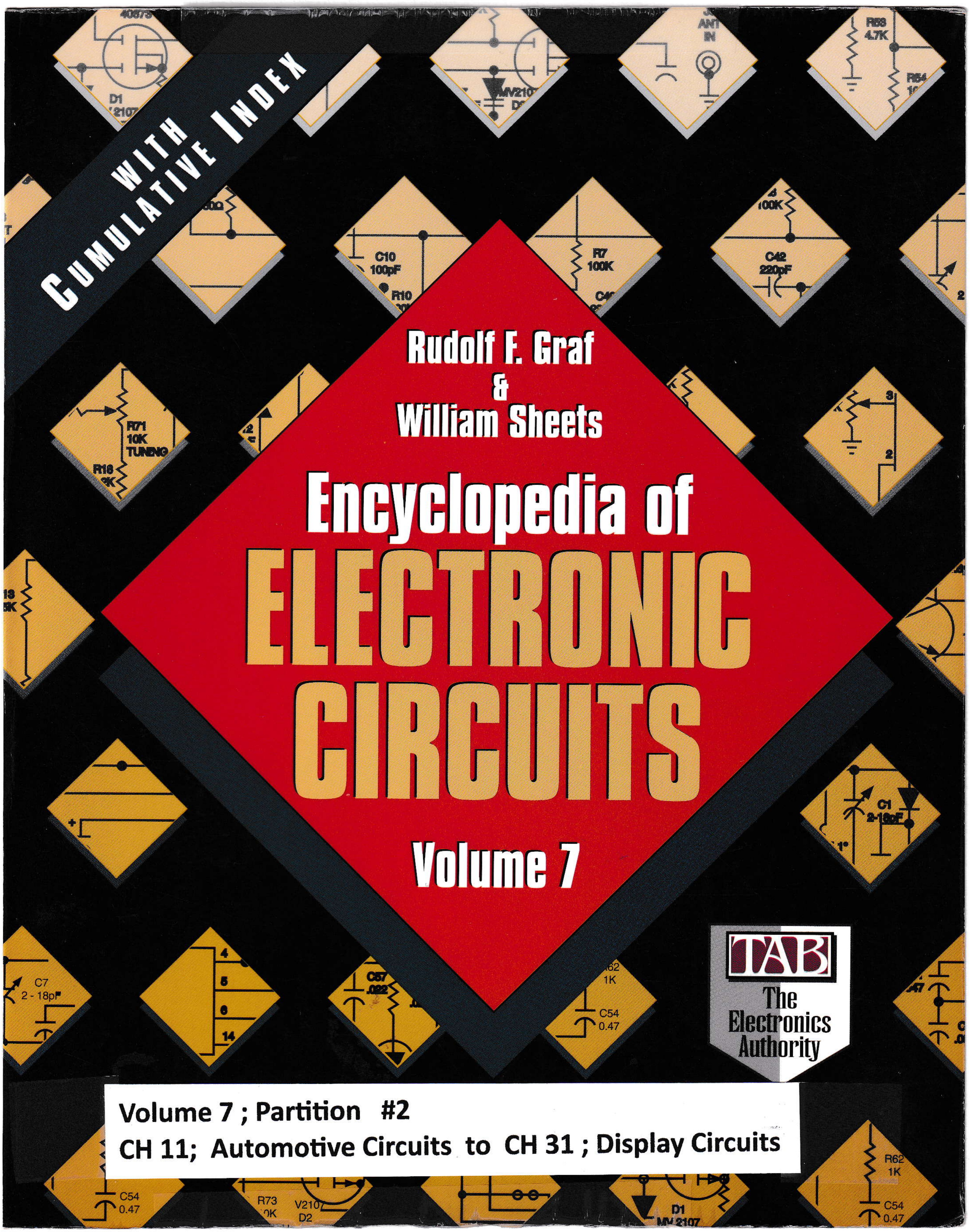

WITH CUMULATIVE INDEX

Rudolf F. Graf
&
William Sheets

Encyclopedia of ELECTRONIC CIRCUITS

Volume 7

TAB
The Electronics Authority

Volume 7 ; Partition #2
CH 11; Automotive Circuits to CH 31 ; Display Circuits

To Scott
With much love from Popsi

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Encyclopedia of

ELECTRONIC CIRCUITS

Volume 7

Rudolf F. Graf
and
William Sheets

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Contents

Preface

This latest volume of *The Encyclopedia of Electronic Circuits* contains approximately 1000 new electronic circuits that are arranged alphabetically into more than 100 basic circuit categories, ranging from "Active Antenna Circuits" to "Weather-Related Circuits." When taken together with the contents of the previously published six volumes, we provide instant access to more than 7000 circuits that are meticulously indexed and cross referenced. This represents, by far, the largest treasure trove of easy-to-find, practical electronic circuits available anywhere.

We wish to express our sincere gratitude and appreciation to the industry sources and publishers who graciously allowed us to use some of their material. Their names are shown with each entry and further details are given at the end of the book under "Sources."

Our thanks also go out to Ms. Tara Troxler, whose skill at the word processor and dedication to this project made it possible for us to deliver the manuscript to the publisher in a timely fashion.

Rudolf F. Graf and William Sheets
January 1998

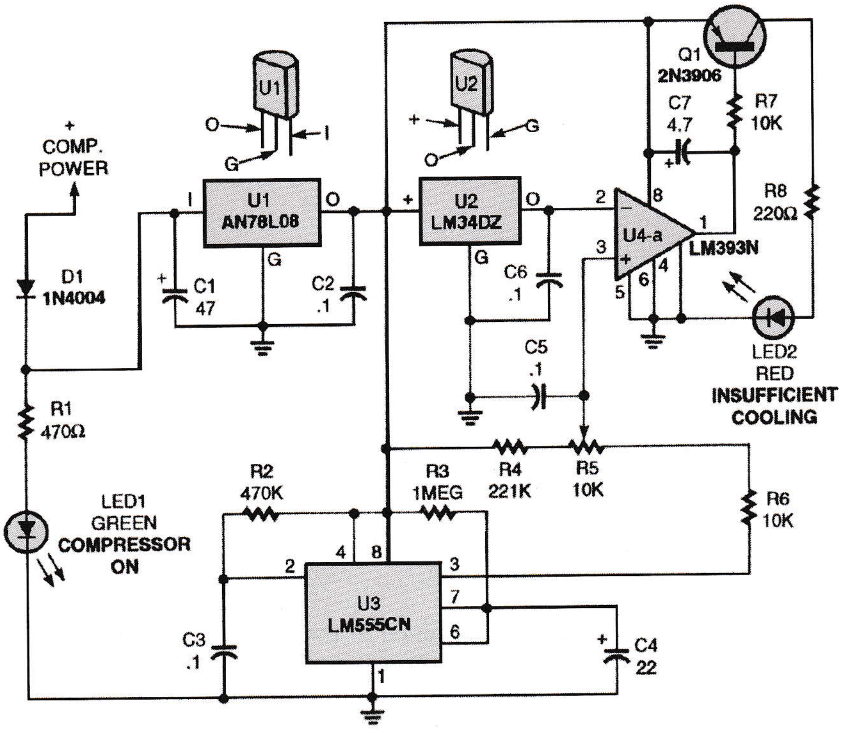
11

Automotive Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Air Conditioner Monitor
Oil-Pressure-Actuated Running Lights
Electrical System Analyzer
Battery Cranking Tester
Car Presence Detector
Automatic Headlight Dimmer
Car Battery Voltmeter with Bar Graph Display
Auto Stethoscope
Daytime Running Light Circuit
Radio Automatic Level Control
Automotive Neon Driver
Intermittent Windshield Circuit
Capacitor-Discharge Ignition Circuit
Visual and Audible Headlight Monitor
Lights-On Indicator
Windshield Wiper Circuit
Headlight Monitor
SW Converter
Automatic Vehicle Door Unlock Circuit

AIR CONDITIONER MONITOR



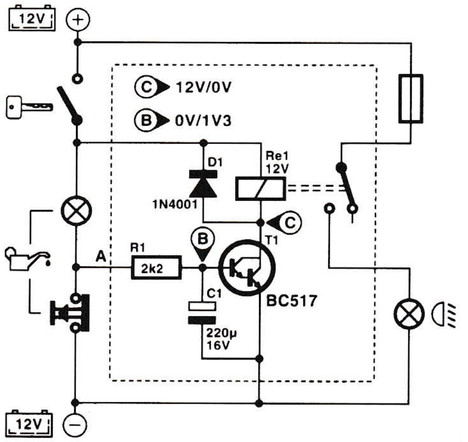
POPULAR ELECTRONICS *Fig. 11-1*

Power for the air conditioner monitor is derived from the +12-V power lead that feeds the magnetic clutch of the air conditioning compressor. Thus, the circuit is active only when cooling is demanded of the A/C system. The heart of the circuit is U2, a factory-calibrated three-terminal temperature-sensing IC that is designed to deliver an output voltage of 10 mV per degree Fahrenheit. The sensor, which is driven by the regulated 8-V supply, is physically attached to the A/C evaporator-coil return pipe so that it accurately senses the operating temperature. Its temperature-dependent output voltage, which is proportional to the sensed temperature, is fed to negative input terminal U4-a (half of an LM393N voltage comparator) at pin 2. The output of U4-a can thus be used to determine the operating temperature of the evaporator return pipe. The positive input of the comparator allows the trigger voltage level of U4-a to be set slightly higher than the normal operating temperature of the A/C evaporator return pipe, or about 0.4 to 0.5 V, representing 40 to 50°F.

In order to avoid a false alarm caused by the warm evaporator return pipe each time the cycling A/C compressor starts, a time delay is provided by U3, a 555 oscillator/timer connected as a one-shot or monostable multivibrator that has an output pulse width of about 25 s as determined by R3 and C4. When compressor power is applied to the monitor, U3 is automatically triggered. Once triggered, U3 generates a positive output voltage at pin 3. That causes the open-collector output transistor within U4-a to be cut off. No base current flows to Q1, and LED 2 will not light. At the end of the timed cycle of U3, U4-a is ready to monitor the evaporator temperature.

Should the temperature be above the limit set by R5, the output of U4-a is pulled low, illuminating the warning LED (LED2). As mentioned earlier, a warm evaporator return pipe is a symptom of loss of refrigerant or other problems with the air-conditioning system. Another light-emitting diode, LED1, has been included in the circuit as a visual indication as to the operation of the air conditioner compressor. Should the refrigerant charge be extremely low, the compressor will cycle rapidly, alerting the driver to an almost total loss of refrigerant.

