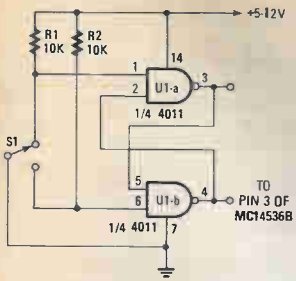


Fig. 6. This bounce-free switch circuit can be connected to the timer circuit. Pressing S1 clears and resets the timer circuit.

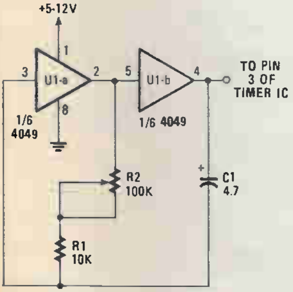


Fig. 7. A simple square-wave oscillator circuit (like this one) can be used to drive the timer if a lower clock frequency is required.

nal at pin 14, disabling the oscillator during standby to conserve power. Removing that jumper causes the timing cycle to repeat over and over as long as power is applied to the circuit. To use the timer in the multivibrator mode, disconnect pin 15 from ground and connect a timing resistor between that pin and the positive supply rail. Connect a timing capacitor between pin 15 and ground.

The bounce-free switch circuit shown in Fig. 6 can be connected to the timer circuit with pin 4 of the 4011 going to the in "1" pin of the timer. Push S1 to clear and reset the timer circuit. Each time S1, in Fig. 6, is activated the counter advances one count. When the total count is reached, the timer gives a positive output at pin 13. If a lower clock frequency is needed to drive the timer, try the simple square-wave oscillator circuit shown in Fig. 7. Resistor R2 controls the oscillator's frequency and the output (pin 4 of the 4049) connects to pin 3 of the timer. ■

CIRCUIT CIRCUS

(Continued from page 17)

the rejuvenating circuit and tune R7 until the LED1 responds in step with the dit-dah's.

Tunable Audio Filter. If you are dealing with signals that are heavily affected by noise, the circuit in Fig. 4 will help clean them up so they can be fed to either of the rejuvenating circuits.

A 741 op-amp is the heart of a simple *Tunable Audio Filter* circuit that takes the incoming signal and amplifies it, while attenuating all other frequencies. The values of C1, C2, and R8 determine the filter's operating frequency; with the values given, the circuit covers the tuning range of the two rejuvenating circuits.

To calibrate the circuit, connect a scope to pin 6 of U1 and adjust R7 until the gain of the circuit is increased to the point where the circuit goes into self oscillation. Connect a frequency counter to pin 6 and adjust R8 for the desired input frequency. Observe the scope and slowly back R7 off until the oscillation ceases. That sets the "Q" of the filter, which will probably need to be readjusted slightly when receiving a signal.

The value of R9 also effects the circuit's "Q" and should be as large as possible. If the circuit's gain is set too high, the output will "ring" and the continuity of a coded signal will be lost. If fixed-frequency operation is desired, replace R8 (a dual gang potentiometer) with two ¼-watt, 5% resistors. Two resistor decade boxes can be used to determine the exact values needed.

That's all the time and space allotted to us for this month, but be sure to tune in again next month, when we'll present another group of fun circuits designed to entertain and educate you in the ways of electronics. ■

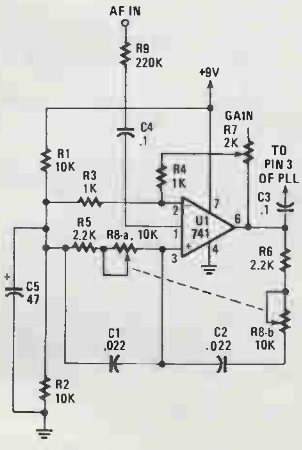


Fig. 4. At the heart of the Tunable Audio Filter is a 741 op-amp. The values of C1, C2, and R8 determine the filter's operating frequency.

PARTS LIST FOR THE SIGNAL CONDITIONER

SEMICONDUCTORS

U1, U2—567 tone decoder, integrated circuit
Q1—2N3906 general-purpose silicon PNP transistor
Q2—2N3904 general-purpose silicon NPN transistor
LED1—Light-emitting doide

RESISTORS

(All resistors are ¼-watt, 5% units, unless otherwise noted.)
R1, R4—4700-ohm
R2, R6—470-ohm
R3—2200-ohm
R5—10,000-ohm
R7, R8—20,000-ohm potentiometer
R9—1000-ohm potentiometer

CAPACITORS

C1–C4—0.1-µF, ceramic-disc
C5–C8—0.47-µF, 15-WVDC, electrolytic
C9—47-µF, 15-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

Printed-circuit or perfboard materials, enclosure, IC sockets, 5-volt power source, wire, solder, hardware, etc.

