The Basic Circuits Handbook for Project Builders

36 Time Tested Circuits

By the Editors of POPULAR ELECTRONICS

A GERNSBACK PUBLICATION

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ABOUT THIS BOOKLET

A helter-skelter collection of diagrams stashed in a drawer is the *modus operandi* for many circuit designers. For others, well-organized book shelves bulging with thick tomes is the obvious solution. This editor is a cross between the two collectors with a slight variation. I save Charles Rakes' Circuit Circus columns that appear in Popular Electronics magazine. After many years of publishing these columns, my files always have the circuit I need no matter what the application. Well, almost always.

Thus, when it came time to publish a booklet for the home experimenter and professional circuit designer alike, what better source of absolute fun material than selected columns of Circuit Circus! Thumb through the pages slowly scanning each diagram. You'll find that each page will have an attraction that will hold you and have you at the workbench with soldering iron in hand almost immediately. Have fun!

Julian Martin, Editor Emeritus
Popular Electronics

CIRCUIT CIRCUS

By Charles D. Rakes

Simple Circuits With Practical Applications

This month we are going to take a look at a number of unrelated circuits that can be used as is, or modified to fit some specific application. Even if you don't have a project in mind, it can be a lot of fun building and experimenting with a new circuit just to see how it operates.

PROXIMITY SWITCH

Our first circuit (see Fig. 1) came about when we were working on a project that required a proximity switch in which RF could not be used as the sensing medium. In addition, the sensor's pick-up plate had to be mounted in a location where it could not be touched or bridged to activate. Those restrictions resulted in some real head scratching that, after a time, produced an IR-triggered, proximity-detector circuit.

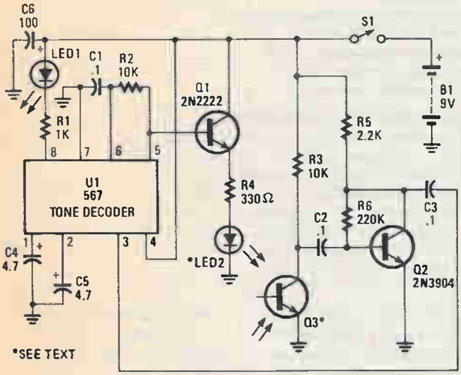

Fig. 1. The unusual thing about our Proximity Switch is that it is not triggered by direct IR radiation, but instead is triggered by a reflected IR signal.

The unusual thing about the circuit is that it is not triggered by direct IR radiation in its original application; reflected IR radiation striking the detector triggered the circuit. At the heart of the circuit in Fig. 1 is a single 567 tone decoder IC (U1) which, in this circuit, performs a dual function: it operates both as a basic IR-transmitter driver and as a receiver. Capacitor C1 and resistor R2 are used to set U1's internal-oscillator frequency to about 1 kHz.

The square-wave output of U1 at pin 5 is fed to the base of Q1. Transistor Q1 (a 2N2222 general-purpose unit) is configured as an emitter-follower amplifier, which applies a 20-mA pulse to the anode of LED2 (an infrared-emitting diode, that's half of an IR-emitter/detector pair). Transistor Q3 (the other half of the IR-emitter/detector pair) detects the IR output of LED2 and sends the signal on to Q2 for additional amplification.

After amplification by Q2, the signal is fed back to the input of U1 at pin 3, causing pin 8 to go low, biasing LED1 on. If desired, LED1 can be replaced with an optocoupler to control just about any AC-operated circuit.

Since the circuit is so simple, just about any construction scheme will do. The IR emitter (LED1) and the phototransistor (Q3) should be placed about ½-inch apart in a side-by-side position and aimed in the same direction.

You'll need to experiment with the spacing and mounting angle of the two IR devices to determine the best location for a given distance between the detector and the emitter. As a guideline, a ½-inch spacing between the IR-emitter/detector pair allows the proximity circuit to detect an object about ½ to 1-inch away. Lighter colored objects reflect better and will work at greater distances than those made of darker materials.

The optocoupler-based, Triac-driver circuit shown in Fig. 2 can be added to the proximity switch in Fig. 1 to control a small AC motor. As long as the proximity sensor detects an IR signal, the controlled circuit remains activated, and when the signal disappears the output turns off.

GAIN CONTROLLER

Our next entry places a 4066 quad bilateral switch in a remote gain-control circuit to illustrate the IC's basic function in a simple application. The 4066 contains four independently controlled, normally open, single-pole single-throw (SPST) switches in a single plastic package. Each SPST switch can be viewed as (essentially) a micro-powered Triac, since, like the Triac (which is also called a bilateral switch), they are capable of conducting current in either direction.

Each normally open switch has its own control input; when a positive logic signal is applied to a switch's control input, the switch closes, tying any devices connected to it to each other. The switch contacts are opened by applying a negative logic signal to the control input.

All input/output circuitry is internally protected against damage from high static voltages or electrical fields,

PARTS LIST FOR THE PROXIMITY SWITCH

SEMICONDUCTORS

U1—567 tone decoder, integrated circuit
Q1—2N2222 general-purpose NPN silicon transistor
Q2—2N3904 general-purpose NPN silicon transistor
Q3—IR detector transistor (from matched emitter/detector pair, RS 276-142 or similar)
LED1—Jumbo light-emitting diode (any color)
LED2—IR emitter (from matched emitter/detector pair, RS 276-142 or similar)

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1—1000-ohm
R2, R3—10,000-ohm
R4—330-ohm
R5—2200-ohm
R6—220,000-ohm

CAPACITORS

C1–C3—0.1-µF, ceramic-disc
C4, C5—4.7-µF, 25-WVDC, electrolytic
C6—100-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

B1—9-volt transistor-radio battery
S1—SPST switch
Perfboard materials, enclosure, AC molded power plug with line cord, battery(ies), battery holder and connector, wire, solder, hardware, etc.

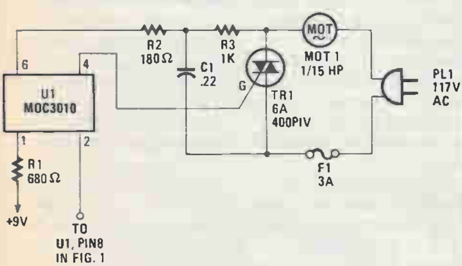

Fig. 2. The Triac Driver can be added to the proximity switch to control a small AC motor.

PARTS LIST FOR THE TRIAC DRIVER

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1—680-ohm
R2—180-ohm
R3—1000-ohm

ADDITIONAL PARTS AND MATERIALS

TR1—6-amp, 400-PIV Triac
U1—MOC3010 optoisolator/coupler (Triac driver), integrated circuit
C1—0.22-µF, ceramic-disc capacitor
F1—3-amp fuse
Perfboard materials, enclosure, AC molded power plug with line cord, battery(ies), battery holder and connector, wire, solder, hardware, etc.

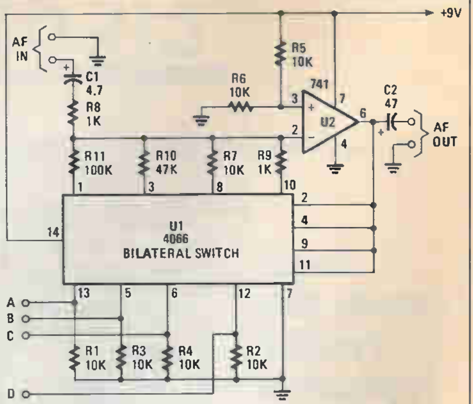

Fig. 3. The Gain Controller uses a 4066 quad bilateral switch to electronically select a feedback resistor for the 741 op-amp. One or more switches can be turned on at the same time to produce a stepped, variable-gain range of from less than 1 to 100.

PARTS LIST FOR THE GAIN CONTROLLER

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1–R7—10,000-ohm
R8, R9—1000-ohm
R10—47,000-ohm
R11—100,000-ohm

ADDITIONAL PARTS AND MATERIALS

U1—4066 quad bilateral-switch, integrated circuit
U2—741 general-purpose op-amp, integrated circuit
C1—4.7-µF, 16-WVDC, electrolytic capacitor
C2—47-µF, 16-WVDC, electrolytic capacitor
Perfboard materials, enclosure, AC molded power plug with line cord, battery(ies), battery holder and connector, wire, solder, hardware, etc.

but to be on the safe side, don't let any of the input/output pins go above the IC's supply voltage. The 4066 IC performs admirably in modulator/demodulator, signal-gating, attenuator, gain-control, commutating-switching, multiplexing, analog-to-digital and digital-to-analog conversion, and other circuits.

The 4066 in Fig. 3 switches four gain-setting resistors in and out of a single-stage AF amplifier (built around a 741 op-amp) to obtain up to 12 different gain settings. When the control input of U1 at pin 13 is tied high, R11 (a 100k resistor) is connected in U2's feedback loop. With the 100k value of R11 (and ignoring the switch's resistance), U2 has a voltage gain of 100; the gain is found by dividing the feedback resistor's value by the input resistor's value (R11/R8 = 100k/1k = 100).

When pin 5 of U1 is tied high, R10 (a 47k resistor) is connected in the op-amp's feedback loop, and the op-amp's gain drops to 47; when pin 6 is tied high, R7 (a 10k resistor) is connected in the op-amp's feedback loop, giving it a gain of 10; and with pin 12 tied high, R9 is connected in the feedback loop, providing a gain of 1 (unity). One or more switches can be turned on at the same time to produce a stepped, variable-gain range of from less than 1 to 100. The values of R7 through R11 can be selected to produce the desired gain for each activated switch, or the combination of two or more activated switches.

The control inputs (labeled A–D) can be remotely operated through either a wire cable or a wireless system to control the amplifier's gain. By changing the values of the feedback resistors, the circuit can be changed into a remote-controlled attenuator. Additional gain or attenuator steps can be added by using more than one 4066 IC and additional gain-setting resistors.

WAVEFORM GENERATOR

Figure 4 shows another application of the 4066 quad bilateral switch. In that circuit, the 4066 (U1) is used to perform sequential switching to produce a symmetrical stepped waveform; see Fig. 5. As shown, the generator's waveform is made up of 3-up and 3-down steps in 1-volt increments. Switch trigging for the 4066 is controlled by a 4017 decade counter/divider (U2); a 567 tone decoder configured as a square-wave generator supplies the clock pulses for the 4017.

The 4017 is programmed to count from 0 to 5 (0-1-2-3-4-5) sequentially and reset on the leading edge of the seventh step by tying pin 5 (output 6) of U2 to pin 15 (reset). When output 6 (pin 5 of U2) goes high, the reset terminal of U2 forces output 0 (pin 3) to toggle from low to high, beginning the sequence anew. The high pin-3 output (output 0) of U2 is fed to the control terminal of the first switch in U1, turning it on and thereby bridging the junction of R4 and R5 to the output bus.

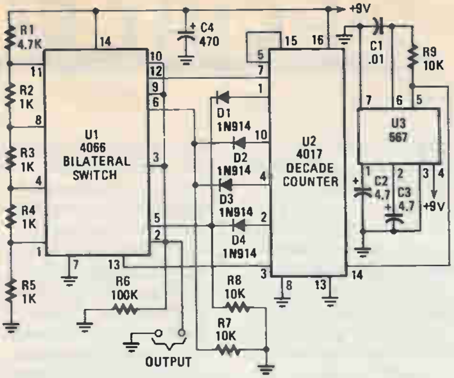

Fig. 4. In the Waveform Generator, the 4066 (U1) is used to perform sequential switching to produce a symmetrical stepped waveform.

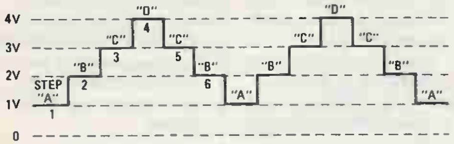

Fig. 5. The output of the stepped waveform generator is made up of 3-up and 3-down steps in 1-volt increments (much like the output of a digital-to-analog converter). Switch trigging for the 4066 is controlled by a 4017 decade counter/divider (U2), which is clocked by a square-wave generator built around a 567 PLL (phase-locked loop).

PARTS LIST FOR THE STEPPED WAVEFORM GENERATOR

SEMICONDUCTORS
U1—4066 quad bilateral-switch, integrated circuit
U2—4017 decade counter/divider, integrated circuit
U3—567 tone decoder, integrated circuit
D1–D4—1N914 small signal silicon diode

RESISTORS
(All resistors are ¼-watt, 5% units.)
R1—4700-ohm
R2–R5—1000-ohm
R6—100,000-ohm
R7–R9—10,000-ohm

CAPACITORS
C1—0.01-µF, ceramic-disc
C2, C3—4.7-µF, 16-WVDC, electrolytic
C4—470-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS
Perfboard materials, enclosure, 9-volt power source, IC sockets, wire, solder, hardware, etc.

That sets the first step at a one-volt level. On the next clock pulse from the 567, the 4017 produces a high output at pin 2, which is fed through D4 to the next switch control at pin 5, turning it on. That connects the junction of R3 and R4 to the output bus. The second step produces a 2-volt output. On the next pulse received from U3, pin 4 of U2 goes high, causing the third switch (in U1) to conduct, which in turn produces a 3-volt output for step 3. The fourth pulse from U3 causes pin 7 to go high, turning on the final switch, and thereby producing a 4-volt output for step 4.

The fifth pulse applies a high to pin 10 of U2, which passes through D4 to the control input of the third switch, turning it on (for a second time) and giving a 3-volt output for the fifth step. On the next clock pulse, the switch connected to pin 6 of U1 is again triggered, producing a 2-volt output for step 6. After step six is completed the counter resets and starts over by turning on the first switch for step 1.

There are a number of applications for this circuit. The stepping waveform generator can be used to supply a number of progressive voltages for testing the on/off switching points of various CMOS devices. Each step on the waveform can be set for any voltage from zero to full supply voltage by using individual voltage dividers for each step. Also, the generator's output can be buffered to supply sufficient voltage and current outputs to serve as an increasing voltage or current source for a semiconductor curve tracer. ■

CIRCUIT CIRCUS

By Charles D. Rakes

Test Gear For The Beginner

Once again it's time to drag out your junkbox and join me here at the Circus as I share a few circuits that I've worked up especially for your experimenting pleasure. There's one unique aspect about our hobby when it comes to experimenting with a new circuit; if we don't like the performance, we can dig in and modify or redesign it to meet our own special needs. Just about any circuit that's not buried in epoxy can be modified for better or worse.

Patience and a thorough understanding of the circuit's operation are a must if your modification is to be successful. In any case, procede with caution and do nothing that can't be undone, so that, at the very least, you can go back to square one and either stay with the original or start over. Our circuits here at Circuit Circus are designed to be "modifier" friendly, so have at it.

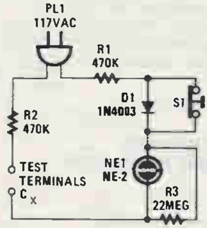

Fig. 1. This simple Capacitor Checker is ideally suited to the beginning electronics builder.

CAPACITOR CHECKER

Our adventure begins with a circuit that came about when an old-timer friend asked if I could build him a simple and inexpensive capacitor checker. His only requirements were to determine if a capacitor was open or shorted, if it would withstand at least a 100-volt charge without breaking down, and, if possible, indicate a "rough" value of the capacitance. And to make the job less difficult, all of the capacitors values would fall between 0.1-µF and 0.5-µF.

The circuit in Fig. 1 meets the above requirements and shouldn't cost more than two or three dollars to duplicate. Power for the circuit is taken form any AC outlet and will cost zilch to operate.

Here's how the checker operates. With power applied and nothing connected to the test terminals, the circuit draws no current so the neon lamp (NE1) is off. If a capacitor is connected to the test terminals (denoted C_X), and if the capacitor isn't open, the lamp will glow. That test can be used to weed out open capacitors only, not shorted ones; the lamp would glow if the capacitor is good or even shorted.

Pushing S1 changes the voltage applied to the capacitor under test from AC to DC. If the capacitor is good, one element of the neon lamp will glow for the time that it takes the capacitor to charge and then will slowly dim and go out completely. If the lamp remains on, or even shows a slight glow, the capacitor has an internal leak and should be discarded.

The value of the capacitor can be estimated by the time it takes the lamp to go out after S1 is pressed. The larger the capacitor's value, the longer it takes to charge and for the lamp to go out. Select several known values of capacitors in the range of 0.1 to 0.5 µF and check each one, while noting the charge time. With a little practice, you'll be able to determine if the capacitor under test is near its marked value.