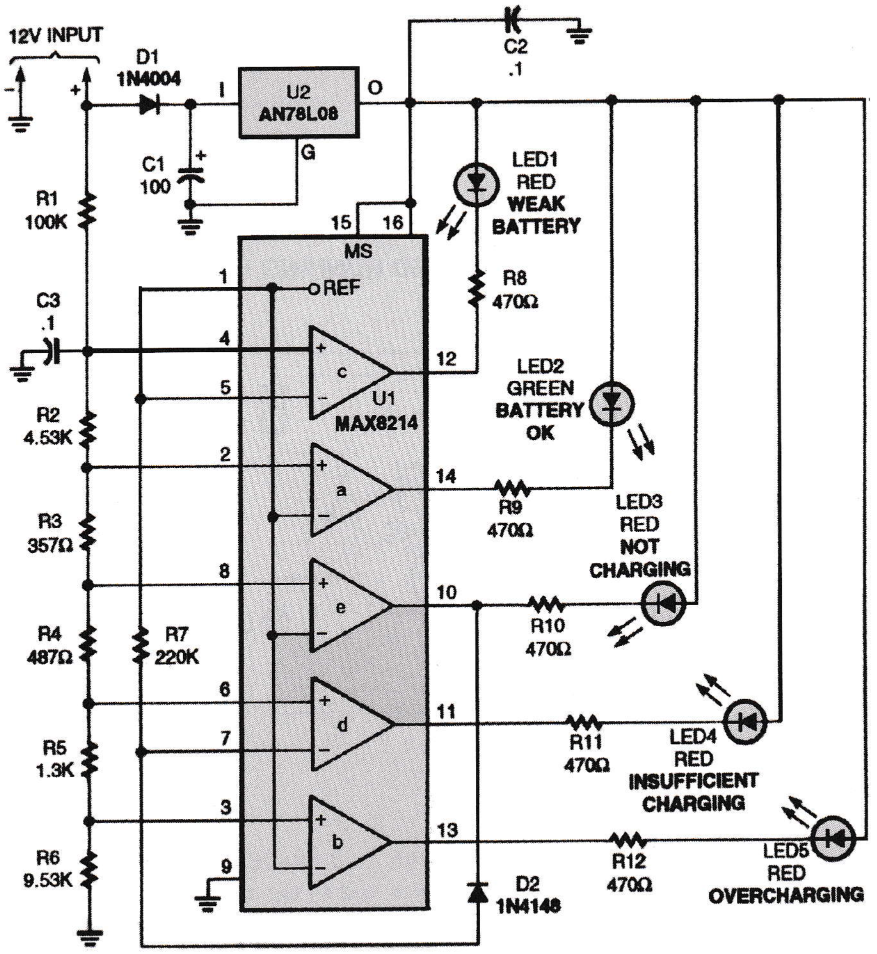
OIL-PRESSURE-ACTUATED RUNNING LIGHTS



ELEKTOR ELECTRONICS *Fig. 11-2*

Motorcycles and cars that are not equipped with (automatic) day running lights can be so equipped with the present circuit. The circuit is connected to the oil-pressure indicator. When the engine is not running, the contacts of the oil-pressure sensor in the engine block are closed. When the ignition is then switched on, the oil-pressure light comes on. The potential at *A* is then low, and nothing happens. When the engine is running, oil-pressure builds up, whereupon the contacts open and the indicator light goes out. The potential at *A* is then high so that T1 comes on and the relay becomes energized. The relay contact in series with the headlights closes so that the headlight is switched on. When the engine is switched off, the relay is deenergized and the headlights go out.

ELECTRICAL SYSTEM ANALYZER



POPULAR ELECTRONICS

Fig. 11-3

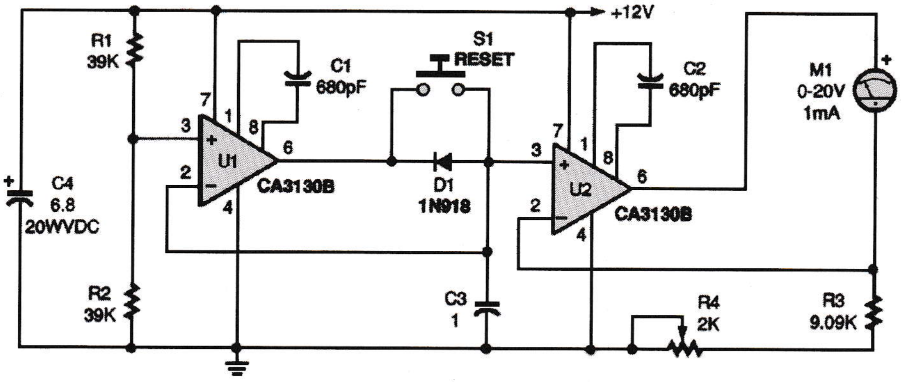
ELECTRICAL SYSTEM ANALYZER *(Cont.)*

AUTOMOTIVE ELECTRICAL FAULTS

Condition	Normal Voltage	Possible Fault
Vehicle at rest	12.6 volts	<12.4 volts: bad cell or severly undercharged battery
Cranking	>9 volts	<9 volts: weak battery
Idling	>12.8 volts	<12.8 volts: not charging; bad alternator or wiring
Running minimum load	>13.4 volts	<13.4 volts: defective alternator or voltage regulator
Running minimum load	<15.2 volts	>15.2 volts: overcharging; defective regulator
Running maximum load	>13.4 volts	<13.4 volts: alternator defective or belt slipping

The automotive electrical diagnostic system is built around a Maxim MAX8214ACPE five-stage voltage comparator, which contains a built-in 1.25-V precision reference and on-board logic that allows the outputs of two of the comparators to be inverted.

BATTERY CRANKING TESTER

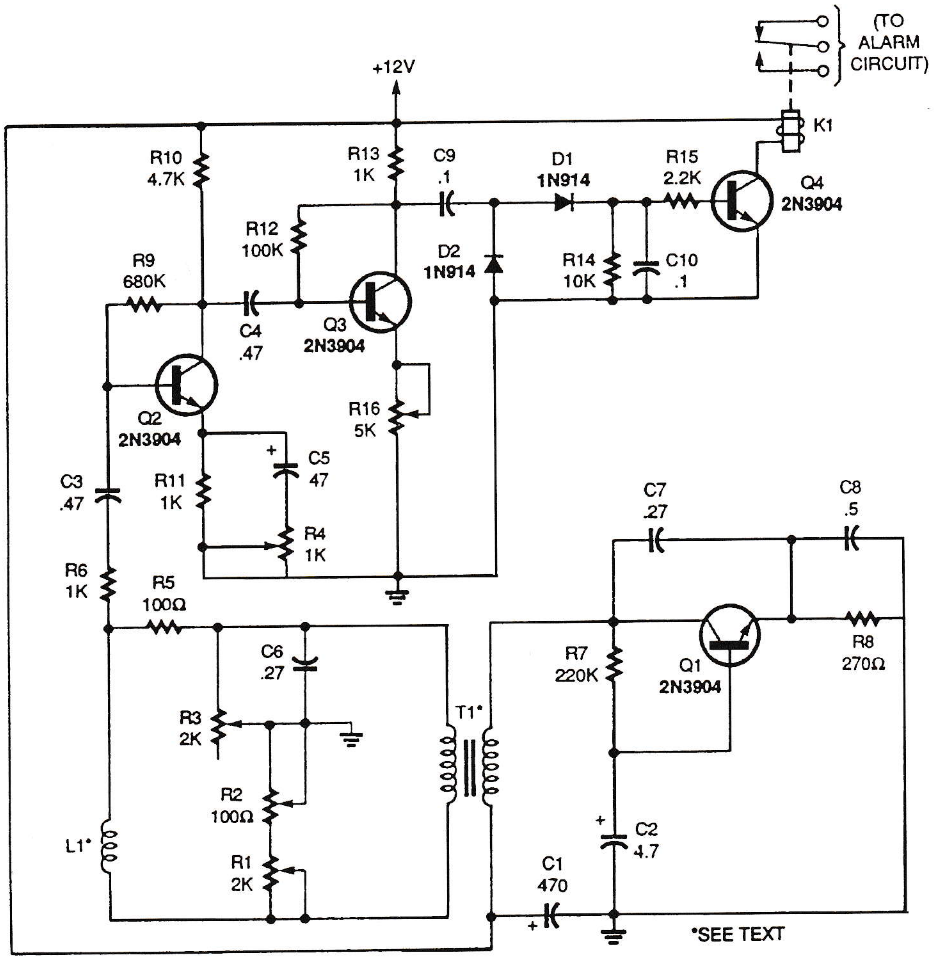


POPULAR ELECTRONICS

Fig. 11-4

Need to discover if your battery is weak or if your starter's windings are shorted? This meter will display how low your battery voltage drops during a start. The circuit is a negative-peak reading voltmeter.

CAR PRESENCE DETECTOR



POPULAR ELECTRONICS

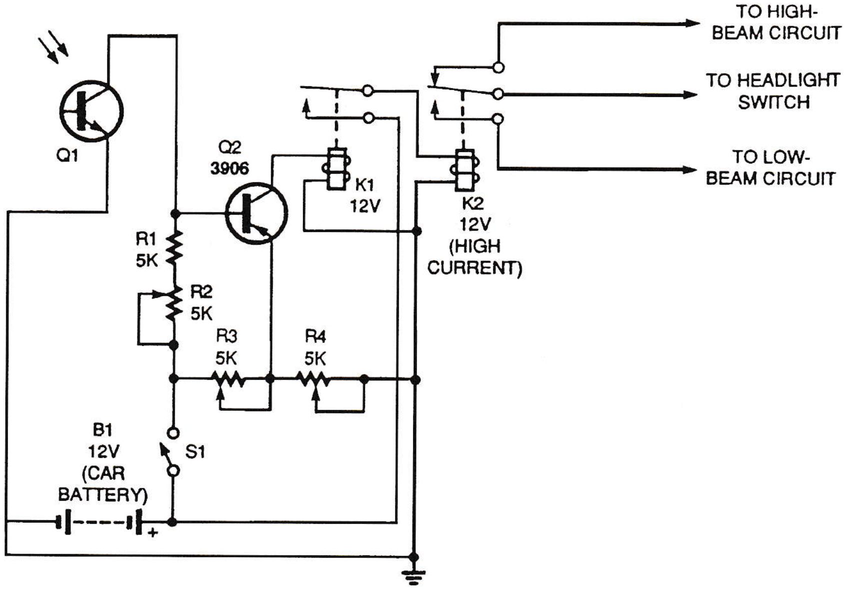
Fig. 11-5

Here's a circuit that will, if calibrated carefully, detect the presence of a large metal object. Coil L1 is made by winding 50 turns of 26-gauge wire on a 50-inch form. If L1 is buried in the ground, the circuit can be used to detect any car or truck that is driven over the coil. Transistor Q1 and its surrounding components make up a Colpitts oscillator, operating at 10 kHz. The output is coupled to a Maxwell bridge through the secondary of T1, which is a 600-Ω-to-600-Ω audio coupling transformer. With R1, R2, and R3 set properly, the bridge is balanced when no metal is close to L1, producing a near-zero ac signal at the bridge's output (the R5/L1 junction and ground). Should a large enough ferromagnetic object pass over L1, the bridge becomes unbalanced, producing a signal at the junction of R5 and L1. That signal is fed to the base of Q2, part of a common-emitter amplifier stage.