PARTS LIST FOR THE TUNABLE AUDIO FILTER

RESISTORS

(All resistors are ¼-watt, 5% units, unless otherwise noted.)
R1, R2—10,000-ohm
R3, R4—1000-ohm
R5, R6—2200-ohm
R7—2000-ohm, potentiometer
R8—10,000-ohm dual-gang potentiometer
R9—220,000-ohm (see text)

CAPACITORS

C1, C2—.022-µF, Mylar or similar
C3, C4—0.1-µF, ceramic-disc
C5—47-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

U1—741 op-amp, integrated circuit
Printed-circuit or perfboard materials, enclosure, IC sockets, 9-volt power source, wire, solder, hardware, etc.

CIRCUIT CIRCUS
(Continued from page 29)

input gives a high output, and a low input gives a low output (see note below).

Unlike the previous circuit, this one is somewhat more complicated, so a brief circuit description is in order: When a positive input is applied to the base of Q1, it turns the transistor on, pulling the base of Q2 low, turning Q2 on. At the same time, the low at the collector of Q1 is also applied to the base of Q3, causing Q3 to turn off. That means that the circuit's output is the supply voltage minus the voltage drop found across Q2 and R4.

When the input is low, Q1 and Q2 are both off. With Q2 off, it can not sink any current from its output. If the circuit that the driver is connected to requires the load to be pulled to ground, transistor Q3 must be added. With Q1 off its collector is near the supply voltage, which supplies bias to Q3, turning it on and clamping the output to ground. When Q1 turns on, bias is removed from the base of Q3, turning it off and unclamping the output ■

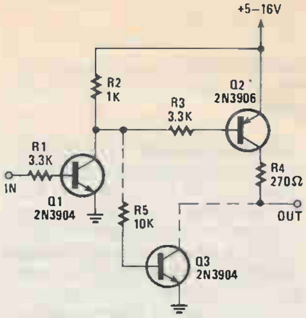


Fig. 10. The non-integrated buffer, like its integrated counterparts, can be used to increase the output drive current.

PARTS LIST FOR FIGURE 10

- Q1, Q3—2N3904, 2N2222, or similar silicon NPN transistor
- Q2—2N3906, 2N3638, or similar silicon PNP transistor
- R1, R3—3300-ohm, ¼-watt, 5% resistor
- R2—1000-ohm, ¼-watt, 5% resistor
- R4—270- to 1000-ohm, ¼-watt, 5% resistor (see text)
- R5—10,000-ohm, ¼-watt, 5% resistor
- Printed-circuit or perfboard materials, 5- to 16-volt power source, wire, solder, hardware, etc.

"We're in luck—I managed to buy the last 12 boxes of fuses."

(Continued from page 25)

are configured as a linear audio-amplifier that is used to increase the input signal level by a factor of 10 or 100. The amplified output signal feeds a miniature piezo element for audible detection.

The cost of parts for this multi-purpose tester should be less than five dollars without drawing from your junkbox, and far less if you do. The method of construction is your choice (perfboard or a printed-circuit board), but whichever method is used, keep the leads short and the layout neat.

Simple VCO. Our last circuit, see Fig. 4, places a 555 into service as an ultra-simple, voltage-controlled oscillator (VCO). The output frequency of the VCO (U1) varies inversely with the input voltage. With a 1-volt input, the oscillator's output frequency is about 1500 Hz, and with a 5-volt input, the output frequency of the oscillator drops to around 300 Hz.

The output frequency range of U1 can be altered by varying the values of C1, R2, and R3. Increasing the value of any of those three components will lower the oscillator frequency, and decreasing any of those values will cause the frequency to rise.

The output-waveform symmetry suffers as the frequency varies from one extreme to the other. At the highest frequency, the waveform is almost equally divided. But as the frequency drops, the output of the circuit turns into a narrow pulse.

If a symmetrical waveform is required, add the second IC, U2 (half of a 7473P dual TTL J-K flip-flop) to the oscillator circuit.

However, there's one catch: The signal frequency output by U2 is only one-half of what's going in. To overcome that deficiency just double the frequency of the VCO and the problem will be solved. ■

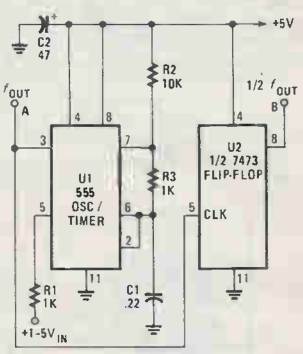


Fig. 3. In this circuit, a 555 oscillator/timer is used as a simple VCO. The signal produced by the VCO is fed to U2 (half of a 7473 dual TTL flip-flop), which provides a square-wave output that varies at half the input frequency.

PARTS LIST FOR THE SIMPLE VCO

- U1—555 oscillator/timer, integrated circuit
- U2—7473 dual TTL J-K flip-flop, integrated circuit
- R1, R3—1000-ohm, ¼-watt, 5% resistor
- R2—10,000-ohm, ¼-watt, 5% resistor
- C1—0.22-muF mylar capacitor
- C2—47-µF, 16-WVDC, electrolytic capacitor

ADDITIONAL PARTS AND MATERIALS

Printed-circuit or perfboard materials, enclosure, IC sockets, 5-volt power source, wire, solder, hardware, etc.