Also, capacitors with values less than 0.1 µF can be successfully tested with the circuit. Just keep in mind that small-value capacitors require very short charging times, so you'll have to keep a close watch on the neon lamp to see the brief glow.

PARTS LIST FOR THE CAPACITOR CHECKER

D1—1N4003 1-amp, 200-PIV, general-purpose silicon rectifier diode
NE1—NE-2 neon lamp
R1, R2—470,000-ohm, ¼-watt, 5% resistor
R3—22-megohm, ¼-watt, 5% resistor
S1—Normally-closed pushbutton switch
Perfboard materials, enclosure, molded AC-power plug with line cord, test terminals, wire, solder, hardware, etc.

SQUARE-WAVE SIGNAL GENERATOR

Our next entry, see Fig. 2, uses a 555 oscillator/timer as the basis of a variable-frequency audio square-wave generator that can be used as a square-wave

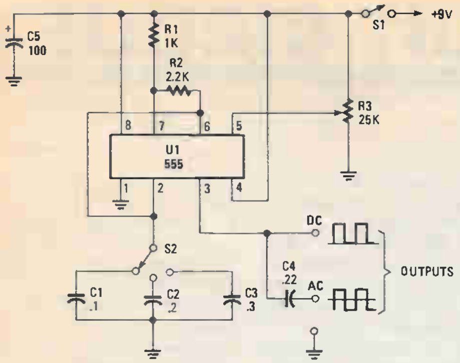

Fig. 2. Built around a 555 oscillator/timer, this audio-frequency, square-wave generator makes an inexpensive addition to your electronics workbench.

PARTS LIST FOR THE SQUARE-WAVE SIGNAL GENERATOR

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1—1000-ohm
R2—2200-ohm
R3—25,000-ohm potentiometer

CAPACITORS
C1—0.1-µF, ceramic-disc
C2—0.2-µF, ceramic-disc
C3—0.3-µF, ceramic-disc
C4—0.22-µF, ceramic-disc
C5—100-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS
U1—555 oscillator/timer, integrated circuit
S1—SPST toggle switch
S2—SP3T rotary switch
Perfboard materials, enclosure, molded AC power plug with line cord, test terminals, wire, solder, hardware, etc.

or pulse generator for troubleshooting or to supply a drive signal for a new circuit design. The 555 (U1) is configured as a VCO (Voltage-Controlled Oscillator).

Switch S2 sets the frequency range of the circuit (from about 500 Hz to over 4 kHz), while R3 (which feeds U1's voltage-control input at pin 5) determines the actual operating frequency of the VCO. Additional ranges may be added, or the existing ranges changed, to go above and/or below the frequencies presently available. With S2 in the position shown (connected to C1), the circuit provides the highest output-frequency range available; as S2 is switched to C2 and C3, the frequency range decreases. (In other words, as the switched capacitance increases, the output frequency-range decreases.)

Extremely low-frequency operation can be obtained by using an electrolytic capacitor in the timing circuit. Just be sure to tie the negative end of the unit to ground and the positive end to S2.

The output waveform is symmetrical near the center position of R3 and degrades as it approaches either end of rotation. Experiment with the values of R1 and R2 to modify the shape of the output waveform. The circuit also provides both AC- and DC-coupled output signals.

AC/DC INDICATOR

Our next circuit is a simple but extremely useful project that could become one of the most often used little test gadgets on your electronics workbench. The unit can distinguish between AC or DC voltages;

PARTS LIST FOR THE AC/DC INDICATOR

SEMICONDUCTORS
Q1—2N3904 general-purpose NPN silicon transistor
Q2—2N3906 general-purpose PNP silicon transistor
LED1—Jumbo red light-emitting diode
LED2—Jumbo yellow light-emitting diode

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

ADDITIONAL PARTS AND MATERIALS
S1—Normally-open pushbutton switch
B1, B2—9-volt transistor-radio battery
Perfboard materials, plastic enclosure, probe, alligator clip, battery holders and connectors, wire, solder, hardware, etc.

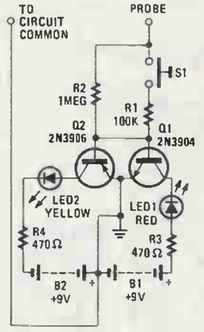

Fig. 3. The AC/DC Indicator can help you in your electronics lab by distinguishing between AC and DC signals, and more.

positive or negative DC voltages; and indicate the presence or absence of a voltage. Figure 3 is a schematic diagram of the AC/DC Indicator.

The circuit operation is simple. If the probe is connected to a positive source of 1 volt or more, current flows into the base of Q1 (a 2N3904 NPN transistor) turning it on, which then causes LED1 (red) to turn on, indicating a positive DC input. If, on the other hand, the applied voltage is negative, current flows to the base of Q2, causing LED2 (yellow) to light indicating a negative DC input.

If the probe is connected to an AC source, both LED's light alternately—yellow during the negative half cycle and red during the positive half cycle. The two LED's will alternate so rapidly that both units will appear constantly lit. Very low-frequency AC or pulsating DC will cause the LED(s) to turn off and on at the same rate. Switch S1 should be closed to check input levels below ten volts.

Since there are so few parts in the circuit, it can easily be assembled on perfboard and housed in a small plastic enclosure. The probe can be fabricated from almost anything from

(Continued on page 10)

CIRCUIT CIRCUS

By Charles D. Rakes

Generator Circuits

STAIRCASE GENERATOR

Our first entry is a 10-step staircase generator (see Fig. 1). Staircase generators are circuits that produce an increasing or decreasing stepped voltage or current.

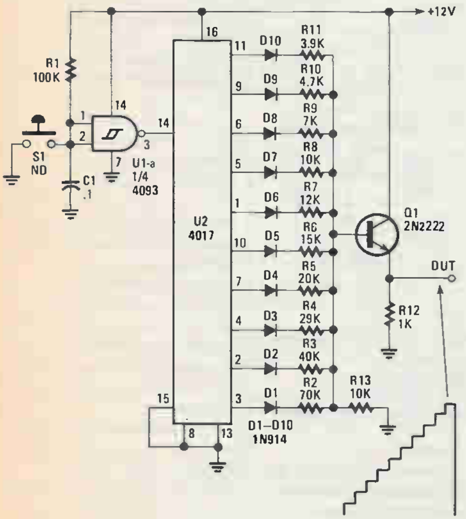

Fig. 1. This 10-step staircase generator is a manually operated circuit built around a 4017 decade counter/divider and one fourth of a 4093 2-input NAND Schmitt trigger, which is used as a switch-debouncing circuit.

Such generators are very useful in many applications such as semiconductor curve tracers, for example. The stepped waveform generator is also found in a variety of video circuits, test instruments, and specialized test set ups, as well as facsimile or fax machines and gray-scale generators.

The stepping generator in Fig. 1 is a manually operated circuit built around a 4017 decade counter/divider, U2. One fourth of a 4093 2-input NAND Schmitt trigger (U1-a) is used as a switch-debouncing circuit; its job is to ensure that one and only one clock pulse is applied to pin 14 of U2 each time S1 is closed. The values of C1 and R1 are selected to give a time constant that's longer than the closing transition time of S1. The values specified work well with most available switches. However, if you happen to select a really noisy switch, the values of C1 and/or R1 can be increased to extend the time period to cover for S1's poor performance.

The circuit is designed to convert each closure of S1 into an increasing output voltage at the base Q1, causing it to conduct harder. As Q1 conducts harder, the circuit's output voltage at the emitter of Q1 increases by about 0.5-volt per step. That produces an uphill staircase output beginning at near ground level and peaking at about 5 volts. Once the peak has been reached, the next switch closure resets U2, beginning the cycle anew. The inputs of the three unused gates in U1 must be tied to ground or the +V bus.

The upward direction of the staircase can be reversed (producing a downhill staircase) by reversing the positions of R2 through R11. That is, placing R2 (a 70k unit) at pin 11, R3 (a 40k unit) at pin 9, R4 (a 29k unit) at pin 6, and so on.

The staircase generator can easily be converted into a self-generating circuit by reconfiguring U1-a to conform to the schematic diagram shown in Fig. 2, and then feeding its output to pin 14 of U2 in Fig. 1. Simply remove S1 and R1 from the circuit and series connect a 10k fixed resistor and 1-megohm potentiometer in the feedback loop as shown.

The generator's repetition rate can be varied from a low of about 3 Hz to over 300 Hz with the component values shown. If you want to pick up the tempo, all that's required is to reduce the value of C1; or if a speed reduction is desired, increase the value of C1.

The simple circuit in Fig. 3 adds yet another dimension to the staircase-generator circuit in Fig. 1; this one allows any or all of the output steps to be increased in length (time duration). Transistor Q1 (a 2N3904 general-purpose NPN unit) operates as a switch. When Q1 turns on placing C1 in Fig. 3 in parallel with C1 in Fig. 2, the higher capacitance created (remember capacitors in parallel add like resistors in series), lowers the oscillator circuit's normal operating frequency.

The step-stretcher circuit is activated by connecting any one of the inputs in Fig. 3 to the appropriate output pin on the 4017 for the desired step. Output pin 3 is the bottom step, pin 2 is the second, pin 4 is the third, pin 7 is the fourth, pin 10 is the fifth, pin 1 is the sixth, pin 5 is the seventh, pin 6 is the

PARTS LIST FOR FIG. 1

SEMICONDUCTORS
U1—4093B quad 2-input NAND Schmitt trigger, integrated circuit
U2—4017 decade counter/divider, integrated circuit
Q1—2N2222 general-purpose, NPN silicon transistor
D1–D10—1N914 small-signal silicon diode

RESISTORS
(All resistors are ¼-watt, 5% units.)
R1—100,000-ohm
R2—70,000-ohm
R3—40,000-ohm
R4—29,000-ohm
R5—20,000-ohm
R6—15,000-ohm
R7—12,000-ohm
R8, R13—10,000-ohm
R9—7000-ohm
R10—4700-ohm
R11—3900-ohm
R12—1000-ohm

ADDITIONAL PARTS AND MATERIALS
C1—0.1-µF ceramic-disc capacitor
Perfboard materials, 9–12-volt power source, wire, solder, hardware, etc.

eighth, pin 9 is the ninth, and pin 11 is the top step.

Only six input diodes are shown in Fig. 3, but any number can be added as needed to match the number of steps to be stretched. The length of the step can be doubled by making C1 of Fig. 3 a 0.1-µF capacitor. For a longer stretch, make C1 larger, and for less make it smaller. The Fig. 3 circuit allows only the selected steps to be stretched; each step is stretched by equal amounts.

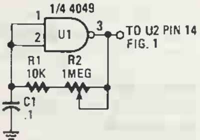

Fig. 2. The staircase generator can easily be converted into a self-generating circuit by reconfiguring U1-a to conform to this schematic diagram, and then feeding its output to pin 14 of U2 in Fig. 1.

PARTS LIST FOR FIG. 2

U1—4093B quad 2-input NAND Schmitt trigger, integrated circuit
R1—10,000-ohm, ¼-watt, 5% resistor
R2—1-megohm potentiometer
C1—0.1-µF, ceramic-disc capacitor
Perfboard materials, wire, solder, hardware, etc.

More than one stretch-time period can be provided by adding a second circuit like that in Fig. 3, and selecting the value of C1 for the desired time period. In fact, you can add a stage for each step and have all 10 steps controlled individually. Experiment with the circuit to obtain the right timing combination.

The staircase-generator circuit may also be used to drive a VCO to produce a sequentially stepped output. That arrangement can be used to generate a string of musical notes, doorbell chimes, sequential encoder tones, or to fill some special circuit requirement. Each step of the generator's output may be made variable by replacing R2 through R11 with 100k potentiometers. With such an arrangement each step can be individually set to whatever duration is desired or required.

SAWTOOTH GENERATOR

The sawtooth generator just might be the most prolific waveform-generator circuit in use today. Everywhere you look there's a TV set or a computer monitor that contains at least one sawtooth sweep-generator circuit. Oscilloscopes; spectrum analyzers; and AF, RF, and IF sweep generators are a few of the test instruments that rely heavily on the sawtooth generator.

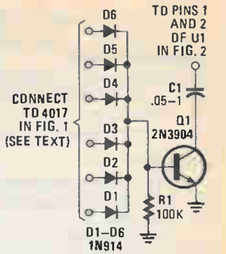

Fig. 3. When added to the staircase generator circuit in Fig. 1, this simple circuit allows any or all of the output steps to be increased in length (time duration). Only those outputs selected will have their durations increased.

PARTS LIST FOR FIG. 3

Q1—2N3904 general-purpose, NPN silicon transistor
D1–D6—1N914 general-purpose, small signal silicon diode
R1—100,000-ohm, ¼-watt, 5% resistor
R2—10,000-ohm, ¼-watt, 5% resistor
C1—0.05-µF, ceramic-disc capacitor (see text)
Perfboard materials, wire, solder, hardware, etc.

Refer to Fig. 4. In the sawtooth generator circuit, Q1, D1–D3, R1, R2, and R7 form a simple constant-current generator circuit that charges C1 at a constant rate. That steady charging current produces a linear rising voltage across C1. Transistors Q2 and Q3 are wired in a Darlington configuration to transfer the voltage across C1 to the output without loading or distorting. When the volt-

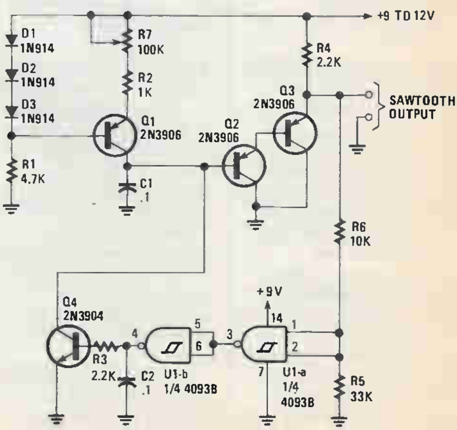

Fig. 4. The Sawtooth Generator's output frequency is controlled by R7, which provides a low end frequency of about 30 Hz and an upper end frequency of close to 3.3 kHz.

PARTS LIST FOR FIG. 4

SEMICONDUCTORS
U1—4093B quad 2-input NAND Schmitt-trigger, integrated circuit
Q1–Q3—2N3906 general-purpose, PNP silicon transistor
Q4—2N3904 general-purpose, NPN silicon transistor
D1–D3—1N914 general-purpose, small-signal silicon diode

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1—4700-ohm
R2—1000-ohm
R3, R4—2200-ohm
R5—33,000-ohm
R6—10,000-ohm
R7—100,000-ohm potentiometer

ADDITIONAL PARTS AND MATERIALS
C1, C2—0.1-µF, ceramic-disc capacitor
Perfboard materials, 9–12 power source, wire, solder, hardware, etc.

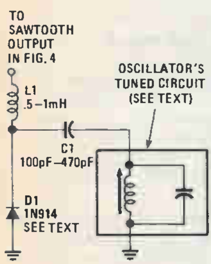

Fig. 5. The sawtooth generator can be used to vary the frequency of an RF oscillator, thereby turning a transistor-based RF oscillator into a usable narrow-band sweep generator.

age across C1 increases to about 70% of the supply voltage, U1-a (¼ of a quad NAND Schmitt trigger) turns on, causing the output of U1-b to go high and momentarily turn on Q4; Q4 is held on as C1 discharges. That completes one cycle and starts the next.

The circuit's output frequency is controlled by R7, which provides a low-end frequency of about 30 Hz and an upper-end frequency of close to 3.3 kHz. The frequency range can be increased by lowering the value of C1 and decreased by increasing the capacitor's value. To keep Q4's peak discharge current in check, C1 should be no larger than 0.27-µF.

The sawtooth generator can be a very handy test item to have around the shack, and it's well worth the small cost in time and funds to build. The circuit isn't critical and any suitable construction scheme will do.

The circuit in Fig. 5 illustrates one way that the sawtooth generator can be used to vary the frequency of an RF oscillator. That simple approach can turn a transistor-based RF oscillator into a usable narrow-band sweep generator.