CAR PRESENCE DETECTOR *(Cont.)*

Resistor R4 adjusts to the gain of that stage. The signal from the amplifier is fed to the base of Q3, which drives a voltage doubler that supplies current to the relay driver, Q4. The relay, K1, is a 1000-Ω, sensitive, 12-V unit that can drive a normally open or closed alarm circuit to indicate the presence of a vehicle. Use shielded cable to attach L1 to the circuit, and do not bury L1 deeper than 8 inches for best results. Remember to weatherproof all components that will reside outside.

AUTOMATIC HEADLIGHT DIMMER

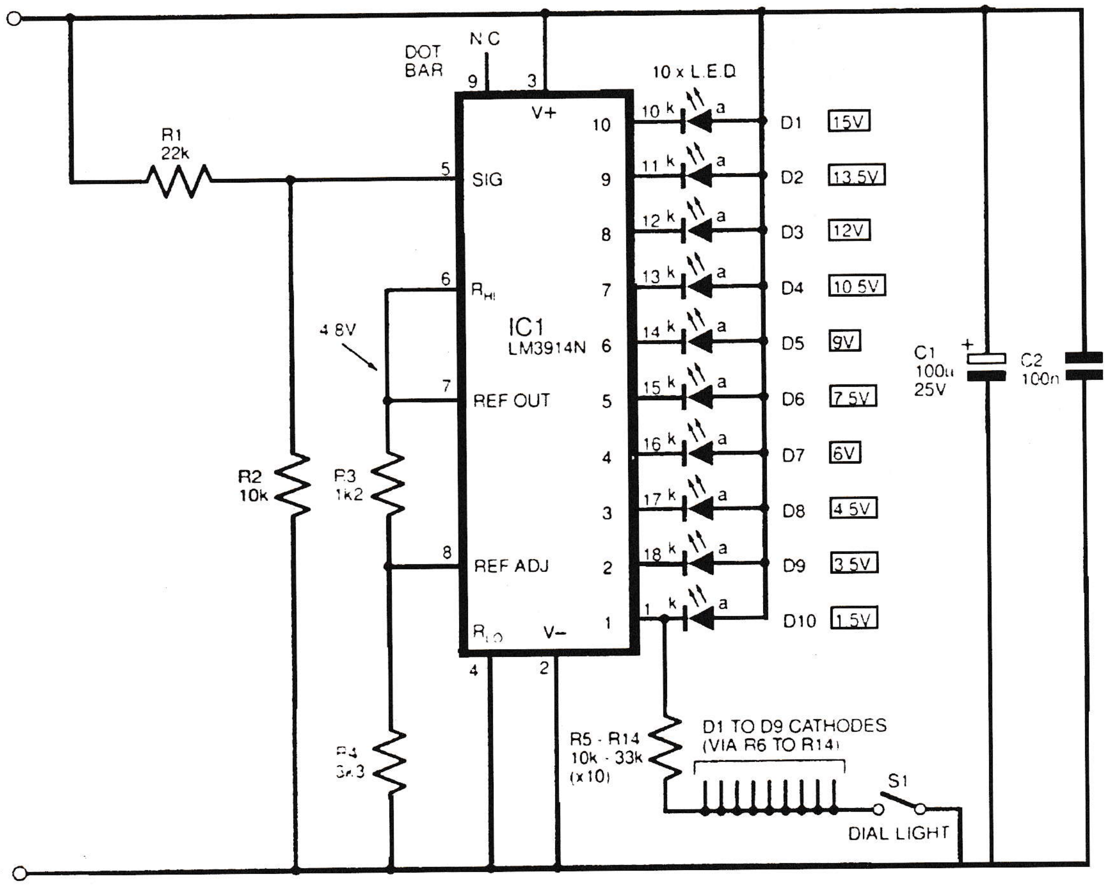


POPULAR ELECTRONICS

Fig. 11-6

The circuit is designed to switch your car's lights from its high beams to its low beams when traffic approaches. With Q1 in moderate darkness, the variable resistors should be adjusted to produce no base current through Q2. When there are no approaching headlights to trigger the system, K1 is not energized, and its contacts remain closed. Relay K2 is energized, and the high-beam lights are on. When light from an approaching car shines on the phototransistor, the base current and collector current of the PNP transistor increase substantially, and K1 is energized. That automatically deenergizes K2 (a power-type relay fed directly by the car battery), shutting off the high-beam headlights and turning on the low-beam lamps. Switch S1 should be conveniently located on the dash of the vehicle. Keep the switch turned off during the day so that the circuit will not leave your lights on in sunlight.

CAR BATTERY VOLTMETER WITH BAR GRAPH DISPLAY



EVERYDAY PRACTICAL ELECTRONICS

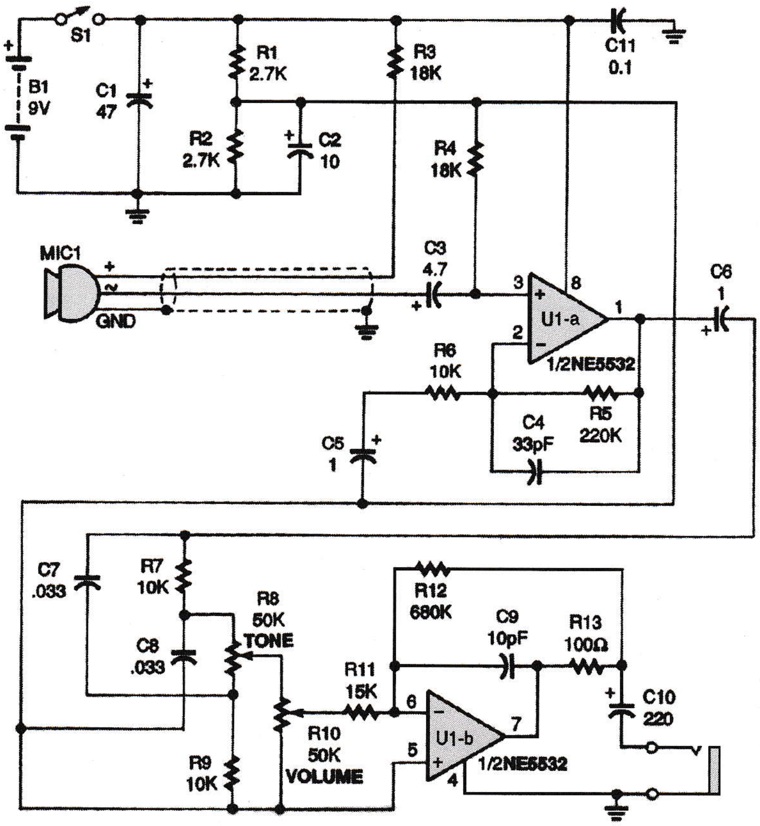
Fig. 11-7

This uses an LM3914 bar-graph display, IC1, adapted to measure its own supply, so you simply wire it directly across the 12-V supply voltage (right way round—watch pins 2 and 3 carefully!). Ten LEDs, D1 to D10, will indicate the applied battery voltage, ranging from 1.5 to 15 V. The IC contains 10 internal comparators connected totem-pole-like, each sinking current through an LED. They compare an internal reference voltage against the chip's input voltage, at pin 5. Set the IC reference voltage with resistors R3 and R4 to just under 5 V. This means that one LED will light for every 500 mV (5 V reference/10 stages) increase in the signal. To enable this to be used to read a 12-V battery (the chip's own supply rail, in this case), resistors R1 and R2 are included as a divider: An input of roughly +15 V will cause D1 to light. When the voltage gradually falls, LEDs D2 to D10 will progressively illuminate. The circuit is set as a "moving dot" display. Connect pin 9 to the positive rail for a bar-graph display (not recommended because of the current consumption). Because the 10

CAR BATTERY VOLTMETER WITH BAR GRAPH DISPLAY *(Cont.)*

outputs are effectively constant-current sinks, the LEDs will glow at a level independent of the changes in the supply rail; they won't dim when the rail drops. However, the first two or three display LEDs (D8 to D10) are superfluous in this application, because the LM3914 won't operate correctly below a rail of about +5 V.

AUTO STETHOSCOPE



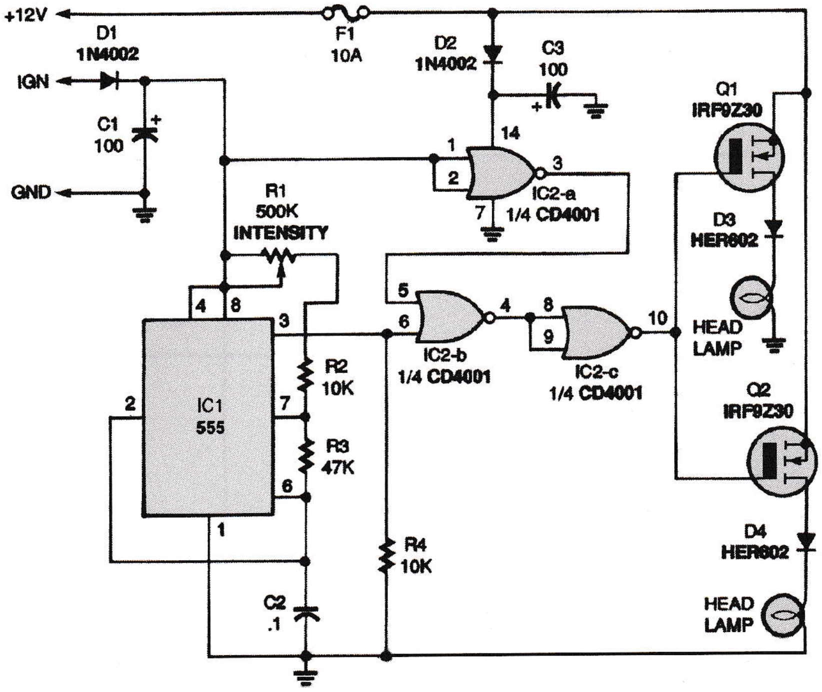
ELECTRONIC HOBBYIST HANDBOOK

Fig. 11-8

The heart of the stethoscope is the NE5532 audio op amp, U1. That component directly drives low impedances and allows the use of headphones without adding another amplifier.

This circuit uses an electret microphone and an audio amplifier using a NE5532 audio op amp as an automotive diagnostic tool. The mike is mounted in a probe or piece of tubing and placed near or on various parts of the engine or other components as an aid in diagnosis; the sound generated by the suspected part is used to determine possible problems.