When the input to the circuit in Fig. 5 is tied to the circuit in Fig. 4, the sawtooth signal is fed through an RF choke (L1), across the cathode of D1, and on to the RF oscillator's tuned circuit through coupling capacitor C1 (an NPO ceramic disc). As the reverse voltage increases across the diode, its internal capacitance decreases, causing the oscillator's frequency to climb until the cycle is completed.

Looks like we've used up all of our space for this time. See you here again next month with more fun circuitry. Good luck and so long until then. ■

CIRCUIT CIRCUS

(Continued from page 7)

a ballpoint-pen housing and a nail to an old meter probe. In any case, attach the probe to one end of the enclosure in a location where the two LED's can be easily seen when the probe is in use.

Also locate S1 in a convenient position so it can easily be pressed while making a test. Use a 24-inch length of test lead wire with alligator clip attached at one end for the circuit's ground return lead. A power switch may be added to the circuit if desired, but it's really not necessary because the standby current is too low to measure.

DC ADAPTER

How many times have you needed to use a battery-operated device only to find out too late that the batteries have gone dead. Even if your batteries are always good, you might still consider the circuit in Fig. 4 as a way to save the batteries for a real emergency.

The circuit in Fig. 4 is a simple series regulator that can supply about 1 amp at 6 or 9 volts to an external load. The circuit can be used to run most radios and other similar battery-operated devices. And if you happen to need an output other than 6 or 9 volts, you can either replace one of the Zener regulators or substitute a three position switch for S1 and add another suitable Zener diode.

If you are going to take the latter route, keep in mind that the regulator's output is going to be about 0.6 volt less than the Zener diode's rated voltage.

Since there are only eight parts to the circuit, you can follow any construction scheme as long as you heat sink the power transistor sufficiently. A 3- × 3-inch piece of aluminum will suffice. Switch S1 should be a shorting-type rotatory switch (that's the one that connects with the new contact before breaking with the old). ■

PARTS LIST FOR THE DC ADAPTOR

SEMICONDUCTORS
Q1—2N3055 NPN silicon power transistor
D1—6.6 to 6.9-volt, 1-watt, Zener diode
D2—9.6 to 9.9-volt, 1-watt, Zener diode

ADDITIONAL PARTS AND MATERIALS
R1—270-ohm, 1-watt, 5% resistor
R2—1000-ohm, ½-watt, 5% resistor
C1, C2—470-µF, 25-WVDC, electrolytic capacitor
S1—SPDT shorting-type switch
Perfboard materials, enclosure, 3 × 3-inch piece of aluminum (see text), output jacks, wire, solder, hardware, etc.

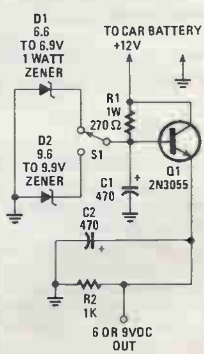

Fig. 4. This simple regulator circuit uses a power transistor in a common- or grounded-base configuration.

CIRCUIT CIRCUS

By Charles D. Rakes

Circuits For Your Circuits Library

This month we are going to spend our time together exploring several circuits that are just plain fun to build, and may be useful in existing or future projects, too. In any case, bring out the junkbox, heat up the soldering iron, and let's make a cold winter's night disappear.

TIME-OUT CIRCUIT

Our first circuit, see Fig. 1, uses a 555 oscillator/timer in a circuit that shifts gears at the end of a predetermined time cycle to generate its own announcement signal. This circuit differs from generic timer applications of the

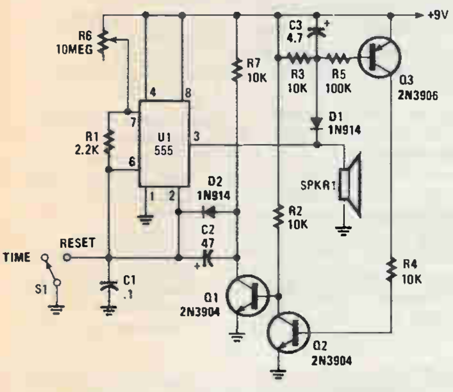

Fig. 1. This time-out circuit differs from conventional 555-timer applications in that this circuit has the 555 configured in the astable mode as opposed to the monostable, or one-shot mode.

555 in that this circuit operates in the astable mode as opposed to the monostable, or one-shot mode. Since the astable mode of operation is self triggering, the circuit functions as a dual-frequency oscillator. The first portion of the oscillator's cycle produces the long-term timing period and the second part shifts the frequency to a much higher repetition rate, which is fed to a speaker to serve as an audio annunciator.

The circuit's operation is rather simple. With S1 in the RESET position two timing capacitors, C1 and C2, are returned to ground, placing the 555 (U1) is in a wait state. During the timing cycle (while the circuit is in the reset condition) the 555's output at pin 3 is in a high state. Since SPKR1 is a piezo mini-speaker or sounder element, this steady voltage produces no output sound. (If, on the other hand, you were to substitute a piezo buzzer with a built-in oscillator, the circuit would produce a steady output while in the reset and timing modes and at the end of the timing cycle the output would be an interrupted tone.)

A piezo speaker without an internal driver circuit is what you want to use for SPKR1. Placing S1 in the TIME position allows C1 and C2 to charge through R6 to start the timing cycle. Transistor Q1 is biased on through R2, pulling the negative end of C2 to ground, while both Q2 and Q3 remain off. As long as the negative end of C2 is tied to ground, the circuit is in the long time-delay mode of operation. When the timing cycle is completed, pin 3 switches to ground allowing C3 to charge through D1 to supply a bias current to the base of Q3, through R5, turning it on.

With Q3 turned on, a bias current is fed through R4 to the base of Q2, turning it on. The collector of Q2, in turn, pulls the base of Q1 to ground, turning it off and allowing the negative end of C2 to rise toward the positive supply-voltage rail. Resistor R7 ties the negative end of C2 to the positive supply for a quick discharge and D2 keeps the voltage across C2 from reversing. As soon as C2 is discharged, the circuit is ready for another timing cycle.

When the time-out cycle is completed, a new frequency-setting RC network is switched into place. With C2 switched out of the circuit, C1 takes over as the sole timing capacitor; at the same time that Q1 takes C2 out of the circuit, it brings R7 into play as the new charging resistor. That new RC combination shifts the U1 astable oscillator into high gear, generating a tone to drive SPKR1. The output tone continues until the circuit is reset or the power is removed.

The maximum time delay of the circuit is about twelve minutes with the component values given, but can be lengthened by increasing the value of C2. The tone-frequency output can be changed by varying the value of R7 between 4.7k and 50k.

What might the circuit be used for? Well if your phone bill is rising like a hot-air balloon, the timer can save you money by giving a friendly reminder that talk isn't necessary cheap. The timer can also help the jawbreaker radio ham from running over the ten-minute ID time period. I'm sure that

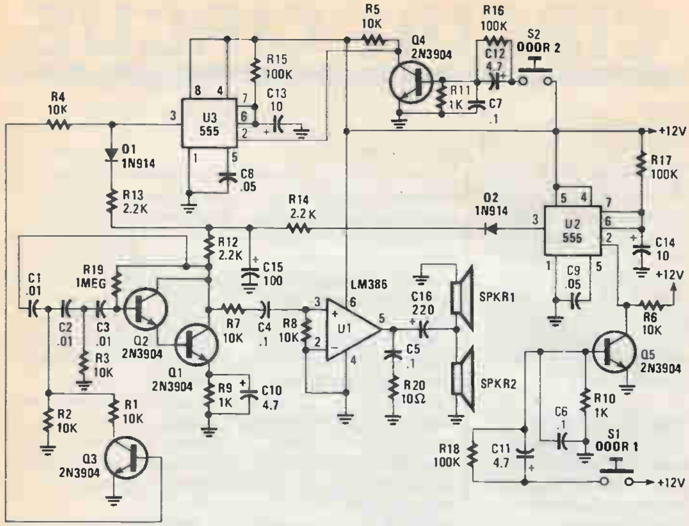

Fig. 2. This expandable two-door annunciator circuit (built around three IC's, five transistors, and a few support components) provides two distinctively different tones, so that you can tell which door to answer.

PARTS LIST FOR THE ANNUNCIATOR CIRCUIT

SEMICONDUCTORS

U1—LM386 low-power audio amplifier, integrated circuit
U2, U3—555 oscillator/timer, integrated circuit
Q1–Q5—2N3904 general-purpose NPN silicon transistor
D1, D2—1N914 general-purpose small-signal silicon diode

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1–R8—10,000-ohm
R9–R11—1000-ohm
R12–R14—2200-ohm
R15–R18—100,000-ohm
R19—1-megohm
R20—10-ohm

CAPACITORS

C1–C3—0.01-µF, 100-WVDC, Mylar
C4–C7—0.1-µF ceramic-disc
C8, C9—0.05-µF, ceramic-disc
C10–C12—4.7-µF, 16-WVDC, electrolytic
C13, C14—10-µF, 16-WVDC, electrolytic
C15—100-µF, 16-WVDC, electrolytic
C16—220-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

S1, S2—single-pole single-throw pushbutton switch
SPKR1, SPKR2—8-ohm speaker
Perfboard materials, enclosure, AC molded power plug with line cord, battery(s), battery holder and connector, wire, solder, hardware, etc.

PARTS LIST FOR THE TIME-OUT CIRCUIT

SEMICONDUCTORS

U1—555 oscillator/timer, integrated circuit
Q1, Q2—2N3904 general-purpose NPN silicon transistor
Q3—2N3906 general-purpose PNP silicon transistor
D1, D2—1N914 general-purpose, small-signal silicon diode

RESISTORS

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

ADDITIONAL PARTS AND MATERIALS

C1—0.1-µF, ceramic-disc capacitor
C2, C3—47-µF, 16-WVDC, electrolytic capacitor
SPKR1—Piezo speaker
S1—SPST toggle switch
Perfboard materials, enclosure, 9-volt battery, battery holder and connector, wire, solder, hardware, etc.

some of you ingenious experimenters will come up with a few other creative uses for this timer circuit.

ANNUNCIATOR CIRCUIT

Our next entry turns three IC's, five transistors, and a few support components into a two entrance (expandable) door-bell annunciator. Such a circuit might make a welcome addition to that weekend cabin, your new digs, or to replace an existing ding-dong door bell. The circuit provides each door location with a distinct and easily identifiable bell-like tone. Additional door positions may be provided by duplicating a part of the circuit. Up to three strategically located speakers may be used to saturate the area with the announcement.

The schematic diagram for the circuit is shown in Fig. 2. The tone generator is built around two 2N3904 NPN transistors (Q1 and Q2) connected in a simple phase-shift oscillator configuration. The output of the tone generator is fed to the input of an LM386 audio power amplifier (U1), which is used to drive two speakers, SPKR1 and SPKR2.

Looking at the portion of the circuit that's tied to S1, we see a series 4.7-µF electrolytic capacitor (C11) connected to the base of transistor Q5, the door switch (S1), and the 12-volt power source. When S1 is closed, capacitor C11

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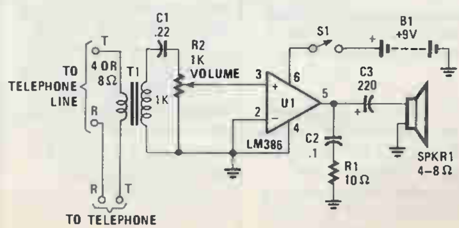

Fig. 3. This simple telephone amplifier circuit (which can be switched off for privacy) allows everyone in the room to listen in on your telephone conversations.

CIRCUIT CIRCUS

By Charles D. Rakes

Detector Circuits

Fellow experimenters, it's time to dig out your junkbox and join me at the Circus for a little circuit wizardry. I find that trying new circuit ideas is a good way to escape the troubles of the world and, at the same time, gain some knowledge in the process. And who knows, one of the circuits that we cover just might be what your next project needs.

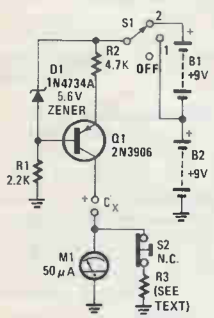

Fig. 1. The leak detector circuit is a simple circuit built around a 2N3906 general-purpose PNP transistor that's configured as a constant-current source, through which a 1-mA charging current is applied to the test capacitor.

This time around, we're going to look at a couple of detector circuits; the first of which is a simple electrolytic-capacitor leakage-test circuit. If you have ever put together an R/C timer circuit that, for some unknown reason, didn't perform as expected, it's very possible that the culprit was a leaky electrolytic timing capacitor.

Some leaky capacitors develop an internal resistance that varies with temperature and/or voltage changes. That internal leakage is like having a variable resistor in parallel with a timing capacitor. In extremely short timing periods, the effect of the leaky capacitor may be minimal, but as the timing period is extended, the leakage current can cause the timer circuit to vary greatly or even fail altogether. In any case, an unstable timing capacitor will turn a perfectly sound timer circuit into an erratic piece of junk.

LEAK DETECTOR.

Figure 1 is a schematic diagram of our electrolytic leak detector. In that circuit, a 2N3906 general-purpose PNP transistor (Q1) is connected in a constant-current circuit configuration through which a 1-mA charging current is applied to the test capacitor. A dual-range metering circuit is used to monitor the capacitor's charge and leakage current. Two 9-volt transistor batteries provide power for the circuit. A 5-volt Zener diode (D1) sets Q1's base at a constant 5-volt level, guaranteeing a constant voltage drop across R2 (Q1's emitter resistor) and a constant current to the capacitor under test (which we'll refer to as C_X).

With S1 in position 1, the voltage applied to C_X is limited to about 4 volts; with S1 in position 2, the voltage across the capacitor rises to about 12 volts. Another battery can be added in series with B1 and B2 to increase the charging voltage to about 20 volts. With S2 in its normally closed position (as shown), the meter is connect in parallel with R3 (the meter's shunt resistor), giving the circuit a full-scale reading of 1 mA. When S2 is depressed (open), the metering range of the circuit is reduced to 50-μA full scale.

MODIFYING THE CIRCUIT.

The circuits in Figs. 2 and 3 illustrate two methods of selecting a shunt resistor (R3 in Fig. 1) to extend M1's range from its basic 50-μA range to 1 mA.

If you have an accurate voltmeter that can read 1 volt, use the circuit in Fig. 2

PARTS LIST FOR THE LEAK DETECTOR

RESISTORS

(All fixed resistors are ¼-watt, 5% units.)
R1—2200-ohm
R2—4700-ohm
R3—See text

ADDITIONAL PARTS AND MATERIALS

Q1—2N3904 general-purpose NPN silicon transistor
D1—1N4734A 5.6-volt Zener diode
M1—50-μA meter
B1, B2—9-volt transistor-radio battery
S1—SP3T switch
S2—Normally-closed pushbutton switch
Perfboard materials, enclosure, AC molded power plug with line cord, battery(s), battery holder and connector, wire, solder, hardware, etc.

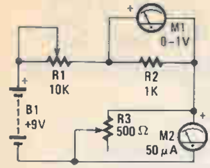

Fig. 2. Use this circuit to determine the value of R3 (in Fig. 1), if you are using a voltmeter.

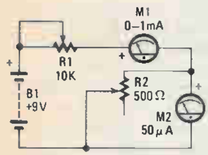

Fig. 3. If your most-accurate measuring instrument is a current meter that can monitor 1-mA, use this circuit to determine R3's value.

to select the value of R3. To use the Fig. 2 circuit, set R1 (the 10k potentiometer) to its maximum resistance and R3 (the 500-ohm potentiometer) to its minimum value. Connect a battery as shown and adjust R1 for a 1-volt reading on M1. Slowly increase the resistance of R3 until M2 (the current meter) reads full scale. Readjust R1 as you adjust R3 to keep a 1-volt reading on M1. When M1 reads 1 volt and M2 reads full scale, the potentiometer is set at the resistance value needed for R3. You can either use the potentiometer for the shunt resistor or select one of equal value from your resistor supply.

On the other hand, if your most-accurate measuring instrument is a current meter that can monitor 1 mA, use the circuit in Fig. 3. Follow the same procedure for the circuit in Fig. 3 as in Fig. 2 and adjust the R1 for a 1-milliampere reading.

To use leakage test circuit, start with S1 in the off position. Connect the capacitor under test to the C_X terminals, with the proper polarization. Switch S1 to position 1 and the meter should (depending on the value of the capacitor) read full scale for a brief time and then drop back to a zero current reading. If the capacitor is shorted or extremely leaky, the meter will read up scale continuously.