DAYTIME RUNNING LIGHT CIRCUIT



POPULAR ELECTRONICS

Fig. 11-9

The DRL circuit is a variable-duty-cycle power oscillator that allows pulses of current to be applied to the headlights whenever the ignition of the vehicle is turned on. The 12-Vdc power that drives the circuit is taken from two sources in the vehicle. Power for the headlights is provided by the vehicular battery and generator system, and is input through fuse F1 to the circuit. The power source for the digital or logic part of the circuit is the +12-V line that feeds the ignition system of the vehicle. When the ignition is turned on, the circuit is on, and when the ignition is turned off, so is the circuit. When the ignition is on, power is applied through D1 to operate IC1, a 555 timer that is connected as a free-running multivibrator. Pin 3 of IC1 provides the output of the oscillator; the duty cycle is determined by the following ratio:

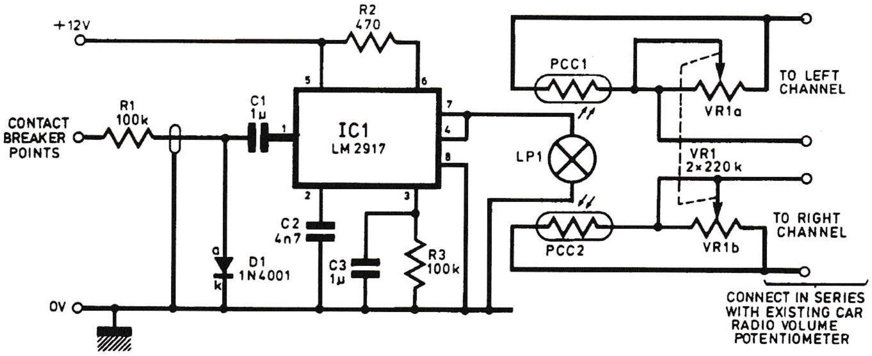
$$(R_1 + R_2) / R_3$$

Potentiometer R1 allows the duty cycle of the negative part of the waveform to be adjusted from about 10 percent to almost 50 percent. Adjustment capability is provided so that the intensity of illumination can be set as desired. A set of logic gates (IC2), powered by the battery and generator, is used to control the operation of the circuit. When the ignition is off, the logic output of pin 3 of IC2-a is high. Under that high-logic condition, the transistors are not forward-biased and the headlights remain off. When the ignition is on, the oscillator is powered through D1. The pulse train output of IC1 appears simultaneously at the gates of Q1 and Q2. Those two transistors then feed +12-V pulses

DAYTIME RUNNING LIGHT CIRCUIT *(Cont.)*

through their respective diodes, D3 and D4, to the low-beam headlights of the vehicle. The diodes provide isolation between the DRL circuit and the electrical system of the vehicle. The design of the circuit makes it possible to add second pairs of hex-FET transistors and corresponding diodes to the circuit and have them driven by IC2-c. Thus, if desired, the taillights of the vehicle may also be used for DRL operation.

RADIO AUTOMATIC LEVEL CONTROL

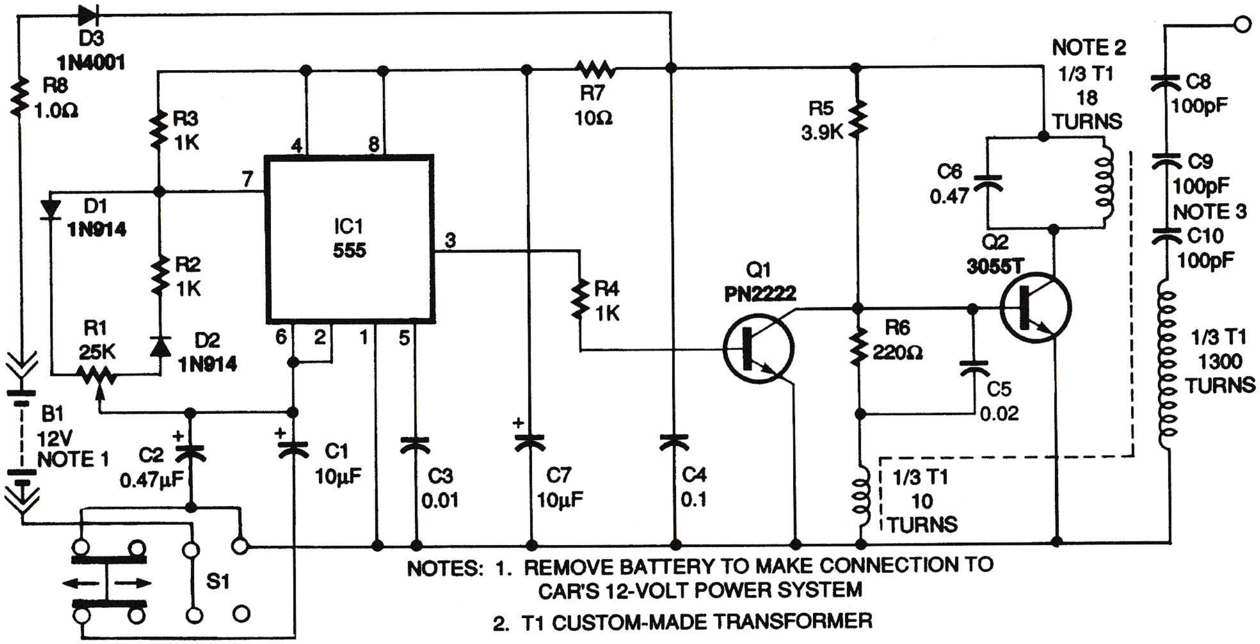


EVERYDAY PRACTICAL ELECTRONICS

Fig. 11-10

This experimental circuit automatically increases the volume of a car radio when the vehicle's speed (and consequently road and wind noise) rises, and returns the volume to a pleasant level at lower speeds. This relieves the driver of the distracting chore of continually fiddling with the radio's volume control. In the figure, a special tachometer IC type LM2917 takes its input from the ignition system's contact breaker points and converts this into a voltage that is directly proportional to engine speed. This voltage will always be in the range of 0 to 5 V and is used to illuminate a miniature filament lamp LP1. On either side of this lamp is mounted a pair of light-dependent resistors (LDRs) that are connected in series with the wipers of the radio's volume control potentiometers. A ganged potentiometer across each of the LDRs sets the minimum volume level, the radio's own volume being used for the high level. The value of capacitor C2 determines the range over which the unit will function satisfactorily. A suggested value of 4n7 would be a suitable starting point for further experimentation. The 100-kΩ input resistor (R1) should be placed as near as possible to the ignition coil to prevent RFI (radio frequency interference) and to ensure that the contact breakers are not shorted out should the wire short to earth (chassis) for any reason.

AUTOMOTIVE NEON DRIVER



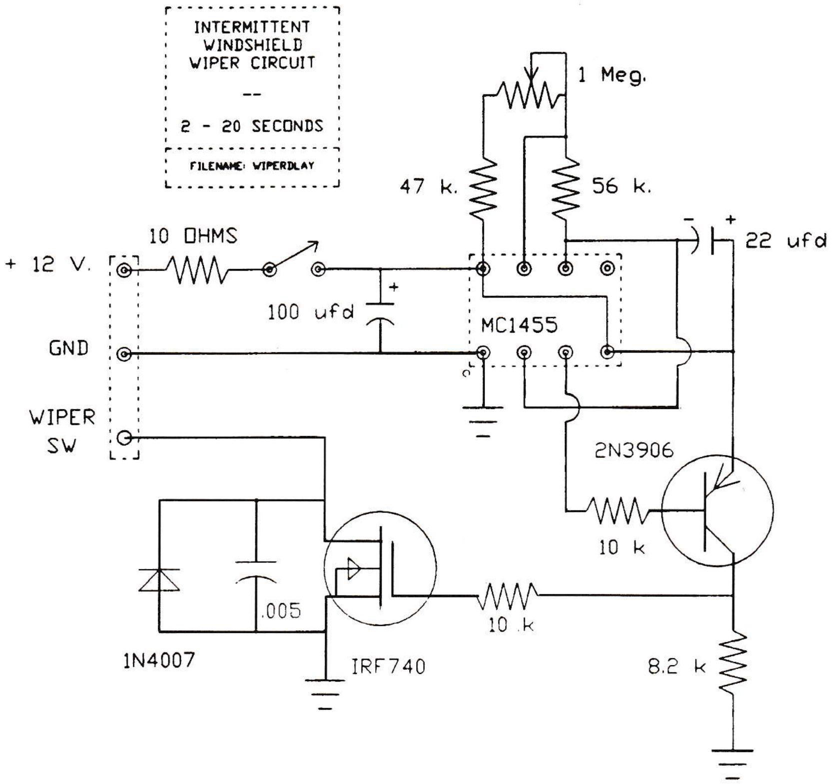
NOTES: 1. REMOVE BATTERY TO MAKE CONNECTION TO CAR'S 12-VOLT POWER SYSTEM
2. T1 CUSTOM-MADE TRANSFORMER
3. CAPACITORS C9 AND C10 FOR NON-AUTO APPLICATIONS

ELECTRONICS NOW

Fig. 11-11

A 555 timer drives driver transistor Q1 and switching transistor Q2 at 25 to 30 kHz. T1 is wound on a ferrite core (try using a core from an old B/W TV flyback) and has the windings arranged as shown in the schematic. About 2500 Vac p-p is produced, so be careful to avoid any possibility of contact with this voltage, as it can cause a bad shock or RF burn. The neon tube is a custom-size item that can be made up at any neon sign shop or possibly purchased commercially. It is not legal to illuminate certain parts of your vehicle in some parts of the United States and in some nations.

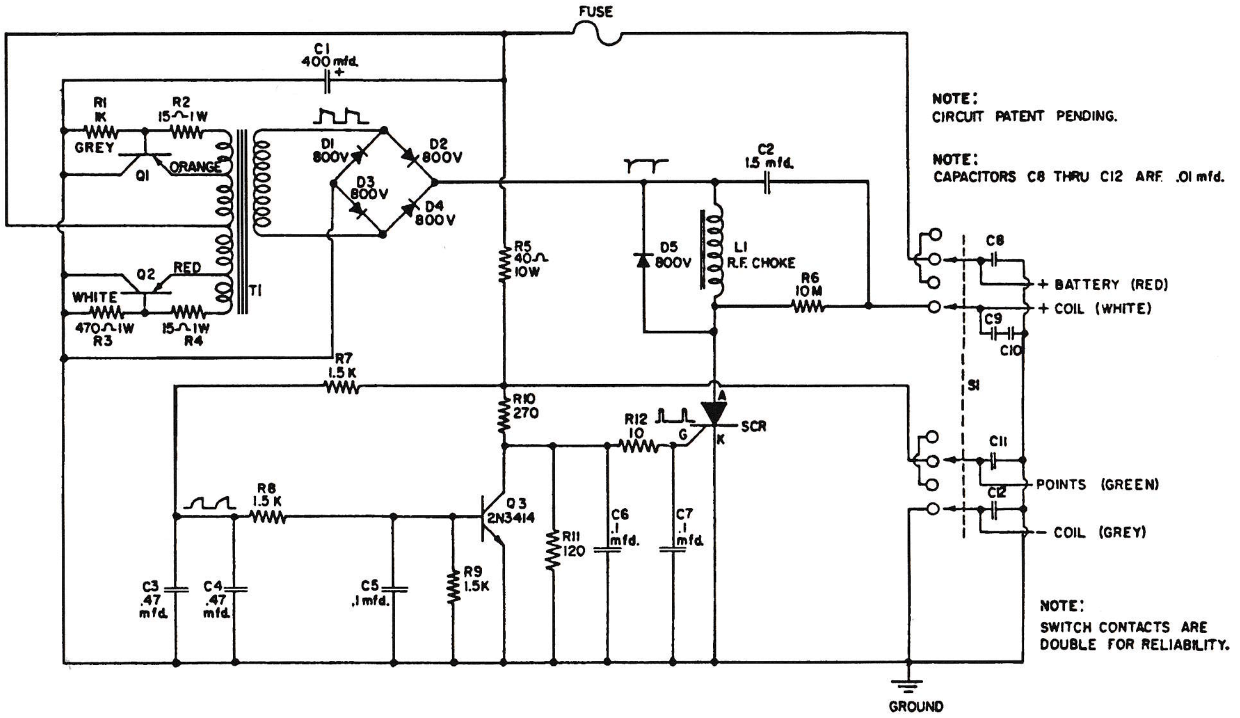
INTERMITTENT WINDSHIELD CIRCUIT



NUTS AND VOLTS MAGAZINE ***Fig. 11-12***

Basic timing is accomplished by the 555 IC. The resistor and capacitor network on pins 6, 7, and 8 sets the minimum delay at 2 s and the maximum at 20 s. The 555 output on pin 3 drives a 2N3906 PNP transistor to provide the proper input to the IRF740 power MOSFET. The MOSFET does the work and switches the wiper motor on at the end of the delay time. The wiper circuit uses a cam and switch arrangement on the drive assembly to cause the wiper blades to "park" in the proper place when the wipers are turned off. This cam switch is open when the blades are parked; the dash-mounted wiper switch is in parallel with the cam switch. The intermittent circuit is wired to the cam switch as shown. When activated, and with the dash switch in the OFF position, the power MOSFET puts a ground on one side of the wiper motor, and the motor starts running. Shortly afterwards, the cam switch closes and forces the motor to continue running (regardless of the MOSFET's on/off status) until the PARK position is reached and the cam switch opens. The motor then stops, and one cycle is complete.

CAPACITOR-DISCHARGE IGNITION CIRCUIT

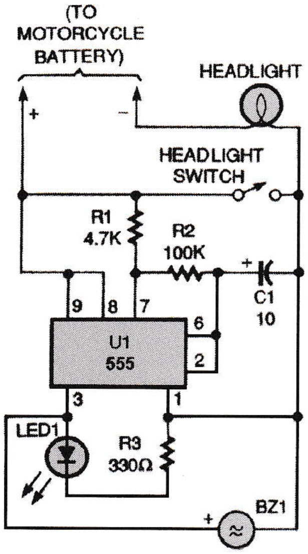


NUTS AND VOLTS MAGAZINE

Fig. 11-13

This ignition circuit consists of a dc-to-dc converter delivering 250 to 300 V to a 1.5-mF capacitor, and discharging it through the ignition coil primary upon the opening of the distributor points. SCR is triggered by the opening of the distributor points via inverter and pulse shaper Q3 and associated components. This circuit is typical of CD ignition systems. T1 is a special transformer for this circuit, but any suitable dc-to-dc converter transformer and circuit that delivers 250 Vdc (or more) can be used.

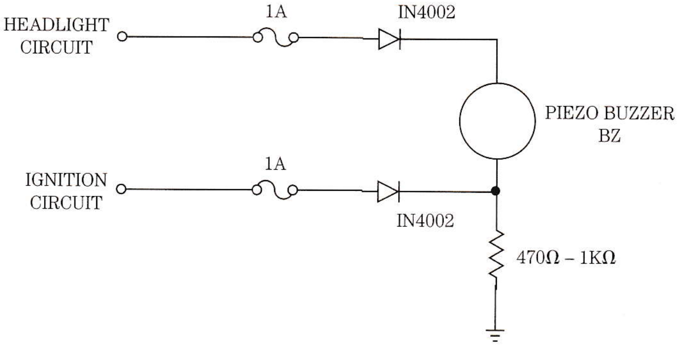
VISUAL AND AUDIBLE HEADLIGHT MONITOR



POPULAR ELECTRONICS *Fig. 11-14*

If the LED in this circuit is flashing and the piezo sounder is buzzing, then your headlights are not on.

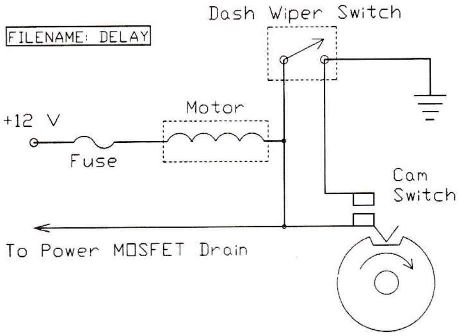
LIGHTS-ON INDICATOR



WILLIAM SHEETS *Fig. 11-15*

The buzzer (BZ) will sound if the ignition is off and the headlights are on.

WINDSHIELD WIPER CIRCUIT

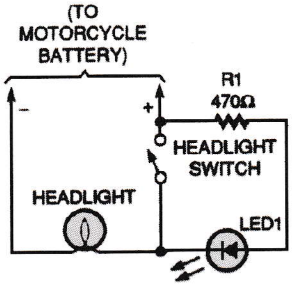


NUTS AND VOLTS MAGAZINE

Fig. 11-16

When the wipers are turned on, the switch in parallel with the cam-operated points keeps the motor running. When the switch is turned off, the motor keeps running until the cam opens the points, stopping the motor when the wipers are in the PARK position.

HEADLIGHT MONITOR

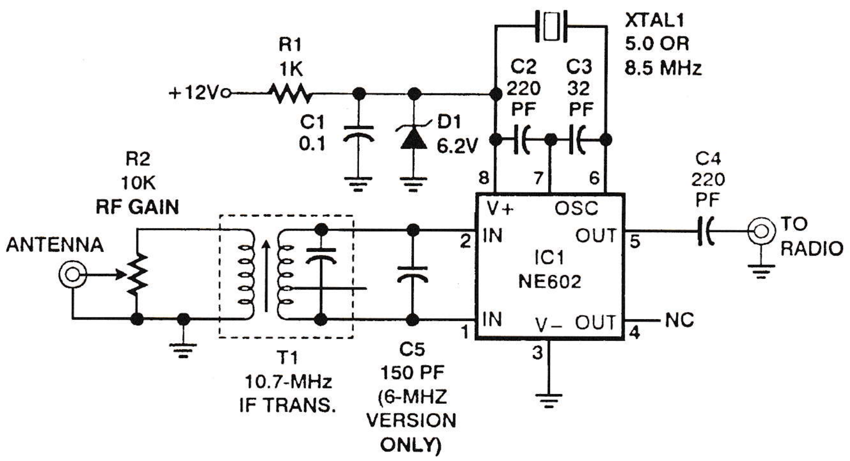


With this simple circuit, you'll never again forget to turn your headlights on.

POPULAR ELECTRONICS

Fig. 11-17

SW CONVERTER

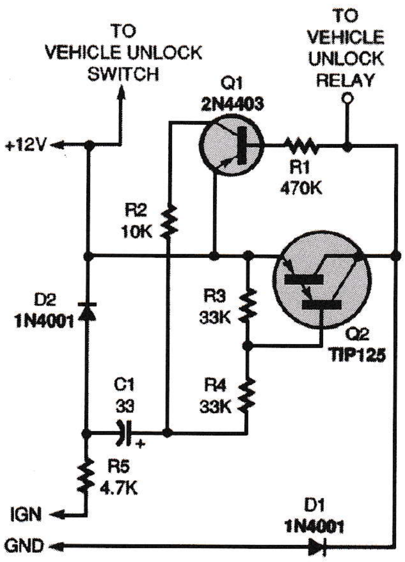


ELECTRONICS NOW

Fig. 11-18

This simple circuit, built around a NE602, allows you to receive either the 6- or 9.5-MHz shortwave band on your car radio.

AUTOMATIC VEHICLE DOOR UNLOCK CIRCUIT



POPULAR ELECTRONICS

Fig. 11-19

When the ignition switch is on, the +12V and IGN lines connected to the circuit are within half a volt or so of each other. Resistor R3 reverse-biases Darlington Q2 and keeps it cut off. Transistor Q1 is in parallel with Q2's emitter and collector; Q1 is ON as a result of the large voltage drop across Q2's emitter and collector. When the ignition switch is turned off, voltage is removed from the IGN line, effectively placing R5 at ground level. Capacitor C1 provides a path for current to flow through R3 to R5 and the vehicle components to ground. That flow will forward-bias Q2, driving it into saturation and lowering its emitter/collector voltage to less than 0.5 V. As a result, almost full battery voltage is applied to the vehicle unlock relay; transistor Q1 is cut off at the same time. The voltage divider of R3 and R4 prevents false triggering during voltage sags on the IGN line.