If the meter does drop to zero, press S2 and the meter shouldn't move up scale on a good capacitor. If the capacitor's voltage rating is above 6 volts, switch S1 to position 2 and the results will be the same for a good capacitor. If the meter reading rises, the capacitor is not a good candidate for use in a timer circuit.

It's possible that a capacitor will fail the test and still be a good unit. If an electrolytic capacitor is idle for long periods without being charged, the leakage current can be high when a voltage is first applied; but if the voltage remains across the capacitor for an extended time, it can often be rejuvenated. The test circuit can be used to regenerate a sleeping capacitor and the results monitored on M1.

METAL DETECTOR.

A while ago we discussed a simple metal-detector circuit and, judging from the response, it was obvious that a number of you were very enthusiastic about the subject. So the next circuit that we'll discuss is one that is designed to do the same job, but in a different way.

One of the most sensitive and inexpensive metal detectors that you can build is a variation of the VLF TX/RX (very-low frequency, transmitter/receiver) detector, which is a two part apparatus. Such double-box detectors—which would not respond to anything smaller than a pound coffee can—were generally designed to detect large metal objects buried deep, beneath the ground.

Our's is a mini-version that can detect coin-sized objects from a few inches away, or larger objects at a distance of over two feet. The sensing loops (coils) on both the transmitter and receiver portions of our detector are slightly over 4 inches in diameter and are separated by about 12 inches. The operation of the TX/RX metal detector is based on the directional properties of the magnetic field produced by the transmitter loop and the reception properties of the receiver loop.

In such circuits, the majority of the magnetic energy flows from the transmitter loop in an edgewise direction with almost no

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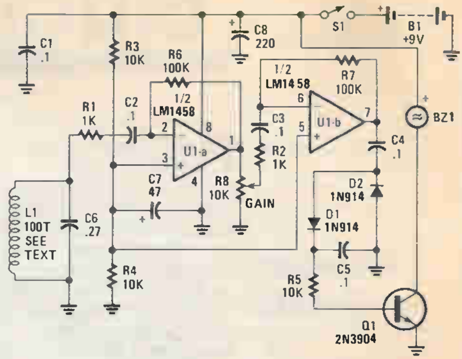

Fig. 4. The receiver portion of the metal detector is built around an LM1458 dual op-amp, a single 2N3904 general-purpose silicon transistor, and a 100-turn homebrew coil that's tuned to about 7 kHz via C6.

PARTS LIST FOR THE VLF RECEIVER

SEMICONDUCTORS

U1—LM1458 dual op-amp, integrated circuit
Q1—2N3906 general-purpose NPN silicon transistor
D1, D2—1N914 general-purpose small-signal silicon diode

RESISTORS

(All fixed resistors are ¼-watt, 5% units.)
R1, R2—1000-ohm
R3–R5—10,000-ohm
R6, R7—100,000-ohm
R8—10,000-ohm potentiometer

CAPACITORS

C1–C5—0.1-µF, ceramic-disc
C6—0.27-µF, Mylar or similar
C7—47-µF, 16-WVDC, electrolytic
C8—220-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

B1—9-volt transistor-radio battery
BZ1—Piezo buzzer
S1—SPST switch
L1—Receiver loop, see text
Perfboard materials, enclosure, battery holder and connector, wire, solder, hardware, etc.

CIRCUIT CIRCUS

By Charles D. Rakes

Oscillator Round-Up

TTL CRYSTAL OSCILLATOR

Our first circuit came about when a project we were working on required a low-cost crystal oscillator that would produce both a square- and a sine-wave outputs. Frequency stability, low cost and a small parts count were the three major design criteria to be considered. The TTL crystal oscillator circuit shown in Fig. 1 fills the bill.

With TTL IC's and 2N3904 transistors going for pennies, the cost of the oscillator primarily depends on the crystal's frequency and its surplus availability. If the required frequency happens to be one of the popular computer or industrial standards, the price is likely to be very low, but if a special non-standard frequency is required, be prepared to pay a much higher price. In any case, it would be difficult to build a circuit that performs as well as this one for less money.

Two gates of a 7400 quad two-input NAND gate make up the actual oscillator circuit, with a crystal and a variable capacitor functioning as the feedback network between the input of gate U1-a and the output of gate U1-b. Gate U1-c operates as a buffer between the oscillator and output stage, U1-d. Switch S1 serves as a manual gate control to turn the square-wave output of U1-d at pin 11 on and off. With S1 open, as shown, the square-wave appears at the output, and when closed it is turned off. The switch may be replaced with a logic gate to electronically control the output.

A near perfect 6- to 8-volt peak-to-peak sine wave is generated at the junction of C1 and XTAL1. The impedance at that point is extremely high and can not supply a direct output signal. Transistor Q1, configured as an emitter-follower amplifier, offers a high input impedance to the sine-wave signal and a low output impedance to an external load.

The circuit will kick start even the most stubborn crystals and can operate with crystal frequencies of less than 1 MHz to over 10 MHz. Setting up the oscillator circuit is easy. If you have an oscilloscope available, connect it to the square-wave output of U1-d at pin 11 and set C1 in the middle of the range that produces the best output waveform. Now monitor the sine-wave output and set C2 for the best looking waveform. Go back to C1 and tweak adjust it back and forth slightly for the best sine-wave output.

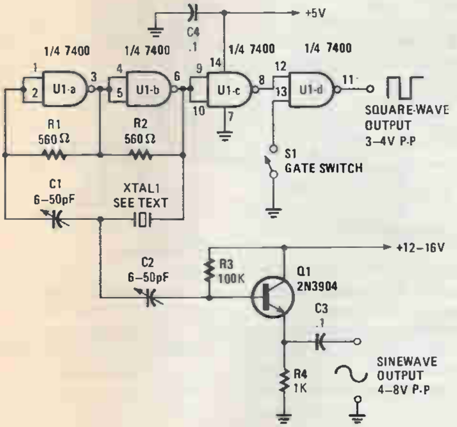

Fig. 1. Two gates (U1-a and U1-b) of a 7400 quad 2-input NAND comprise the actual oscillator circuit, with feedback controlled by a crystal (XTAL1) and a variable capacitor (C1). Gate U1-c is used to buffer the output of the oscillator, while U1-d is used to turn the output on and off.

PARTS LIST FOR THE TTL CRYSTAL OSCILLATOR

RESISTORS
(All resistors are ¼-watt, 5% units.)
R1, R2—560-ohm
R3—100,000-ohm
R4—1000-ohm

ADDITIONAL PARTS AND MATERIALS
U1—7400 quad two-input NAND gate, integrated circuit
Q1—2N3904 general-purpose NPN silicon transistor
C1, C2—6–50-pF, trimmer capacitor
C3, C4—0.1-µF, ceramic-disc capacitor
S1—SPST toggle switch
XTAL1—Crystal (see text)
Perfboard materials, enclosure, 5-volt power source, wire, solder, hardware, etc.

TWO-TRANSISTOR CRYSTAL OSCILLATOR

Our next item, see Fig. 2, is a two-transistor, crystal-oscillator circuit that works

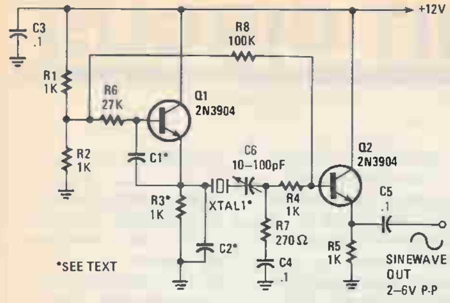

Fig. 2. Built around two general-purpose transistors, this oscillator produces a sine-wave output of from 2 to 6 volts peak-to-peak.

PARTS LIST FOR THE TWO-TRANSISTOR CRYSTAL OSCILLATOR

RESISTORS
(All resistors are ¼-watt, 5% units.)
R1–R5—1000-ohm
R6—27,000-ohm
R7—270-ohm
R8—100,000-ohm

CAPACITORS
C1, C2—See text
C3.–C5—0.1-µF, ceramic disc
C6—10- to 100-pF, trimmer

ADDITIONAL PARTS AND MATERIALS
Q1, Q2—2N3904 general-purpose NPN silicon transistor
XTAL1—See text
Perfboard materials, enclosure, 12-volt power source, wire, solder, hardware, etc.

great, costs little, and uses no coils or chokes. Here again, the cost depends mainly on the crystal used, as the total cost of the other components (provided that you have a full junkbox to raid) should be no more than a couple of dollars.

Transistor Q1 and the few surrounding components make up the oscillator circuit. The ground return for the crystal is routed through C6, R7, and C4. At the junction of C6 and R7, which is a fairly low impedance point, the RF is fed to an emitter-follower amplifier, Q2. The shape of the waveform at the C6/R7 junction happens to be a near perfect sine wave. The output, at the emitter of Q2 varies in amplitude from about 2- to 6-volts peak-to-peak, depending on the crystal's Q and the values used for capacitors C1 and C2.

The values of C1 and C2 determine the frequency range that the circuit will cover. For crystal frequencies below 1 MHz, C1 and C2 should be 2700 pF (.0027 µF). For frequencies of 1 MHz to about 5 MHz, use 680-pF capacitors; and for 5 MHz up to about 20 MHz, use 200-pF capacitors. You might try experimenting with values of those capacitors to obtain the best looking output waveform. Also, the setting of capacitor C6 will influence both the output level and waveform shape.

METAL DETECTOR

The next entry is one of my favorite gadgets—a simple two-transistor metal detector—which you can put together in an evening or two and enjoy using for hours on end. The circuit (see Fig. 3) probably won't lead you to a pot of gold, or any other treasure for that matter. But it can help locate wiring in the walls or pipes in the floor, and will cost you next to nothing to build. And if you happen to have a youngster under foot with nothing to do, this circuit just might be the one gadget that will get junior outdoors and into a fun hobby.

In Fig. 3, transistor Q1 (a 2N3904 NPN device) is connected in a simple LC-oscillator circuit with the values of L1, C3, C4, and C9 determining the circuit's operating frequency. The oscillator's output is fed through C1 and R4 to a 455-kHz ceramic filter. When the oscillator is tuned to the filter's center frequen-

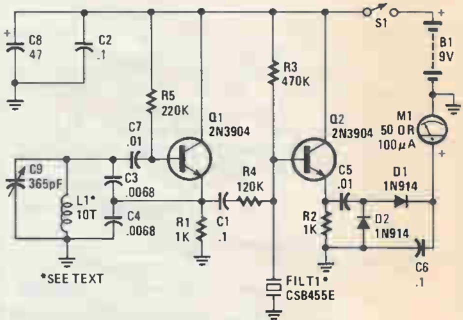

Fig. 3. The metal detector is little more than a simple oscillator circuit (built around Q1), whose output is fed to a meter (M1), causing it to deflect to about mid-scale. When the sense coil (L1) is brought near metal, the oscillator frequency changes, and that change causes the meter needle to move either up or down the scale depending on the type of metal detected.

PARTS LIST FOR THE METAL DETECTOR

RESISTORS
(All resistors are ¼-watt, 5% units.)
R1, R2—1000-ohm
R3—470,000-ohm
R4—120,000-ohm
R5—220,000-ohm

CAPACITORS
C1, C2, C6—0.1-µF, ceramic-disc
C3, C4—0.0068-µF, 50-WVDC polystyrene
C5, C7—0.01-µF, ceramic-disc
C8—47-µF, 16-WVDC, electrolytic
C9—365-pF variable (see text)

ADDITIONAL PARTS AND MATERIALS
Q1, Q2—2N3904 general-purpose, NPN silicon transistor
D1, D2—1N914 general-purpose, small-signal silicon diode
L1—Search loop (see text)
F1—455-kHz crystal-filter (Murata CSB455E or similar)
B1—9-volt transistor-radio battery
M1—50- to 100-mA meter (see text)
Perfboard materials, enclosure, wire, solder, hardware, etc.

cy, the filter acts like a parallel tuned circuit and produces a high level 455-kHz signal at the junction of R3 and R4. The 455-kHz signal is fed to the base of Q2, which is configured as an emitter follower. The output of Q2 (taken from its emitter) is then converted to DC by D1, and from there, is applied to M1 (a 50- to 100-μA meter).

With the oscillator operating at, or very near the filter's center frequency, the meter will read somewhere in the vicinity of mid-scale. But when any metal object larger than a BB is brought near the loop, the meter's reading will either increase or decrease, depending on the type of metal. The circuit will detect a penny two inches away or a "D"-cell battery at about five inches in open air.

The search loop is wound on a small diameter form that's best suited for locating smaller objects at close range, but a larger loop may be built to detect larger objects located at greater distances. A plastic end cap for a 4-inch PVC sewer pipe (which can be purchased at just about any plumbing-supply shop) can be used as the coil form for the search loop. The search loop should be ten close-wound turns of number-26 enamel-coated copper wire wound around the bottom of the end cap and taped firmly in place. The electronics can be built on perfboard and should be housed in a metal cabinet.

Capacitor C1 can be any variable capacitor that you happen to find in your junkbox or one removed from an old broadcast-radio receiver. The 50-μA meter movement can come from an older volt-ohm meter or from some other piece of retired gear. Several different 455-kHz ceramic filters were tried in the circuit and all seemed to work just fine. If you can't locate a ceramic filter, just send an S.A.S.E. (self-addressed, stamped envelope) to me at "Circuit Circus," **Popular Electronics** Magazine, 500-B Bi-County Blvd., Farmingdale, NY 11735 and I'll send you one.

The loop should be located at least one foot away from the locator's cabinet, separated by a non-metal support. A wood dowel rod is a good choice. Run a twisted pair of unshielded wires between the loop and the circuit board.

If for some reason you don't get a meter reading when turning C9 through its rotation, it could be that the oscillator just isn't tuning to the filter's frequency. A frequency counter can be connected to the emitter of Q1 to see what signal (if any) is present. Or, if a counter isn't available, use a standard BC receiver and tune to the oscillator's second harmonic. If the oscillator is operating at 500 kHz, tune your radio to 1 MHz and you should hear the carrier. If the oscillator's frequency is too high, add capacitance across C9. If the frequency is too low, decrease C3 and C4.

Also if the meter won't quite make it to full scale, R4 can be reduced in value; if the needle bongs full scale, R4 can be increased.

Through a little experimenting, you'll soon determine the best method to use in tuning the locator for detecting the size and type of desired metal objects. The circuit is more sensitive when the tuning is adjusted so that the meter is at about half scale when no metals are present; at that setting, the circuit will indicate ferrous and non-ferrous metals by causing the meter to increase with one and decrease with the other. ■

CIRCUIT CIRCUS

(Continued from page 12)

volts, with the charging current flowing through the base-emitter junction of Q5, turning it on and pulling its collector to ground. The negative pulse, at the collector of Q5, triggers U2 (a 555 configured for monostable operation), producing a brief positive voltage output at pin 3.

The positive output of U2 is fed through D2 and R14 to charge a 100-μF capacitor, C15. The voltage across C15 supplies power to the tone generator (Q1/Q2), turning it on for a short period of time to announce that someone is at DOOR 1.

The on-time of the tone oscillator is controlled by the values of R17 and C14 (connected to pins 6 and 7 of U2) for DOOR 1, while R15 and C13 (connected to pins 6 and 7 of U3) does the same for DOOR 2. The operation of the second door-switch circuitry is like the first with an exception (which we'll get to in a moment). The values of those components (100k for R15 and R17, and 10 μF for C13 and C14) set the timers' output duration to about two seconds for each closure of a door-bell switch. The length of each tone can be increased by increasing the value of either or both of its associated timing components. By the same token, decreasing either timing component will shorten the on time.

The operation of the second door switch circuit is like that of the first, except that in addition to the output of U3 being fed to the tone oscillator (Q1/Q2), it is also fed to a transistor switch (Q3) that shifts the oscillator's frequency. The positive output pulse of U3 turns Q3 on with its collector pulling R1 to ground and raising the tone's output frequency. A third door switch may be added by duplicating the second door-switch circuit and by adjusting the value of the new frequency-shifting resistor for a tone that's different from the other two.

The output may be modified to sound more or less bell like by varying the values of R13 and R4 between 100 ohms and 4.7k. A resistor value that's too large may not allow the voltage across C15 to reach a level that reliably starts the oscillator. If that happens, reduce the resistor's value until the oscillator starts each time the door switch is activated.