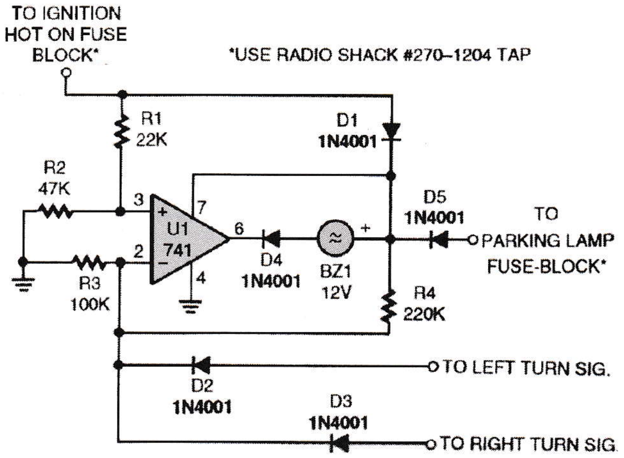
12

Automotive Security Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Auto Signal Minder
Auto Guardian Transmitter
Starter Cutoff
Auto Guardian Receiver
Auto Security Device

AUTO SIGNAL MINDER

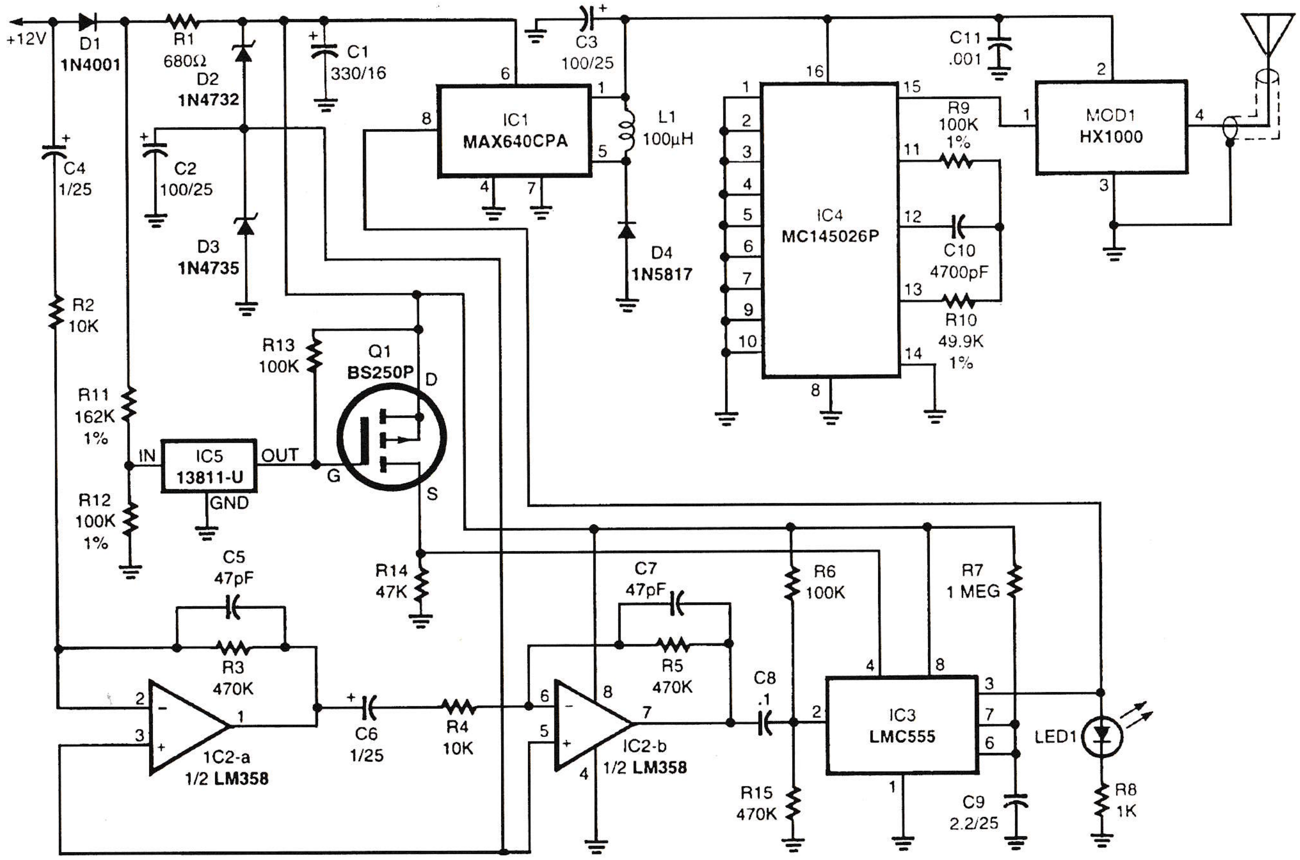


POPULAR ELECTRONICS

Fig. 12-1

If the ignition is on and the parking lights are on or off, the noninverting input of U1 is at 8 V and the inverting input is either 0 or 4 V. That causes pin 6 to go high, keeping the buzzer off. If the ignition is off and the parking lights are on, the noninverting input is at 0 V and the inverting input is at 4 V. That brings pin 6 low, activating the buzzer. With the ignition and turn signal on and the parking lights on or off, the noninverting input is at 8 V and the inverting input pulses at 12 V, causing the buzzer to sound in step with the blinker.

AUTO GUARDIAN TRANSMITTER



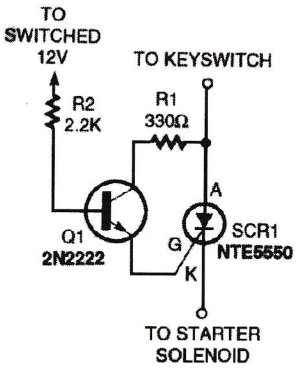
ELECTRONICS NOW

Fig. 12-2

The circuit is powered by the vehicle's 12-V battery. A pair of zener diodes, D2 and D3, create two regulated voltage sources of 10.9 and 6.2 V. Integrated circuit IC2 contains a pair of identical op amps, which are cascaded. The negative input of IC2-a is ac-coupled to the 12-V bus so that it can detect a sudden sag in voltage caused by the current draw of the vehicle's dome lamps when a door is opened. A change in battery voltage of 3 mV will cause a −6-V swing at the output of IC2-b, which is great enough to trigger IC3, a CMOS 555 timer chip. That IC is wired to operate as a one-shot pulse generator. An output pulse about 2[fr1/2] s long appears on pin 3 of IC3 when triggered by IC2-b. The output of IC3 is connected to the enable input of IC1, a switching-type voltage regulator. When IC1 is enabled, it outputs a regulated 3.3-Vdc power source for the transmitter portion of the circuit, encoder IC4 and transmitter module MOD1. When power is applied to the encoder, a series of pulse trains is generated that contain the address of the encoder. Those pulse trains are applied to pin 1 of the hybrid module to produce an RF signal with an on-off pulse modulation, sometimes called *amplitude-shift keying.* When the $2\frac{1}{2}$-s pulse time of IC3 is completed, the transmitter shuts down, returning to its dormant state.

In order to prevent RF transmission while the vehicle is running, voltage detector IC5 uses R11 and R12 as a voltage divider to sense when the supply voltage rises above 12 V as a result of an alternator charging when the engine is running. Under that condition, the output of IC5 is open, turning off Q1. That holds the reset input of IC3 low, preventing the timer chip from responding to any trigger pulses from the amplifier. As a result, no transmission takes place. The HX1000 hybrid-transmitter module, MOD1, is a four-terminal device that contains a surface-acoustic-wave-stabilized UHF oscillator. The oscillation frequency, 433.92 MHz, is stabilized and controlled by the resonant frequency of the internal surface-acoustic-wave filters, which also filter undesirable harmonics. The hybrid module is capable of delivering about 1 mW of power (0 dBm) into a 50-Ω load. It is connected to the transmitting antenna through a 50-Ω coaxial cable.

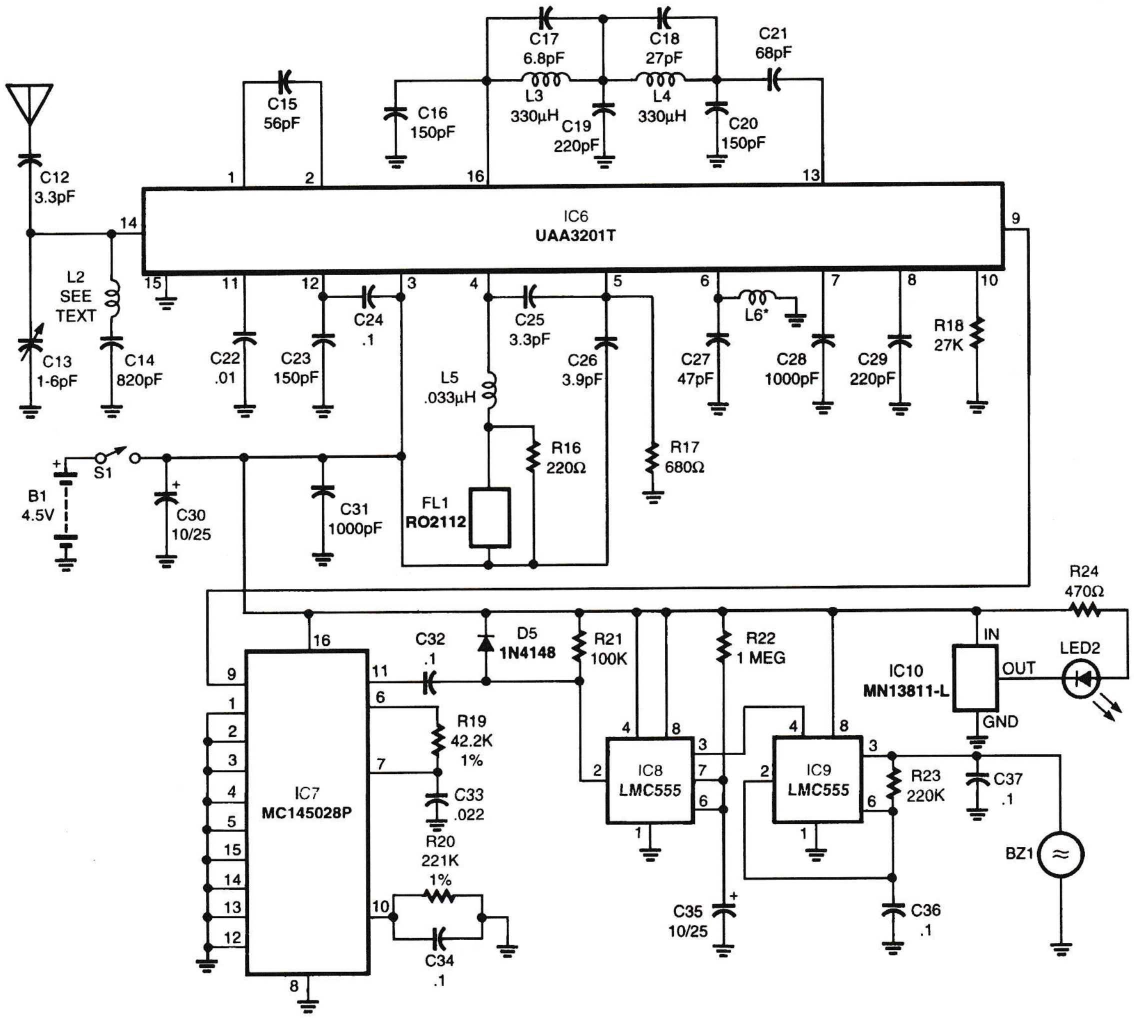
STARTER CUTOFF



POPULAR ELECTRONICS *Fig. 12-3*

In this auto-starter cutoff circuit, two conditions are required to start the car: The key switch must be turned to the starting position, and Q1 must be turned on. When Q1 is switched to the ON state, current flows through the gate, allowing current to pass through the SCR, provided that the key switch is also turned to the starting position. Transistor Q1 can be turned on by connecting R2 through a separate switch to a 12-V power source, or by using an existing switched source. Examples of existing sources might be a brake light, turn signal, parking light, or anything that most people would not normally activate while starting a vehicle. With regard to using a turn-signal indicator, it doesn't matter that the power applied to Q1 is not constant. Only a pulse is required to latch the SCR on, provided that the key switch is in the starting position. The SCR is a 25-A, 50-V unit.