Just about any well-filtered 12-volt DC power supply that can deliver a minimum of 200 milliamperes will operate the circuit. At idle, the circuit requires less than 20 mA to maintain its standby status. This circuit is a candidate for solderless breadboards, thereby allowing you to play with and fine tune the circuit. Then, if you like what you hear, you can make a printed-circuit board layout and turn it into a first-class project. But if, on the other hand, you decide to build the circuit on perfboard, use sockets for the IC's.

TELEPHONE AMPLIFIER

Our next item is a simple, but useful, telephone-accessory circuit that you can throw together in a single evening and use to enhance your very next phone conversation. How often have you had some family member, friend, or an associate near by and wanted to share a telephone conversion, but couldn't because you only had a single phone at that location? If that's the case look at the phone amplifier circuit in Fig. 3.

The phone amplifier is essentially connected in series with one side of the phone line through the low-imped-

PARTS LIST FOR THE TELEPHONE AMPLIFIER

U1—LM386 low-power audio amplifier, integrated circuit
R1—10-ohm, ¼-watt, 5% resistor
R2—1000-ohm potentiometer
C1—0.22-µF, ceramic-disc capacitor
C2—0.1-µF, ceramic-disc capacitor
C3—220-µF, 16-WVDC, electrolytic capacitor
B1—9-volt transistor-radio battery
SPKR1—4 or 8-ohm speaker
S1—SPST toggle switch
T1—1000-ohm to 8-ohm, center-tapped, audio-output transformer
Perfboard materials, enclosure, modular phone plug and jack, battery holder and connector, wire, solder, hardware, etc.

ance winding of an audio-output transformer. A power amplifier (U1) increases the phone's audio level, which is developed across the high-impedance side of T1, to drive the speaker.

Since the amplifier is only used on selected calls, a 9-volt battery will do for the power source. And if you do forget to turn the power off, the circuit will remind you the very next time you use your phone.

The telephone amplifier would be an excellent choice for that first-time, circuit-board project, and since you'll probably end up wanting more than one amplifier, that approach will make duplication of the circuit much easier. For good looks and ease of operation, the circuit may be housed in a small plastic or metal cabinet with a modular telephone plug and cord coming from one side and a receptacle (jack) on the other. That way you only need to disconnect your phone and plug it into the amplifier's receptacle and plug the amplifier's cord into the wall jack. ■

CIRCUIT CIRCUS

(Continued from page 14)

radiation perpendicular to the loop. The receiver loop offers the same directional properties as the transmitter's loop, but since it is positioned perpendicular to the transmitter loop, almost no energy is detected. When a metal object is placed within the field of either loop, the loop's magnetic field is slightly distorted, allowing the receiver to detect a small part of the redirected energy.

The VLF receiver, see Fig. 4, is built around an LM1458 dual op-amp and a single 2N3904 general-purpose NPN silicon transistor. Coil L1, the pick-up device, is a homebrew inductor (100-turn loop) that is tuned to approximately 7 kHz by C6. Any 7-kHz signal picked up by the loop is fed to U1-a, which provides a gain of 100. The second op-amp is also configured for a gain of 100. The two op-amps produce a combined gain of 10,000, depending of the setting of R8. The output of U1-b at pin 7 is fed to a rectifier circuit that converts the 7-kHz signal into a positive DC voltage.

That DC voltage is then fed to the base of Q1 through R5, causing Q1 to turn on. With Q1 turned on, BZ1 sounds to indicate that metal has been detected. Power for the receiver is supplied by a single 9-volt transistor radio battery.

The transmitter portion of the circuit (see Fig. 5) is built around a single transistor that's configured as a Colpitts oscillator. The transmitter's sensing coil, L1 (another 100-turn loop), is tuned to about 7 kHz by capacitors C2–C4. Transmitter power is supplied by a 9-volt battery.

Assembling the circuit is a snap. The loops are wound on plastic end caps (that are made to fit on 4-inch plastic pipe) with an outside diameter of 4½ inches. The coil is made by jumble-winding 100 turns of number-26 enamel-covered copper wire around the center of each end cap. The ends of the coil are then taped in place. The loops are then mounted to opposite ends of a wood dowel (about 12 inches), and oriented perpendicular to each other.

The receiver and transmitter circuitry can be built on perfboard and mounted inside the end caps on which the loops are formed, or placed in separate plastic enclosures and positioned away from the dowel mounted loops.

Tuning up and checking out the detector is easy. Turn both units on; the buzzer (BZ1) should sound. Turn the receiver's gain down until the sound just about ceases, and then slowly rock the transmitter's loop back and forth until a perfect null is obtained. Keep increasing the receiver's gain and re-positioning the transmitter for the deepest null. If everything is working correctly, the null (at full receiver gain) will be sharp. If not, the receiver and transmitter may not be tuned to the same frequency.

To tune the receiver to the transmitter's frequency, connect a DC voltmeter to the cathode of D1 and vary C6 for the maximum output voltage at the diode; 4 to 5 volts is normal.

The detector is most sensitive when the circuit is operating at maximum gain and off null just enough to produce a low-level output from BZ1. ■

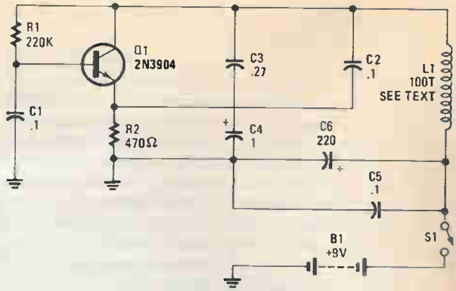

Fig. 5. The transmitter portion of the detector is built around a single transistor that's configured as a Colpitts oscillator, and another 100-turn coil (the transmitter's sensing loop), which is tuned to about 7 kHz by capacitors C2–C4.

PARTS LIST FOR THE VLF TRANSMITTER

CAPACITORS
C1, C2, C5—0.1-µF, ceramic-disc or mylar
C3—0.27-µF, Mylar or similar
C4—1.0-µF, Mylar or similar
C6—220-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS
B1—9-volt transistor-radio battery
Q1—2N3904 general-purpose NPN silicon transistor
R1—220,000-ohm ¼-watt, 5% resistor
R2—470-ohm, ¼-watt, 5% resistor
L1—Transmitter loop, see text
S1—SPST switch
Perfboard materials, enclosure, battery holder and connector, wire, solder, hardware, etc.

By Charles D. Rakes

Voice Scrambler/ Descrambler And More

This month we are going to take a very popular IC and use it in several circuits in the hope that at least one of them will tweak your interest enough for you to heat up your soldering iron and join in. We're going to spotlight on Signetics' NE602 low-power VHF double-balanced mixer. That 8-pin chip (see Fig. 1) features a built-in local oscillator, an differential input amplifier, and a voltage regulator. The internal oscillator circuit will operate up to 200 MHz with either an external crystal or tuned-tank circuit. Its input and output resistance is about 1.5k with an input capacitance of only 3 pF. The IC requires less than 3 mA of current with a supply voltage of from 4.5 to 8 volts.

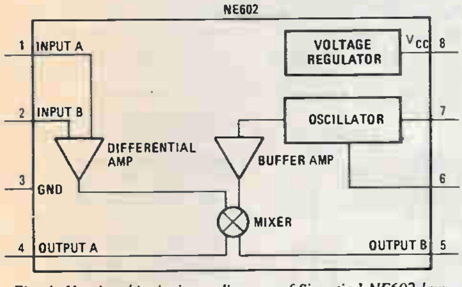

Fig. 1. Here's a block pinout diagram of Signetics' NE602 low-power VHF double-balanced mixer, which contains a built-in local oscillator, an differential input amplifier, and a voltage regulator.

VOICE SCRAMBLER/ DESCRAMBLER

After looking over the NE602's specification sheet, one of the applications that came to mind was how well the IC would perform as a balanced modulator/ demodulator in a single-mode inversion voice scrambler circuit. Excellent results were obtained with the voice scramber/descrambler circuit shown in Fig. 2.

A 567 tone decoder (U2) operates as a carrier oscillator supplying a 2.5 kHz to 3.5 kHz audio squarewave to U1's (the NE602) oscillator input at pin 6. A voltage divider, consisting of R2 and R3, furnishes a square-wave signal of about 600-millivolts peak-to-peak to pin 6 of U1.

The two mixer outputs of U1 (at pins 4 and 5) are coupled through T1, a 1k to 8-ohm audio-output transformer, for a balanced output that provides maximum attenuation to the input and local oscillator signals. A 386 low-power audio amplifier (U3) is used to increase the descrambled output sufficiently to drive a small 4- or 8-ohm speaker.

When a single-mode inversion signal is fed to the input of the circuit and the carrier oscillator is tuned to the original encoded frequency, the audio is reassembled to its normal condition and sounds like a properly tuned single-sideband radio signal. Actually, the scrambler will operate either as a scrambler or a descrambler.

It just depends on what type of audio signal (scrambled or unscrambled) is fed to the circuit. When normal voice is applied to the input of the circuit, the circuit outputs an encoded signal. If the scrambled output is recorded and fed back into the circuit, the circuit outputs a decoded signal. You could use a cassette recorder with the scrambler/ descrambler to give your personal notes a degree of security without spending a

PARTS LIST FOR THE VOICE SCRAMBLER/DESCRAMBLER

SEMICONDUCTORS

U1—NE602 low-power VHF double-balanced mixer, integrated circuit
U2—LM567 tone-decoder, integrated circuit
U3—LM386 low-power, audio-amplifier, integrated circuit

RESISTORS

(All fixed resistors are ¼-watt, 5% units.)
R1, R2—1000-ohm
R3—10,000-ohm
R4—10-ohm
R5—25,000-ohm potentiometer
R6—10,000-ohm potentiometer

CAPACITORS

C1–C5—0.1-µF, ceramic-disc
C6—0.27-µF, mylar or similar
C7—0.039-µF, mylar or similar
C8—0.05-µF, ceramic-disc
C9—100-µF, 16-WVDC, electrolytic
C10—220-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

SPKR1—4 or 8-ohm speaker
T1—1000-ohm to 8-ohm audio transformer
Perfboard materials, enclosure, 9-volt power source, IC sockets, knobs, wire, solder, hardware, etc.

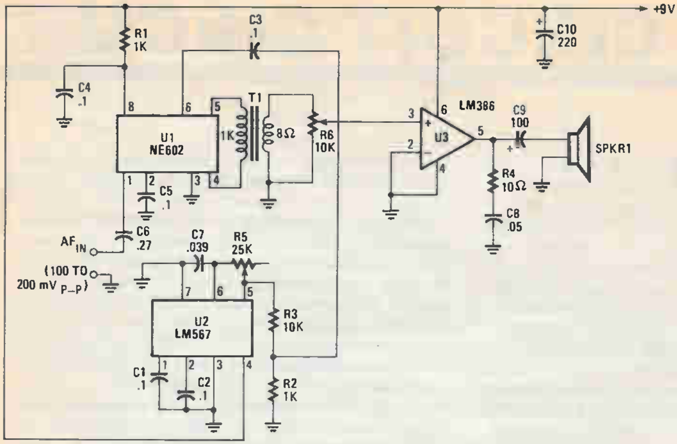

Fig. 2. In this single-mode inversion voice scramberldescrambler circuit, the NE602 is configured as a balanced modulatorldemodulator.

bundle for a commercial system.

PERMANENT-MAGNET DETECTOR

In our next circuit (see Fig. 3), the NE602 is used as the heart of a permanent-magnet detector. The NE602's internal oscillator is tuned to about 15 kHz by an external tank circuit made up of L2, C7, and C8. Transistor Q1 and its associated components make up a similar oscillator circuit that operates at about the same frequency. The output of the transistor oscillator is fed to the A input of U1 at pin 1 and is mixed with the output of U1's internal oscillator.

The difference output of U1 (the mixer's low-frequency product) at pin 5 is fed through a low-pass filter, consisting of L3 and C16, to the base of Q2, which is configured as a grounded- (or common-) emitter low-frequency amplifier. High-frequency feedback is provided through C17 from the collector of Q2 to its base. The circuit's gain is high at frequencies below 10 Hz. The low-frequency component of the signal is fed through a 10-µF capacitor to a voltage-doubler/detector circuit to M1, which is used to indicate relative magnetic-field strength. When a magnet is brought close to either L1 or L2, the circuit produces a meter reading, indicating the relative magnetic-field strength.

The magnet detector is easy to adjust and use. First both oscillators must be tuned to the same frequency. If, by your good luck, the two tank circuits happen to oscillate within a few hertz of each other, then C15 can be used to zero-beat the two signals. If not, the two oscillators are too far apart in frequency. Determine which oscillator is operating at the higher frequency and add small value capacitors across the tuned circuit until that oscillator's frequency is about the same as the other. Then fine tune the circuit via C15 (the variable capacitor) for a zero beat.

When both oscillators are at zero beat (operating at the same frequency), the meter will indicate zero current flow. Positioning a magnet near the end of either L1 or L2 will cause the permeability of the choke's ferrite core to change, shifting the oscillator's frequency and producing a meter reading. The meter can be roughly calibrated to indicate the approximate strength of the magnet by positioning the magnet at a fixed distance from the coil and setting R10 for the desired meter reading.

AUDIO-FREQUENCY GENERATOR

Our last entry, shown in Fig. 4, places the NE602 at the center of an unusual audio-frequency generator. The circuit produces audio sine waves by mixing the outputs of two RF oscillators that are operating at about the same frequency. Varying the frequency of either RF oscillator causes the audio-output frequency to

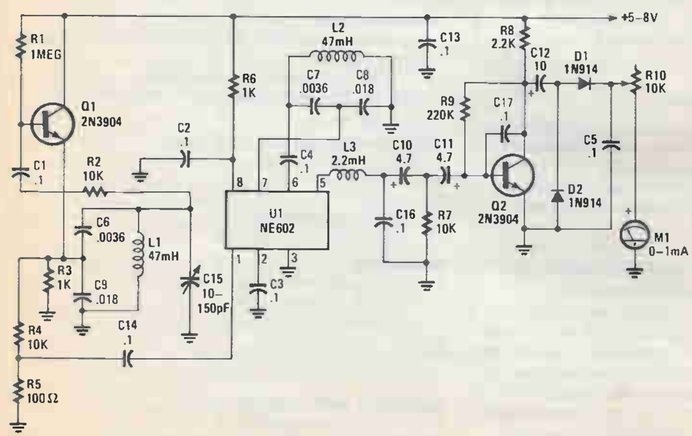

Fig. 3. The NE602 is the heart of the permanent magnet detector. By bringing a magnet close to either L1 or L2, the circuit will respond by producing a meter reading, indicating the relative field strength of the magnet.

PARTS LIST FOR THE PERMANENT-MAGNET DETECTOR

SEMICONDUCTORS
U1—NE602 low-power VHF double-balanced mixer, integrated circuit
Q1, Q2—2N3904 general-purpose NPN silicon transistor
D1, D2—1N914 general-purpose silicon diode

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

CAPACITORS
C1–C5, C13, C14, C16, C17—0.1-µF, ceramic-disc
C6, C7—0.0036-µF, mylar or similar
C8, C9—0.018-µF, mylar or similar
C10, C11—4.7-µF, 16-WVDC, electrolytic
C12—10-µF, 100-WVDC, electrolytic
C15—10–150-pF trimmer

ADDITIONAL PARTS AND MATERIALS
L1, L2—47-mH RF choke
L3—2.5-mH RF choke
M1—0–1-mA current meter
Perfboard materials, enclosure, 5–8-volt power source, IC socket, mangets, wire, solder, hardware, etc.

PARTS LIST FOR THE AUDIO-FREQUENCY GENERATOR

SEMICONDUCTORS
U1—NE602 low-power VHF double-balanced mixer, integrated circuit
Q1—2N3904 general-purpose NPN silicon transistor
D1—See text

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1—2200-ohm
R2—220,000-ohm
R3—1000-ohm
R4, R5—10,000-ohm
R6—10,000-ohm potentiometer

CAPACITORS
C1–C4—0.1-µF, ceramic-disc
C5, C6—680-pF ceramic-disc
C7, C8—.0033µF, ceramic-disc
C9—0.01-µF, ceramic-disc
C10—0.0036-µF, Mylar or similar
C11—0.27-µF, Mylar or similar
C12—365-pF, variable
C13—220-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS
L1, L2—2.5-mH RF choke
FIL1, FIL2—455-kHz ceramic filter (Murata CSB455E or similar)
Perfboard materials, enclosure, IC socket, wire, solder, hardware, etc.

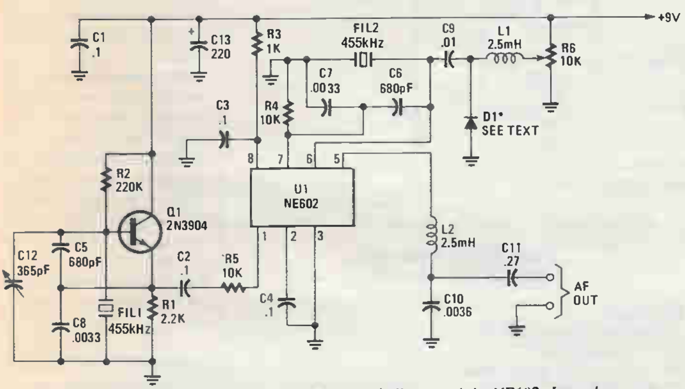

Fig. 4. Here is an unusual audio-frequency generator built around the NE602. It produces an audio sine-wave by mixing the outputs of two RF oscillators operating at about the same frequency.

change by the same number of hertz. It's much easier to shift an RF oscillator a few thousand hertz than it is to shift an AF oscillator the same amount. The method of shifting the RF frequency can be as simple as varying the value of a capacitor or a potentiometer.

Transistor Q1, along with FIL1 (a 455-kHz ceramic filter), and the few surrounding components make up one of the RF oscillators. The NE602's internal oscillator is set to about the same frequency via FIL2. A low-pass filter, consisting of L2 and C10, removes the RF component from the circuit's AF-output signal.

Diode D1 can be a common silicon diode (like the 1N4002) or transistor (base-collector) junction operating as a varicap diode. With the wiper of R6 at ground potential and C12 set so that both oscillators are operating at the same frequency no audio tone will occur at the output. But, by turning potentiometer R6, U1's oscillator will shift in frequency to produce an audio output.

Note: If you can't find the 455-kHz ceramic filters used in the Audio Frequency Generator, just send an S.A.S.E (self-addressed stamped envelope) to Charles D. Rakes, C/O *Circuit Circus*, **Popular Electronics,** 500-B Bi-County Blvd., Farmingdale, NY 11735 and I'll send two along. Also note that if you can not find the NE602 double-balanced mixer locally, it is available by mail order from DC Electronics, PO Box 3203, Scottsdale, AZ 85271-3203; for pricing, availability, and shipping charges, you can call them at 602-945-7736. ■

CIRCUIT CIRCUS

By Charles D. Rakes

Test Instruments

This time around, the Circus deals with a number of unrelated circuits that can be used as simple test instruments or be incorporated into a future project. In any case, get ready for some building fun. The first circuit that we'll explore is a variable-frequency pulse generator.

PULSE GENERATOR

Figure 1 is a schematic diagram of a variable-frequency, pulse-generator circuit. The circuit has a frequency range of 2 Hz to over 50 kHz, and produces narrow, 7-volt, positive-going pulses. The pulses produced by the circuit have widths of about 7 microseconds at the circuit's maximum frequency and 10 milliseconds at its lowest frequency.

The circuit's operating frequency is determined by the value of one of the charging capacitors, C1–C4 (as selected via S1, the range switch) and the values of resistors R1 and R2. The circuit's switching time is fairly rapid due to the regenerative action of the emitter-coupled transistors, Q1 and Q2. That quick switching action produces a fast rising output pulse. With S1 in position 1, the circuit oscillates in the range of 2 to 50 Hz; in position 2, the range is 15 to 500 Hz; in position 3, 120 Hz to 5 kHz; and in position 4, 1.5 to 55 kHz.

Potentiometer R8, a 5k or 10k unit (which can be omitted from the circuit if not needed) is included in the circuit to provide an adjustable pulsewidth. The pulse will increase in width as the resistance of R8 is increased.

The generator circuit isn't complicated, nor is there anything critical about the circuit, so it can be assembled on perfboard and housed in a small plastic cabinet. The circuit can be powered from a 9-volt transistor battery. Such a circuit can be a valuable aid in servicing or experimenting on an existing or future project.

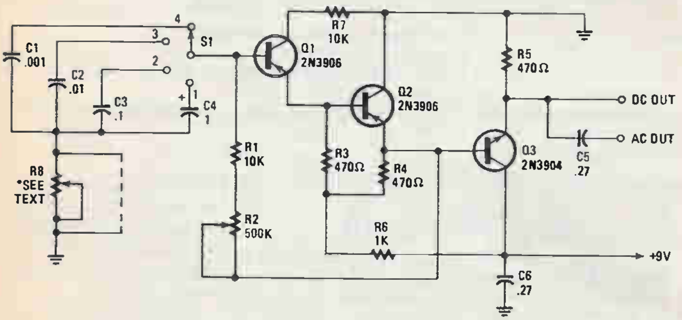

Fig. 1. The variable-frequency pulse generator produces narrow 7-volt positive-going pulses and has a frequency range of 2 Hz to over 50 kHz.

PARTS LIST FOR THE PULSE GENERATOR

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1, R7—10,000-ohm
R2—500,000-ohm potentiometer
R3–R5—470-ohm
R6—1000-ohm
R8—5000-ohm or 10,000-ohm potentiometer (see text)

CAPACITORS
C1—0.001-µF ceramic-disc
C2—0.01-µF, ceramic-disc
C3—0.1-µF, ceramic-disc
C4—1-µF, 100-WVDC, electrolytic
C5, C6—0.27-µF, ceramic disc

ADDITIONAL PARTS AND MATERIALS
Q1, Q2—2N3906 general-purpose PNP silicon transistor
Q3—2N3904 general-purpose NPN silicon transistor
Perfboard materials, enclosure, 9-volt transistor-radio battery and battery connector, wire, solder, hardware, etc.

PROXIMITY DETECTOR

Our next circuit, a proximity detector (see Fig. 2), is designed for those who enjoy modifying an existing circuit to produce a practical and working project. The detector consists of a 567 tone decoder (U1), a couple of transistors, and a few support components. The circuit's operation is simple. The 567 is configured as a decoder; R2 and C4 set its receive frequency to about 100 kHz.

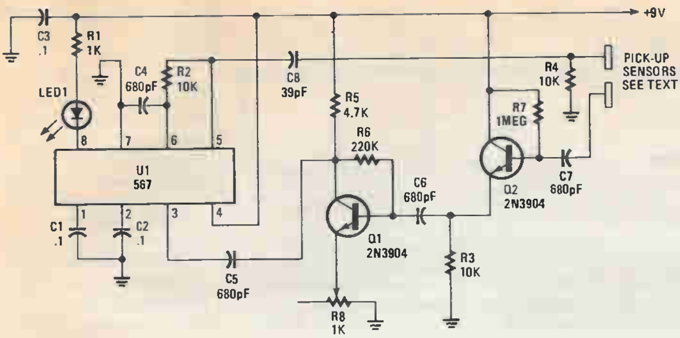

Fig. 2. The proximity detector consists of a 567 tone decoder, a couple of transistors, and a few support components.

PARTS LIST FOR THE PROXIMITY DETECTOR

SEMICONDUCTORS
U1—567 tone decoder, integrated circuit
Q1, Q2—2N3904 general-purpose, NPN silicon transistor
LED1—LED (any color)

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1—1000-ohm
R2–R4—10,000-ohm
R5—4700-ohm
R6—220,000-ohm
R7—1-megohm
R8—1000-ohm potentiometer

CAPACITORS
C1–C3—0.1-µF, ceramic-disc
C4–C7—680-pF, ceramic-disc
C8—39-pF, ceramic-disc

ADDITIONAL PARTS AND MATERIALS
Perfboard materials, enclosure, pick-up material (see text), IC socket, 9-volt transistor-radio battery and connector, wire, solder, hardware, etc.

An LED, connected to U1's pin 8 output, lights when an in-band signal is detected. The pin 5 output of U1 (a 100-kHz square-wave signal) is fed through C8 to R4 and one of the pick-up sensors. That RC combination causes the square-wave output to differentiate, shifting the phase of the signal at the pick-up sensor, and allowing U1 to detect its own output signal.

The other pick-up sensor is connected to the input of an emitter-follower amplifier, Q2, which operates like a matching transformer, offering the sensor a high-input impedance and a low-output impedance, which matches the input impedance of Q1, whose gain is set by potentiometer R8. The amplified output of Q1 is fed to U1 at pin 3. When the input signal is about 100-millivolts or greater, U1 detects the signal and lights LED1.

The detector circuit is slightly more critical in the construction scheme used than most of the circuits presented in *Circuit Circus*, so to avoid problems keep all component leads as short as possible, and avoid criss-crossing wires. The detector circuit can be used to detect metal objects, such as nails and electrical wiring in walls, objects traveling on an assembly line, and any object capable of coupling a signal from one pick-up to the other. For instance, the sensors can be attached to non-metal tubing to monitor the flow of conductive fluids.

The sensors can be made from almost any metal such as aluminum, aluminum foil, brass, copper, etc., and can be as small as two short pieces of hook-up wire or as large as needed. To achieve the best performance, breadboard the circuit and experiment with various size of sensors, the spacing between each sensor, the operating frequency, and different values for C8 and R4.

MOISTURE DETECTOR

Our next entry is a simple circuit that can be used as a "puppy puddle" detector. Now don't laugh; I know of a carpet cleaning company that paid over $80 each for a number of commercial moisture detectors that didn't perform any better than the one shown in Fig. 3. The detector can help in locating those damp spots in your carpet in time to properly clean and dry them before they do permanent damage.

The moisture detector is little more than a single 2N3904 NPN transistor (in a common-emitter configuration) that's used to turn on a piezo sounder, BZ1. The one probe is connected to the base of Q1 through a 1k resistor (R2) and the other probe is tied to the +V terminal of a 9-volt transistor radio battery through current-limiting resistor R1 (another 1k unit). A desensitizing resistor, R3, is connected to the circuit via switch S1.

Since there's zero current drain when the circuit isn't in use, an on/off switch isn't needed and the 9-volt transistor battery should last its shelf life. The detector's maximum sensitivity is about 2.5 megohms with S1 in its normal position and about 100k when S1 is activated. Those two ranges will help in mapping wet spots.

There is nothing critical about the circuit; it can be built on a small piece of perfboard, with point-to-point wiring used to interconnect the components. Two heavy-duty, sewing-machine needles can be used as probes. The circuit can then be housed in a length of 1-inch plastic pipe to give it a manufactured look. If the circuit is to be housed in a plastic pipe, the needles should be long enough to extend at least 1½-inches past the end of the pipe.

Switch S1 can be mounted to the pipe above the circuit. It's a good idea to insulate the battery to prevent its metal case from shorting out the circuit components. That's easily done by stuffing a piece of foam rubber, or similar non-conductive material, into the pipe to

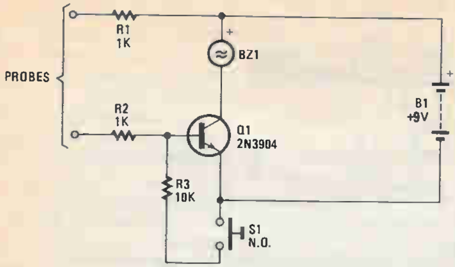

Fig. 3. The moisture detector is nothing more than a transistor (in a common-emitter configuration) that is used as a simple switch.

PARTS LIST FOR THE MOISTURE DETECTOR

Q1—2N3904 general-purpose NPN silicon transistor
R1, R2—1000-ohm, ¼-watt, 5% resistor
R3—10,000-ohm, ¼-watt, 5% resistor
B1—9-volt transistor-radio battery
S1—Normally-open push-button switch
BZ1—Piezo buzzer
Perfboard materials, enclosure, probe, battery connector, wire, solder, hardware, etc.

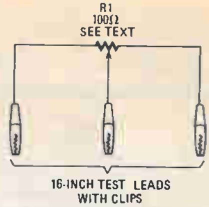

Fig. 4. The variable resistance box can be assembled from junkbox components, and will be of greater service than its simple appearance suggests.

PARTS LIST FOR THE VARIABLE RESISTANCE BOX

RESISTORS
R1—100-ohm linear potentiometer
R2—1000-ohm linear potentiometer
R3—10,000-ohm linear potentiometer
R4—100,000-ohm linear potentiometer
R5—1-megohm linear potentiometer
Cabinet, leads, alligator clips, etc. Perfboard materials, enclosure, AC molded power plug with line cord, battery(s), battery holder and connector, wire, solder, hardware, etc.

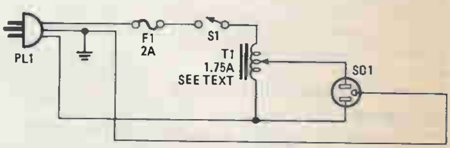

Fig. 5. A variable AC power supply is a very useful tool to have on your workbench when you're servicing malfunctioning electronic equipment, or you are preparing to put back into service equipment that has been idle for a long time.

PARTS LIST FOR THE VARIABLE AC SUPPLY

T1—1.75-amp variable transformer
F1—2-amp fuse
SO1—AC socket
PL1—AC plug
S1—SPST switch
Cabinet, wire, solder, hardware, etc.

maintain separation between the battery, switch, and perfboard-mounted components. The piezo sounder can be attached to the end of the pipe opposite the probes.

To check the circuit's operation, bridge a 2.2-megohm resistor across the probes; doing so should cause BZ1 to sound. With the 2.2-megohm resistor still in place, press S1 and the sound should cease. Remove the 2.2-megohm resistor and replace it with a 100k resistor and BZ1 should sound at full volume. Now press S1 and the volume should drop to a much lower level. If so your probe is ready for action.

VARIABLE RESISTANCE BOX

Often it seems like the simplest form of tester turns out to be one of the most valuable and frequently used gadgets on the workbench. Our next circuit—a variable resistor-substitution box (see Fig. 4)—certainly falls into that category. Note that to conserve space only one potentiometer is shown, but keep in mind that the substitution box can have as many potentiometers as desired; say, five with values of 100 ohms, 1k, 10k, 100k, and 1 megohm.

Mount the potentiometers in a plastic cabinet with a scaled escutcheon for each. Bring out three different color test leads with alligator clips for each potentiometer. That gives you a variable substitution box that can take the place of an expensive resistance decade box. Of course the potentiometer's adjustment won't be as accurate as a decade box, but it will allow you to make a smooth resistance change that's not possible with a decade box.

If your experiments require accurate resistances, a digital ohmmeter can be used to set the selected potentiometer to the needed value. I've found the variable resistance box of this type to be useful in setting up and checking single-transistor amplifiers; one potentiometer can be connected to the collector as a load resistor, another as the emitter resistor, and either one or two of the other units can be used for setting the transistor's base bias.

There are several precautions you should be aware of and follow in using that simple testing procedure. Keep the leads from the potentiometers separated as much as possible to reduce coupling and oscillations, and don't allow current levels through the potentiometers to exceed their ratings. In addition, avoid destroying the transistor by making sure that the potentiometer is at its maximum resistance setting when power is applied to the unit under test.

VARIABLE AC SUPPLY

Our last entry is another simple circuit—a variable

(Continued on page 32)

CIRCUIT CIRCUS

By Charles D. Rakes

Take an Electronics Holiday

ANIMATED BELL

Figure 1 is the schematic diagram of the bell animation circuit. Each of the three bell outlines in the circuit consist of twelve LED's. As each group of LED's is sequentially switched on and off so that the bell outline appears to shift positions, creating the illusion of movement.

To accomplish the apparent animation, two gates (U1-a and U1-b) of a 4001 CMOS quad 2-input NOR gate are configured as a low-frequency astable oscillator, with its operating frequency set by the values of C2, R13, and R14. The circuit's oscillating frequency can be altered by adjusting R14. The oscillator output at pin 4 of U1-b is fed to the clock input of U2 (a 4017 CMOS decade counter/divider) at pin 14.