AUTO GUARDIAN RECEIVER

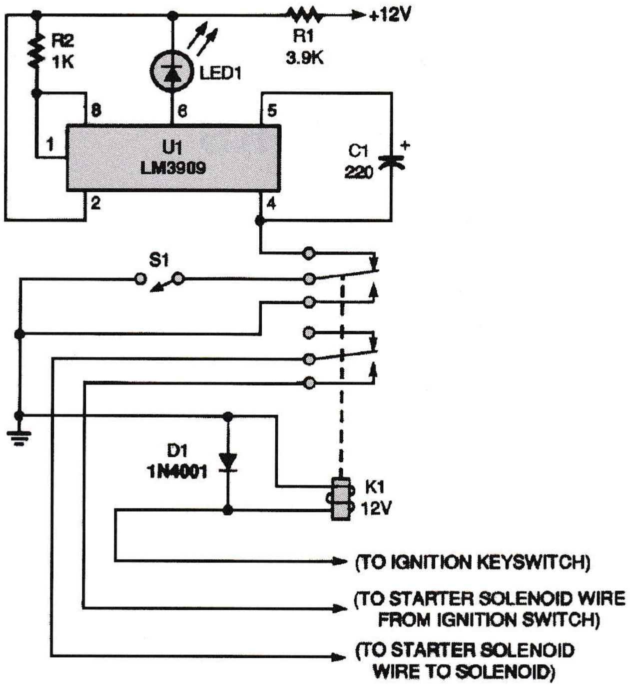


ELECTRONICS NOW

Fig. 12-4

The decoder IC7 checks the incoming pulse train for the correct address. If that address is present, the valid output terminal, pin 11, goes high for the $2\frac{1}{2}$-s duration of the transmitted pulse trains. When the valid output signal returns to a low state, timer IC8 is triggered into operation. The output terminal of IC8, pin 3, goes high for a time period of about 11 s, as determined by R22 and C35. That output, in turn, enables IC9, a timer configured as a 50-percent duty-cycle oscillator with a period of about $\frac{1}{4}$ s. The output of IC9 drives a piezo buzzer, which produces an attention-getting audio signal that alerts the user that a door of the vehicle has been opened. Power to operate the receiver is obtained from a set of three AAA alkaline cells connected in series to produce 4.5 V. Current draw is only 3 mA during standby, so battery life will be in the hundreds of hours. IC10 is a voltage-detector IC that allows current to flow through LED2 when the battery voltage falls below 3 V. That alerts the user that battery replacement is necessary.

AUTO SECURITY DEVICE



POPULAR ELECTRONICS *Fig. 12-5*

Combining two functions in one, this circuit is both a passive cutoff device and a fake car alarm. Depressing S1 with the key in the RUN position disables the flasher and allows the car to start.

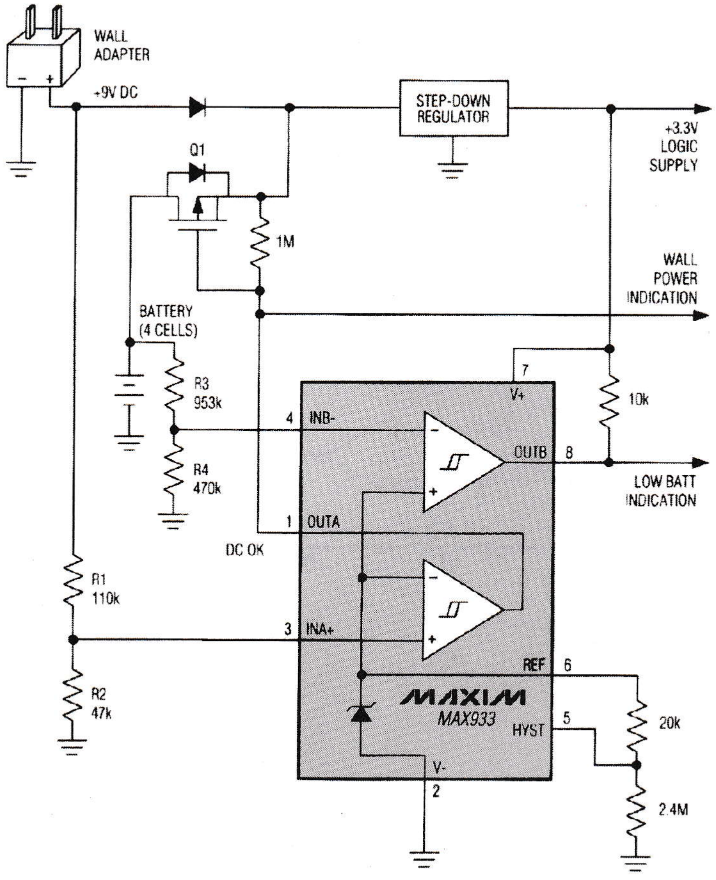
13

Battery Backup and Switchover Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Single-IC Battery-Backup Manager
Low-Voltage Battery Switchover System

SINGLE-IC BATTERY-BACKUP MANAGER

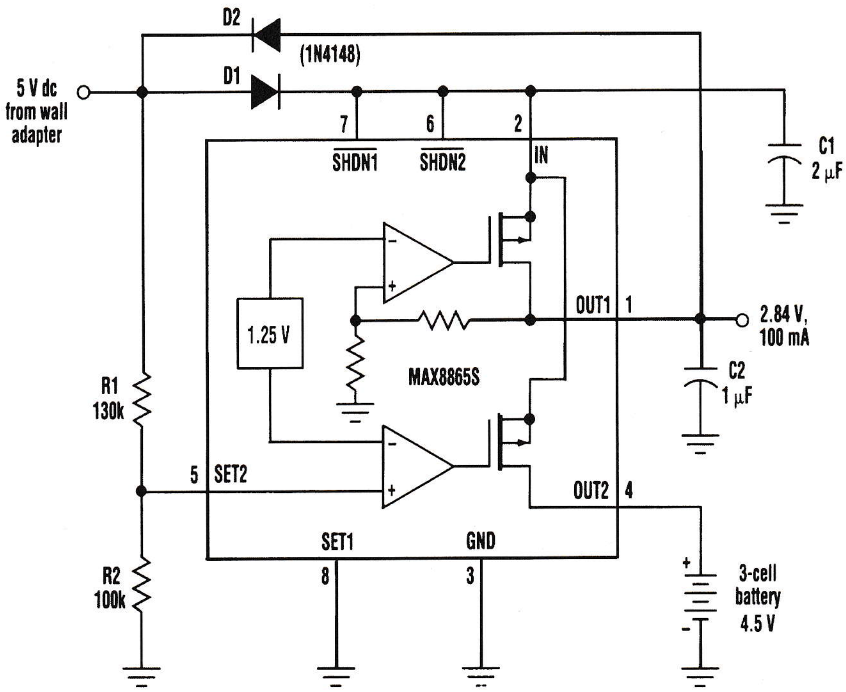


MAXIM ENGINEERING JOURNAL

Fig. 13-1

Instruments powered by a "wall adapter" with battery backup typically diode-OR the battery and wall-adapter connections. That arrangement carries a penalty, however—the diode in series with the battery limits the minimum voltage at which the battery can supply power. One alternative is a dual-comparator/reference IC, which monitors the battery and wall-adapter voltages with respect to its internal reference voltage. The open-drain output of comparator B (with pull-up to 3.3 V) provides a low-battery warning in the form of a low-to-high transition when battery voltage drops to 3.6 V. The open-drain output of comparator A (with pull-up to 9 V) flags low wall-cube voltage in the same way, with a warning threshold of 3.9 V. Comparator A also controls the PMOS switch Q1, which replaces the OR-connection diode in a conventional circuit. When wall power is removed, Q1 turns on and provides a low-resistance path from battery to regulator.

LOW-VOLTAGE BATTERY SWITCHOVER SYSTEM



ELECTRONIC DESIGN *Fig. 13-2*

Portable systems often include the flexibility to operate either from an internal battery or from an ac-dc wall adapter. Many such systems include circuitry that switches automatically between an internal battery and an external source as the user connects and disconnects the wall adapter. The circuit shown implements this idea with a dual linear regulator, one side of which is preset for a regulated output of 2.84 V (other versions of the IC offer 2.80-V and 3.15-V outputs). The other side of the regulator is configured to allow user-adjustable outputs, but, in this case, it monitors the wall-adapter voltage. When that voltage is removed by unplugging the adapter, the regulator's pass transistor routes battery current into the IC for support of the 2.84-V output (current flow in this transistor is counter to that of most applications). The input bypass capacitor (C1) provides enough holdup time for seamless transitions between the battery and adapter voltages. Resistors R1 and R2 sense the wall-adapter voltage and determine the switchover threshold, V_{SW}:

$$V_{SW}=V_{set}[(R_1+R_2)/R_2]=1.25\text{ V}[(130\text{ k}\Omega+100\text{ k}\Omega)/100\text{ k}\Omega]=2.875\text{ V}$$

Diode D1 isolates the wall-adapter voltage so that the battery can't cause limit cycling by retriggering the switchover. D2 holds the IC's dual-mode input in the external feedback mode by maintaining a minimum voltage at the SET2 input. The wall-adapter voltage should be equal to or greater than the maximum battery voltage.