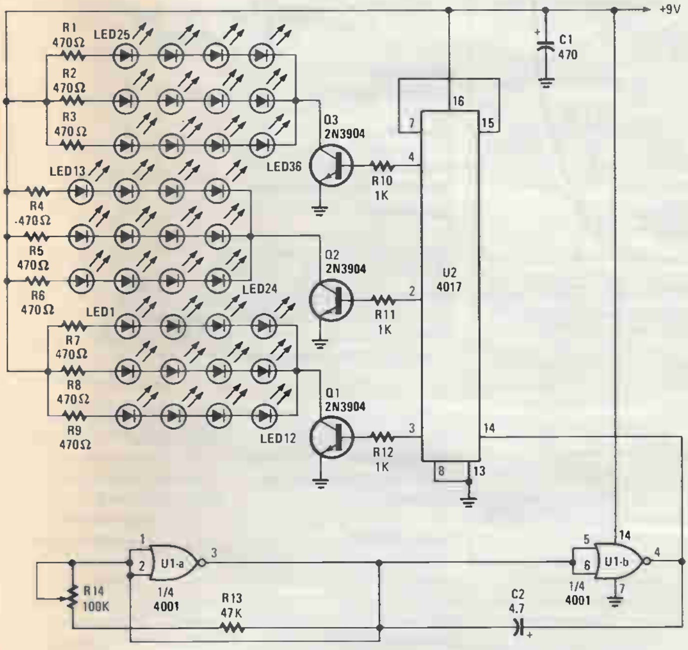

Fig. 1. The bell-animation circuit contains 36 LED's that are controlled by a 4017 counter/divider, which is clocked by an astable multivibrator that consists of half of a 4001 quad 2-input NOR gate.

Counter U2—which has 10 decoded outputs, but is connected in a count three and recycle configuration—advances one count per pulse, causing pins 3, 2, 4, and 7 (which correspond to outputs 0–3) to sequentially go positive.

The first clock pulse forces pin 3 of U2 high, turning on Q1. That grounds the cathodes of LED's 1–12, causing them to light, producing the first bell outline. The second pulse forces pin 2 of U2 high (and pin 3 low), which, in turn, causes Q2 to turn on, and Q1 to turn off. With Q2 turned on, the second set of LED's (LED's 13–24) light, causing the bell outline to appear to have shifted positions. The third pulse turns Q2 off and Q3 on, lighting the third set of LED's, and gives the appearance that the bell outline has once again shifted.

On the fourth clock pulse, pin 7 of U2 (which is tied to U2's reset terminal at pin 15) goes high. That causes U2 to reset to zero, once again causing pin 3 to go high, lighting the first bell outline, and the sequence is repeated.

Figure 2 shows the basic overlapping three-bell outline. However, if more bell outlines are desired, the basic circuit can be easily modified. Refer to Fig. 3. To change the number of outputs, connect U2's reset input at pin 15 to the output pin that's one greater than the number of bells that are used in your display.

For instance, if you want to used five bells instead of three, you'd have to connect pin 15 to output 5. (Remember output 0 at pin 3 is the first output to go

PARTS LIST FOR THE ANIMATED BELL

SEMICONDUCTORS
U1—4001 quad 2-input NOR gate, integrated circuit
U2—4017 decade counter/divider, integrated circuit
Q1-Q3—2N3904 general-purpose silicon NPN transistor
LED1–LED36—Light-emitting diode

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1–R9—470-ohm
R10–R12—1000-ohm
R13—47,000-ohm
R14—100,000-ohm potentiometer

ADDITIONAL PARTS AND MATERIALS
C1—470-µF, 16-WVDC, electrolytic capacitor
C2—4.7-µF, 16-WVDC, electrolytic capacitor
Perfboard materials, enclosure, IC sockets, 9-volt power source, wire, solder, hardware, etc.

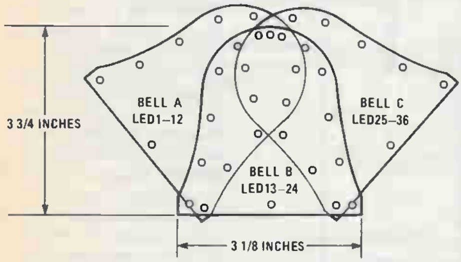

Fig. 2. The 36 LED's of the bell animation circuit are grouped by 12 and arranged to form three bell outlines. Here is the layout of the basic overlapping three-bell outline.

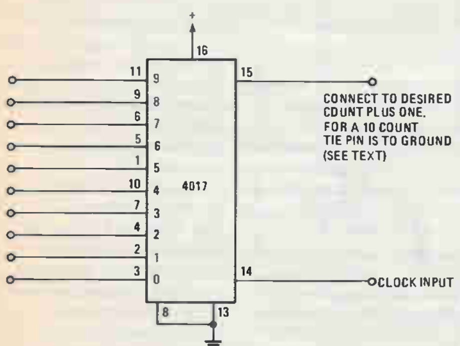

Fig. 3. Additional LED-bell outlines can be added to the circuit using this diagram as a guide. Simply connect pin 15 of the counter to the output that corresponds to the number of bells plus one. See the text for more information.

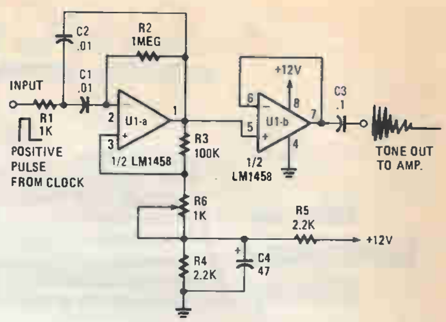

Fig. 4. The tone chime circuit shown here can be added to the animated bell to give the original circuit that extra flare.

PARTS LIST FOR THE MUSICAL CHIME

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1—1000-ohm
R2—1-megohm
R3—100,000-ohm
R4, R5—2200-ohm
R6—1000-ohm potentiometer

CAPACITORS
C1, C2—.01-µF, ceramic-disc
C3—0.1-µF, ceramic-disc
C4—47-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS
U1—LM1458 dual op-amp, integrated circuit
Perfboard materials, enclosure, IC socket, 12-volt power source, wire, solder, hardware, etc.

high, which in this instance is considered as the first output.) If you want to use all 10 of U2's outputs, tie pin 15 to ground. Of course, any increase in LED strings, must be accompanied by a corresponding increase in driver transistors. You can also use the basic circuit to animate other objects, such as a star, a ball, or even a Christmas tree.

TONE CHIME

Our second circuit for this month is a simple add-on musical-chime. You can add the chime circuit to the animated bell circuit in Fig. 1 to jazz up the project, making the bell appear to ring as it swings.

In Fig. 4, half of an LM1458 dual op-amp (U1-a) is configured as a modified active filter whose gain is controlled by R6. If the gain is set too high the circuit will go into oscillation at the filter's resonant frequency. By adjusting the gain to just below the point of oscillation, the circuit can be triggered with a positive pulse, causing it to give out a short ringing signal at the filter's resonant frequency.

The chime-oscillator's output is buffered from external loading by the second op-amp, U1-b, which is configured as a voltage follower. The input of the chime-oscillator circuit can be activated by the output of the clock generator or any of the 4017's outputs in the animated bell circuit. Connect the chime's input to the desired trigger source and set R6 for a ringing output. The chime oscillator's frequency may be increased by lowering the values of C1 and C2, or decreased by increasing the values. ■

CIRCUIT CIRCUS

By Charles D. Rakes

Alarm Circuits

This time around, we're going to share a number of alarm circuits. In most alarm circuits, one or more sensors—each connected in some sort of detection loop—are positioned at strategic locations on or around the item to be protected. The detection circuit (consisting of a sensor loop and trigger circuit) controls an alarm sounder that, when activated, produces an audible or visual alert.

The sensor in an alarm circuit can be as simple as a single strand of fine copper wire, which functions as a sensor and is positioned around the perimeter of an object. As long as the wire remains intact, the alarm circuit is set. If an intruder severs the wire, the sensor sends a signal to the trigger circuit, causing an alarm to be sent out. That type of sensor is a one shot, non-resetable, device.

Such alarms require that the sensor wire be replaced after each breach. (They are referred to as closed-loop circuits.) However, most alarm circuits use some sort of magneticolly-activated switch, which can be reset and used over and over again, as a sensor. The sensor can be either a normally-open or normally-closed magnetically-activated switch. And, depending on the configuration of the trigger configuration, multiple sensors can be series or parallel wired into the circuit.

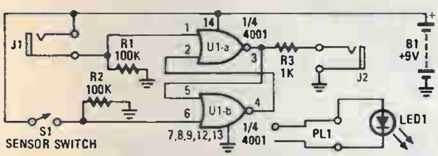

Fig. 1. The Silent Alarm is built around half of a 4001 CMOS quad 2-input NOR gate, configured as a set/reset flip-flop.

SILENT ALARM

Our first circuit, see Fig. 1, is built around half of a 4001 CMOS quad 2-input NOR gate, configured as a set/reset latch. With the circuit in the reset condition (at rest) and switch S1 open, gate U1-a's output is low. If the key (an LED mounted in a mini phone plug, PL1) is plugged into J2, the LED will not light, indicating that no breach has occurred.

But, when S1 is closed, either momentarily or permanently, the output of U1-a at pin 3 goes high and remains high until the circuit is reset. By inserting the key into J2 after a breach, the LED will light. Inserting the key into J1 resets the circuit.

In the standby mode, the circuit draws almost no current, allowing it to keep an undaunted vigil for many months without attention. If the sensor (S1) is triggered by an intruder, the circuit will place the information in temporary storage with no more current drain than would occur in the standby mode.

PARTS LIST FOR THE SILENT ALARM

LED1—Light-emitting diode (any color)
U1—4001 CMOS hex inverter, integrated circuit
R1, R2—100,000-ohm, ¼-watt, 5% resistor
R3—1000-ohm, ¼-watt, 5% resistor
J1, J2—Miniature phone jack
PL1—Miniature phone plug
S1—normally open sensor switch (see text)
B1—9-volt transistor-radio battery
Perfboard materials, enclosure, IC socket, battery holder and connector, wire, solder, hardware, etc.

CLOSED-LOOP ALARM

Our next alarm circuit, see Fig. 2, uses a string of three series-connected normally-closed switches (the closed-loop configuration) connected to the gate of an SCR. Any number of sensors can be connected in series and used to trigger the circuit. In the standby mode, the circuit draws about 2 mA, but the current drain may rise to as high as 500 mA when the circuit is triggered, depending on the alarm sounder used.

The circuit's operation is very simple. With all sensor switches closed and power applied, the voltage at the SCR's gate is near zero; the only current drain is through R1 and the sensors. But when any one of the sensor switches opens, either momentarily or permanently, gate current is delivered to the SCR through R1. That turns on the SCR, providing a ground path for the sounder, causing it to let out a wail. Once triggered, the alarm continues to sound until the reset switch (S1) is activated. Capacitors C1

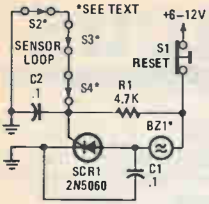

Fig. 2. The Closed-Loop Alarm uses a string of three series-connected normally closed switches (the closed-loop configuration) connected to the gate of an SCR.

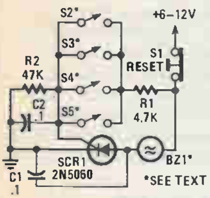

Fig. 3. The Parallel-Loop Alarm is almost identical to the circuit presented in Fig. 2, except the this time the sensors are parallel wired in what is referred to as an open loop.

and C2 are included in the circuit to prevent any transient voltages from falsely triggering the SCR.

PARALLEL-LOOP ALARM

Our next alarm circuit, see Fig. 3, is almost identical to the circuit presented in Fig. 2, except that this time the sensors are parallel wired in what is referred to as an open loop. As you can see, this circuit uses normally-open sensor switches. Any number of normally open switches can be wired in parallel and be used to trigger the alarm; they are connected to the SCR as shown in the schematic.

In the set condition, the alarm circuit draws almost no current, making it a good candidate for battery operation. But when any one of the input sensors is closed, gate current flows through R1 to the SCR, turning it on and activating the alarm sounder. The sounder will continue operating until the circuit is reset or the battery fails.

PARTS LIST FOR THE CLOSED-LOOP ALARM

SEMICONDUCTORS

SCR1—2N5060 sensitive-gate silicon-controlled rectifier
R1—4700-ohm, ¼-watt, 5% resistor
C1, C2—0.1-µF, 100—WVDC, ceramic-disc capacitor
S1—normally closed pushbutton switch
S2–S4—normally closed sensor switch
BZ1—Alarm sounder (see text)
Perfboard materials, enclosure, 6–12 volt power source, wire, solder, hardware, etc.

PARTS LIST FOR THE PARALLEL-LOOP ALARM

SCR1—2N5060 sensitive-gate silicon-controlled rectifier
R1—4700-ohm, ¼-watt, 5% resistor
R2—47,000-ohm, ¼-watt, 5% resistor
C1, C2—0.1-µF, 100-WVDC, ceramic-disc
S1—normally closed pushbutton switch
S2–S5—normally open sensor switch
BZ1—Alarm sounder (see text)
Perfboard materials, enclosure, 6–12 volt power source, wire, solder, hardware, etc.

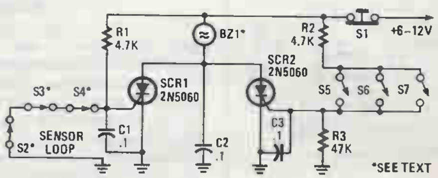

Fig. 4. The Series/Parallel-Loop Alarm combines the alarm in Fig 2 with the one in Fig. 3 to provide both series- and parallel-loop protection.

PARTS LIST FOR THE SERIES/PARALLEL-LOOP ALARM

SCR1, SCR2—2N5060 sensitive-gate silicon-controlled rectifier
R1, R2—4700-ohm, ¼-watt, 5% resistor
R3—47,000-ohm, ¼-watt, 5% resistor
C1–C3—0.1-µF, ceramic-disc capacitor
S1—normally closed pushbutton switch
S2–S4—normally closed sensor switch
S5–S7—normally open sensor switch
BZ1—Alarm sounder, see text
Perfboard materials, enclosure, 6–12 volt power source, wire, solder, hardware, etc.

SERIES/PARALLEL LOOP ALARM

Our next circuit, see Fig. 4, combines the alarm in Fig 2 with the one in Fig. 3 to provide both series- and parallel-loop protection. Here you may use both normally-closed and normally-open sensors to trigger the same alarm sounder.

Note that the main difference between the two sensor loops lies in the way that each sensor switch relates to the others in the loop and the way each loop is wired into the circuit. The loop connected to SCR1 holds the SCR off by tying its gate to ground through the loop sensors. Opening any one of those switches (S2–S4) removes gate grounding, allowing gate current to be delivered to SCR1. That causes SCR1 to turn on and the alarm to sound.

Conversely, SCR2's gate is held low via R3. When any one of its sensors (S5–S7) are closed, the gate of the SCR is connected to the positive supply through R2, which in turn causes it to turn on, sounding the alarm. With one of the sensor switches closed, R2 becomes a gate pull-up resistor.

Once triggered by either sensor loop, the circuit continues to sound until reset by pressing switch S1, which is connected in series with the 9–12 volt power source. Note that removing the trigger source has no affect on conduction through the SCR, so long as current through the SCR remains at or above the holding level (I_H). Pressing S1 causes the current though the SCR's to drop below I_H, turning off the SCR's. Capacitors C1–C3 prevent the circuit from being falsely triggered by transient voltages.

HIGH-POWER ALARM DRIVER

The three circuits discussed so far are only suited for low- to medium-power sounders due to the current limitations of the SCR's associated with them.

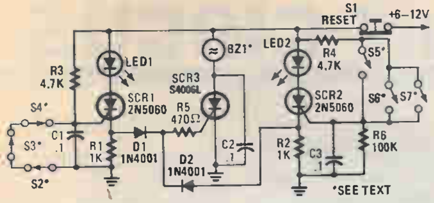

Fig. 5. The High-Power Alarm Driver uses the low-powered SCR's from the circuit in Fig. 4 to control a higher power SCR, which can then be used to turn on a heftier sounder.

PARTS LIST FOR THE HIGH-POWER ALARM DRIVER

SEMICONDUCTORS
SCR1, SCR2—2N5060 sensitive-gate silicon-controlled rectifier
SCR3—S4006L 6-amp, 400-PIV silicon-controlled rectifier
D1, D2—1N4001, 1-amp, 50-PIV silicon rectifier diode
LED1, LED2—Light-emitting diode, any color

RESISTORS
(All fixed resistors are ¼-watt, 5% units, unless otherwise noted.)
R1, R2—1000-ohm
R3, R4—4700-ohm
R5—470-ohm ½-watt
R6—100,000-ohm

SWITCHES
S1—normally closed pushbutton switch
S2–S4—normally closed sensor switch
S5–S7—normally open sensor switch

ADDITIONAL PARTS AND MATERIALS
C1–C3—0.1-µF, ceramic-disc capacitor
BZ1—Alarm sounder circuit, see text
Perfboard materials, enclosure, 6–12-volt power source, wire, solder, hardware, etc.

The circuit in Fig. 5 however, uses the SCR triggers from the previous circuit to control a higher-power SCR, which is then used to turn on a heftier sounder.

The two sensitive-gate SCR's are connected in separate sensor/trigger circuits. As with the circuit in Fig. 4, SCR1 is triggered by the normally closed sensor loop (S2–S4), while SCR2 is triggered by the normally open sensor loop (S5–S7). The output (at the cathode) of each SCR is connected through a separate steering diode and a common current-limiting resistor, R5, to the gate of a 400-PIV, 6-amp SCR (SCR3).

If any one of the normally closed switches (S2–S4) opens, gate current flows through R3, turning SCR1 on, and LED1 lights to indicate that a breach has occurred in one of the normally closed sensors. At the same time, the SCR's cathode voltage rises to about 80% of the supply voltage, causing current to flow through D1 and R5 into the gate of SCR3, turning it on and setting off the alarm sounder. SCR2's normally open sensor loop operates in a like manner. When any one of the normally open sensor switches (S5–S7) is closed, SCR2 is triggered, lighting LED2. At the same time, gate current is sent to SCR3, setting off the alarm.

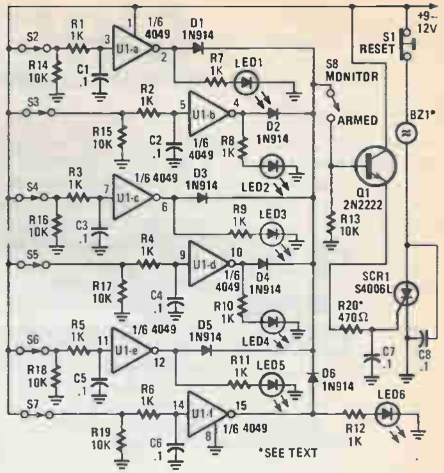

Fig. 6. The Multi-Loop Parallel Alarm has LED's connected across each inverter output to indicate the status of its associated sensor.

PARTS LIST FOR THE MULTI-LOOP PARALLEL ALARM

SEMICONDUCTORS
U1—4049 CMOS hex inverter, integrated circuit
Q1—2N2222 general-purpose silicon NPN transistor
SCR1—S4006L, or similar, 6-amp, 400-PIV silicon-controlled rectifier
D1–D6—1N914 general-purpose, small-signal, silicon diode
LED1–LED6—Light-emitting diode, any color

RESISTORS
(All fixed resistors are ¼-watt, 5% units unless otherwise noted.)
R1–R12—1000-ohm
R13–R19—10,000-ohm
R20—470-ohm, ½-watt

SWITCHES
S1—normally closed pushbutton switch
S2–S7—normally closed sensor switch
S8—SPST toggle switch

ADDITIONAL PARTS AND MATERIALS
C1–C8—0.1-µF, ceramic-disc capacitor
BZ1—Alarm sounder, see text
Perfboard materials, enclosure, IC socket, 9–12-volt power source, wire, solder, hardware, etc.

MULTI-LOOP PARALLEL ALARM

The next circuit (Fig. 6) is a multi-input alarm with a status LED indicator for each sensor. The trigger circuit can be used as a status indicator by placing S8 in the MONITOR position. With S8 set to MONITOR, the sensor circuits can be used during working hours to monitor door openings and other normally used areas that are protected only during closed hours. A 6-amp SCR is used to allow a high-

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CIRCUIT CIRCUS

By Charles D. Rakes

Op-amp Based Circuits

Our first circuit came about after a delivery person dropped a valuable package while trying to ring the shop's doorbell. Fortunately, no damage occurred, but the incident gave birth to the idea of a voice-activated one-way intercom that would allow anyone to get our attention by simply speaking rather than reaching to ring a doorbell.

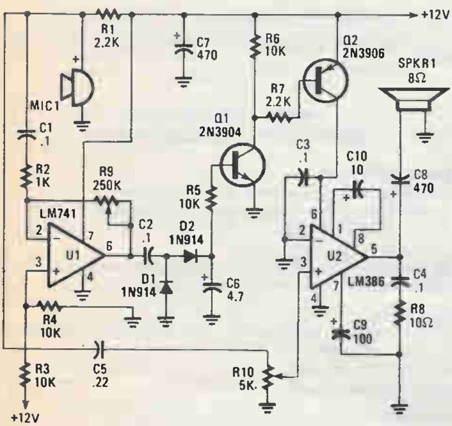

Fig. 1. The one-way intercom uses an omnidirectional electret microphone to pick up sound and convert it to an electrical signal. The resulting signal is used to activate the audio amplifier (U2) that drives the speaker (SPKR1), and is also the audio signal that is output by the speaker.

PARTS LIST FOR THE ONE-WAY VOICE-ACTIVATED INTERCOM

SEMICONDUCTORS

U1—LM741 op-amp, integrated circuit
U2—LM386 low-voltage, audio-power amplifier, integrated circuit
Q1—2N3904 general-purpose NPN silicon transistor
Q2—2N3906 general-purpose PNP silicon transistor
D1, D2—1N914 general-purpose silicon diode

RESISTORS

(All fixed resistors are ¼-watt, 5% units.)
R1, R7—2200-ohm
R2—1000-ohm
R3–R6—10,000-ohm
R8—10-ohm
R9—250,000-ohm potentiometer
R10—5000-ohm potentiometer

CAPACITORS

C1–C4—0.1-µF, ceramic-disc
C5—0.22-µF, ceramic-disc
C6—4.7-µF, 16-WVDC, electrolytic
C7, C8—470-µF, 16-WVDC, electrolytic
C9—100-µF, 16-WVDC, electrolytic
C10—10-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

MIC1—electret microphone element
SPKR1—8-ohm ¼-watt speaker
Perfboard materials, enclosure, IC sockets, knobs, 12-volt power source, wire, solder, hardware, etc.

ONE-WAY VOICE-ACTIVATED INTERCOM

A schematic diagram for the one-way intercom circuit is shown in Fig. 1. An omnidirectional electret microphone is used to pick up the sound and convert it into an electrical signal. The output of the microphone is fed along two paths.

In the first path, the signal is sent to the inverting input of U1 (an LM741 op-amp). The output of the amplifier is fed to a voltage-doubler circuit, made up of D1, D2, C2, and C6. The doubler's positive DC output is used to drive Q1, whose output (taken at its collector) is used to drive Q2. When Q2 turns on, operating power is applied to U2 (an LM386 low-voltage audio power amplifier) at pin 6. In the second path, the microphone signal is fed to the non-inverting input of U2, where it is amplified and output to the speaker, SPKR1.

The gain of U1, and therefore the sensitivity of the circuit, is adjustable via potentiometer R9. Potentiometer R10 can be used to adjust the output-volume level of the circuit as desired. The circuit can be powered from just about any well-filtered, 12-volt DC power source, as long as it has a 100-mA (or more) current capacity.

All of the components, except for the microphone and speaker can be housed in a single enclosure. The electret microphone should be mounted at head level (either on or near the door) and connected to the rest of the circuit through shielded microphone cable. The speaker can be mounted in any convenient location and connected to the rest of the circuit via speaker wire.

AUDIO-FREQUENCY METER

Next up in our parade of circuits is an analog audio-frequency meter. This meter differs from the norm in that it does not use a D'Arsonval movement or digital display to give a reading of the input frequency. Instead, the measured frequency is read from a hand-calibrated dial.

A schematic diagram for the meter circuit is shown in Fig. 2. The circuit is actually made up of three simple sub-circuits. The first of those sub-circuits is centered around U1, an LM741 op-amp that's configured as a conventional inverting amplifier. With the values of R11 and R1 shown, the op-amp provides a gain of about 5.

The second of the sub-circuits is centered around U2, an LM567 tone decoder, which is operated as a phase-locked loop and whose oscillator frequency is variable via R13. The third and final sub-circuit is built around two transistors, Q1 and Q2 (a pair of 2N3904 general-purpose NPN silicon transistors), which, together with their support components, form a mixer/LED driver.

Any audio signal applied to the circuit is amplified by U1, and the resulting output is divided along two paths. In one path, the output signal is applied to the mixer; in the other path, the signal is applied to the input of U2 through S1 (a normally open pushbutton switch).

The portion of the amplifier signal that is fed to the mixer is applied to the base of Q1, causing it to toggle on and off at the signal frequency. In the other path, when S1 is pressed, a portion of the op-amp's output is applied to U2. If the signal is within the range of U2's internal oscillator's operating frequency, LED1 lights, and a signal is fed to the base of Q2. If the two signals arriving at the mixer do not match exactly, LED2 and LED3 light. That means that the circuit must be fine tuned. That's done by releasing S1 and fine tuning R13 until LED2 and LED3 go out. The dial setting at that point gives the frequency of the input signal to within 1 Hz (or as close as the calibrated dial will allow).

An accurate audio-frequency generator and frequency counter should be used to calibrate the meter, but a generator alone can be used. To calibrate the circuit using both a frequency generator and a counter, connect the counter to the junction of R6 and C5 and the generator to the input of the circuit. Adjust R13 to its minimum and maximum positions and note the frequency at each extreme on the dial. Those two extremes represent the minimum and maximum frequencies that the circuit can read. After establishing the upper and lower extremes, mark off the area between into as many divisions as practical. Determine the frequency at each dial division, or setting, in the same manner that the upper and lower frequency limits were set.

To calibrate the meter with an audio generator only, connect the generator to the circuit's input and set its output level to 1 volt. With S1 closed, adjust R13 to its maximum resistance and adjust the generator's frequency to light LED1. That corresponds to the low-frequency setting of the meter. Release S1 and slowly vary the generator's frequency until both LED2 and LED3 go dark. Mark the dial to match the generator's frequency. Continue throughout the frequency range, marking the dial as you go.

To use the meter, close switch S1 and rotate R13 until LED1 lights; then release S1 and fine tune R13 until both LED2 and LED3 go dark. Read the frequency off the calibrated dial.

The range of the circuit can be expanded by replacing C7 with a switchable bank of capacitors; using that scheme, the

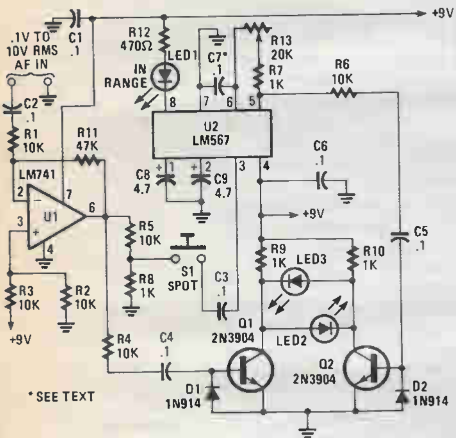

Fig. 2. The analog audio-frequency meter is actually made up of three simple sub-circuits: a conventional inverting amplifier, a phase-locked loop, and a mixer/LED driver.

PARTS LIST FOR THE AUDIO-FREQUENCY METER

SEMICONDUCTORS

U1—741 op-amp, integrated circuit
U2—LM567 tone-decoder, integrated circuit
Q1, Q2—2N3904 general-purpose NPN silicon transistor
D1, D2—1N914 general-purpose silicon diode
LED1–LED3—Light-emitting diode (any color or size)

RESISTORS

(All fixed resistors are ¼-watt, 5% units.)
R1–R6—10,000-ohm
R7–R10—1000-ohm
R11—47,000-ohm
R12—470-ohm
R13—20,000-ohm linear-taper potentiometer

CAPACITORS

C1–C7—0.1-µF, ceramic-disc
C8, C9—4.7-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

S1—Normally open pushbutton switch
Perfboard materials, enclosure, regulated 9-volt power source, IC sockets, wire, solder, hardware, etc.

circuit can be made to indicate frequencies between 10 Hz and 20 kHz. Of course, it will be necessary to provide a calibrated dial for each value of capacitor used in the switchable capacitor bank.

AUDIO POWER AMPLIFIER

Our last entry is a simple audio-power amplifier that can be added to an existing project or incorporated in a future one to increase the circuit's output power to more than a quarter watt. A schematic diagram of the audio-power amplifier is shown in Fig. 3.

The circuit, built around an LM741 op-amp that's configured as an inverting amplifier, is used to drive complementary transistors (Q1 and Q2). The op-amp's feedback loop includes the base-emitter junctions of both transistors—an arrangement that helps reduce crossover distortion that would normally occur due to the emitter-to-base junction voltage drop of about 0.6 volts. Potentiometer R5 varies the amplifier's voltage gain from 1 to about 20. As much as 0.5 watt can be obtained from the circuit if a heat sink is added to the transistors. Also, if your application requires, a beefier pair of complementary transistors may be used to obtain several watts of output power from this circuit. ■

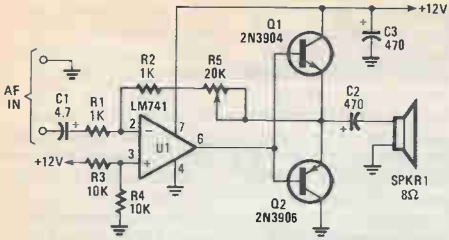

Fig. 3. This simple audio-power amplifier can be added to an existing project or incorporated in a future one.

PARTS LIST FOR THE AUDIO POWER AMPLIFIER

SEMICONDUCTORS
U1—741 op-amp, integrated circuit
Q1—2N3904 (or similar) general-purpose NPN silicon transistor
Q2—2N3906 (or similar) general-purpose PNP silicon transistor

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1, R2—1000-ohm
R3, R4—10,000-ohm
R5—20,000-ohm potentiometer

CAPACITORS
C1—4.7-µF, 16-WVDC, electrolytic
C2, C3—470-µF, 25-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS
SPKR1—8-ohm ¼-watt speaker
Perfboard materials, enclosure, IC socket, heat sink, 12-volt power source, wire, solder, hardware, etc.

CIRCUIT CIRCUS

(Continued from page 29)

powered sounder to be operated with the system.

The circuit's operation is simple. A 4049 hex inverting buffer is used to isolate each of the six input sensors. With S2 in its normally closed position, the input of U1-a at pin 3 is tied to the positive supply. The high input causes U1-a's output to go low. With a low output, LED1 remains dark, and no current passes through diode D1.

Opening S2 pulls the input of U1-a low through R14, forcing its output to go high, causing LED1 to light, while feeding a bias voltage to the base of Q1 (a 2N2222 NPN unit) through D1 and S8. The positive base bias causes Q1 to turn on, supplying gate current to SCR1 through R20 (a ½-watt unit). That causes SCR1 to turn on, activating the sounder, BZ1. Each of the remaining sensors/ buffers stages operate in a like manner. The transistor is connected in an emitter-follower configuration to isolate the buffer outputs and increase the SCR's gate current to ensure that it turns on.

The circuit is modified to provide series loop protection by substituting a string of sensors (say, three or four) switches for each normally closed switch used in the individual loop. You can also use the circuit as a status monitor only by eliminating the diodes (D1–D6) and all of the circuitry that follows. In addition, a piezo buzzer can be connected from the diode side of S8 to ground if an audible output is desired in the monitor-only position. If additional individual inputs are needed, it's easy to add another 4049 hex inverter to the circuit. ■

CIRCUIT CIRCUS

(Continued from page 24)

AC supply—that's handy to have on the workbench. All you need is a variable 117-volt AC transformer, a power cord, fuse, switch, and an output receptacle. Wire the components together as shown in Fig. 5.

A variable AC-power source is a valuable tool to have when checking electronics gear that's been idle for years or when smoke testing a new project. It's usually a good idea to slowly bring up the AC line voltage to such equipment before attempting to use it. Try the surplus stores, flea markets, and hamfests first when trying to locate a variable transformer—a good used unit is cheaper than a new one. ■

"This is really exciting! I heard you guys on my scanner!"