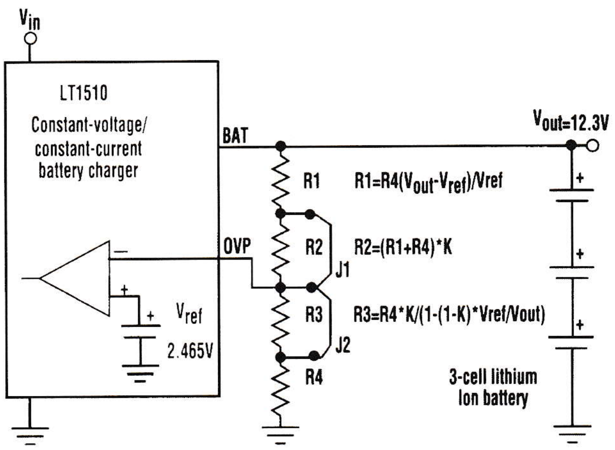
14

Battery Charger Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Precision Li-Ion Battery Charger
300-mA Step-Down Battery Four-Cell NiCd Charger
90-Percent-Efficient Four-Cell NiCd Charger
Battery Charger
More-Efficient Battery Charger
Battery Trickle Charger
Step-Up Supply Battery Charger
3-A Battery Charger for Li-Ion or NiCd
Timed NiCd Charger
2.5-A Battery Charger
Constant-Current NiCd Charger
Float-Charging Circuit
Simple Charger
Lead-Acid Battery Temperature-Compensated Charger

PRECISION Li-ION BATTERY CHARGER



ELECTRONIC DESIGN

Fig. 14-1

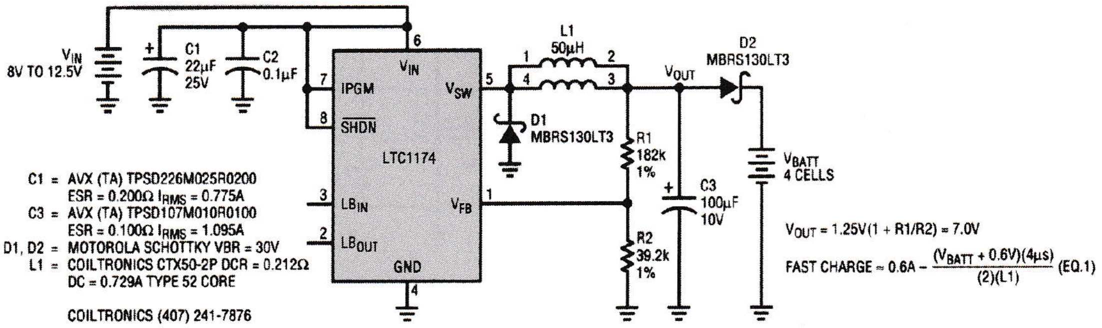
An alternative to using expensive 0.25-percent precision resistors is presented in this battery-charger design, which adds two 1-percent resistors and two jumpers to the charger.

In constant-voltage-mode charging, a lithium-ion cell requires 4.1 V ± 50 mV. The 1.2-percent requirement represents a tight tolerance. In a regulation loop where a voltage divider is compared against a reference, the accuracy is typically achieved by selecting a 0.7-percent reference and a voltage divider with 0.25-percent tolerance resistors. Unfortunately, 0.25-percent precision resistors cost three times as much as 1-percent resistors and have very long lead times. One solution for moderate-volume production involves adding two 1-percent resistors and two jumpers to the charger circuit (see the figure). The jumpers are removed as necessary to bring the constant voltage to the required accuracy of 1.2 percent. The charger selected for this example is the LT1510. There are three lithium-ion cells in the battery. After a value is selected for R_4, the values for R_1, R_2, and R_3 can be calculated using the equations given. K is the relative change required for a circuit with all of its tolerances in one direction. For example, in the case of a 0.5-percent reference and two 1-percent resistors, the total tolerance is 2.5 percent. To bring it back to 1.2 percent, the percentage change required is 2.5 percent − 1.2 percent = 1.3 percent, and $K = 0.013$. The jumpers (J1 and J2) must be opened based on the following:

If V_{out} is $K/2$ below nominal, remove J1.
If V_{out} is $K/2$ above nominal, remove J2.

The following values were calculated: $R_1 = 4.99\ \text{k}\Omega$, $R_2 = 324\ \Omega$, $R_3 = 80.6\ \Omega$, and $R_4 = 20\ \text{k}\Omega$. The voltage below which jumper J1 should be opened is 12.34 V − 1.3 percent / 2 = 12.22 V. The voltage above which jumper J2 should be opened is 12.34 V + 1.3 percent / 2 = 12.42 V.

300-mA STEP-DOWN BATTERY FOUR-CELL NiCd CHARGER



C1 = AVX (TA) TPSD226M025R0200
ESR = 0.200Ω I_{RMS} = 0.775A
C3 = AVX (TA) TPSD107M010R0100
ESR = 0.100Ω I_{RMS} = 1.095A
D1, D2 = MOTOROLA SCHOTTKY VBR = 30V
L1 = COILTRONICS CTX50-2P DCR = 0.212Ω
DC = 0.729A TYPE 52 CORE

COILTRONICS (407) 241-7876

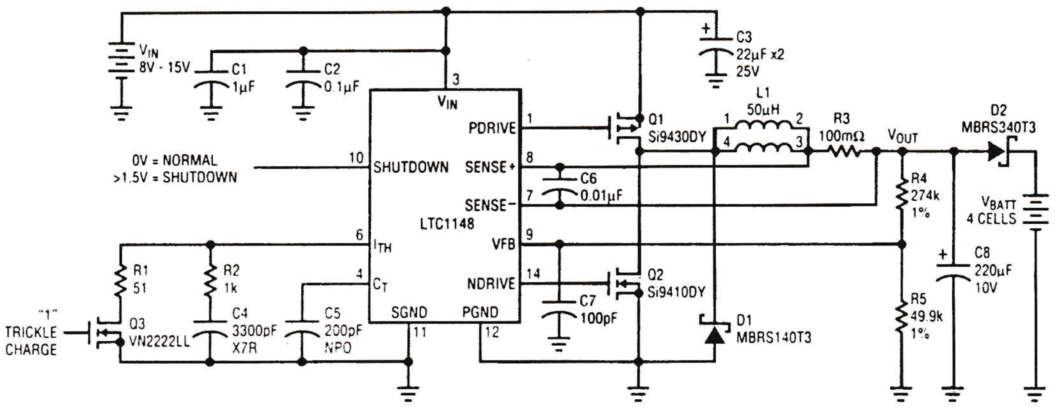
$V_{OUT} = 1.25V(1 + R1/R2) = 7.0V$

$\text{FAST CHARGE} \approx 0.6A - \frac{(V_{BATT} + 0.6V)(4\mu s)}{(2)(L1)}$ (EQ.1)

LINEAR TECHNOLOGY POWER SOLUTIONS *Fig. 14-2*

Low-current battery-charger circuits are required in hand-held products such as palmtop, pen-based, and fingertip computers. The charging circuitry for these applications must use surface-mount components and consume minimal board space. The LTC1174 circuit shown provides both of these features. The LTC1174 is a current-mode, step-down switching regulator with a low-loss internal P-channel MOSFET power switch. In this circuit, the peak switch current is programmed to 600 mA. The average charging current is determined by the choice of inductor value and the actual battery voltage, according to the equation. The voltage feedback resistor network is set for an output voltage of 7 V. NiCd cells have a nominal voltage of 1.2 V, a discharged voltage of 0.9 V, and a fully charged voltage of 1.5 V. A four-cell NiCd pack's voltage will range from 3.6 to 6 V, depending upon its state of charge. When it is attached to the charger, it will pull the output voltage below 7 V and place the LTC1174 into current-limited operation at about 300 mA with the 50-μH inductor shown. Diode D2 prevents the batteries from discharging through the divider network when the charger is shut down by bringing the SHUTDOWN pin low. Less than 10 μA of current is drawn from the supply when the charger is shut down.

90-PERCENT-EFFICIENT FOUR-CELL NiCd CHARGER



C1 = (TA)
C3 = AVX (TA) TPSD226K025R0200 ESR = 0.200 IRMS = 0.775A
C8 = AVX (TA) TPSE227M010R0100 ESR = 0.100 IRMS = 1.149A
Q1 = SILICONIX PMOS BVDSS = 20V RDS_{ON} = 0.125 C_{RSS} = 400pF Q_G = 25nC θJA = 50°C/W
Q2 = SILICONIX NMOS BVDSS = 30V RDS_{ON} = 0.050 C_{RSS} = 160pF Q_G = 50nC θJA = 50°C/W
D1, D2 = MOTOROLA SCHOTTKY VBR =40V
R3 = KRL SP-1/2-A1-0R100J Pd = 0.75V
L1 = COILTRONICS CTX50-4 DCR = 0.175 IDC = 1.350A Kool Mµ® CORE

ALL OTHER CAPACITORS ARE CERAMIC

COILTRONICS (407) 241-7876
KRL (809) 668-3210

V_{OUT} = 1.25V • (1 + R4/R5) = 8.1V

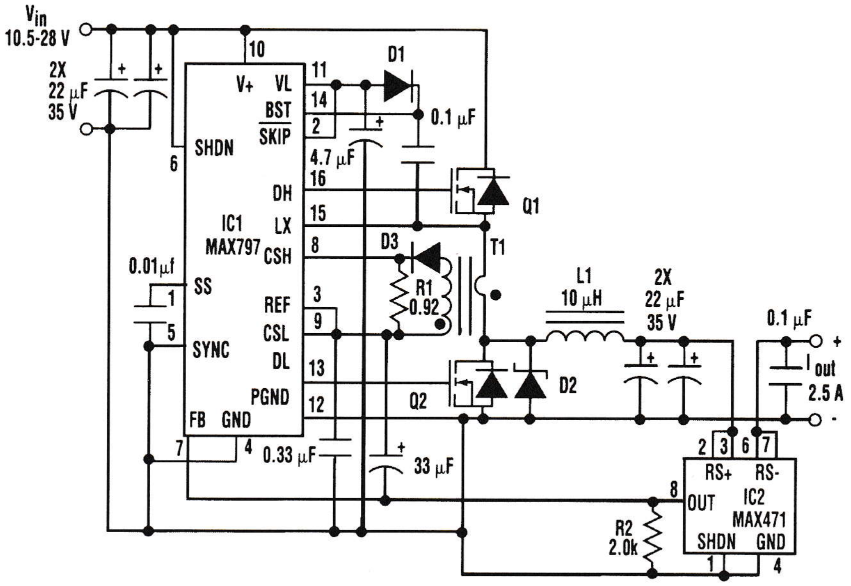
FAST CHARGE = 130mV/R3 = 1.3A (EQ. 1)
TRICKLE CHARGE = 100mA

LINEAR TECHNOLOGY POWER SOLUTIONS

Fig. 14-3

An embedded battery charger requires extremely low power dissipation in order to minimize heat buildup in compact portable systems. This schematic shows a charger that can charge four NiCd cells and is selectable for either a 1.3-A fast charge or a 100-mA trickle charge with up to 90 percent efficiency. The LTC1148 is a step-down synchronous switching regulator; it controls the charge rate, monitoring the output current via external current-sense resistor R3. Fast charge current is determined by the value of R3, according to the fast charge equation. In this case, it is set to 1.3 A. The resistor divider network R4 and R5 sets the output voltage to a nominal 8.1 V under no-load conditions, such as when the battery is removed. A four-cell NiCd pack's voltage will range from 3.6 to 6 V, depending upon its state of charge. When installed, the battery will pull the output below 8.1 V and place the LTC1148 into current-limited operation at 1.3 A. This constant current will be delivered until trickle charge is enabled by an external charge termination circuit or the battery is removed. Q3 enables trickle charge operation with charge current set by choice of R1. Diode D2 prevents the battery from being drained by the feedback resistor network when the LTC1148 is shut down.

BATTERY CHARGER



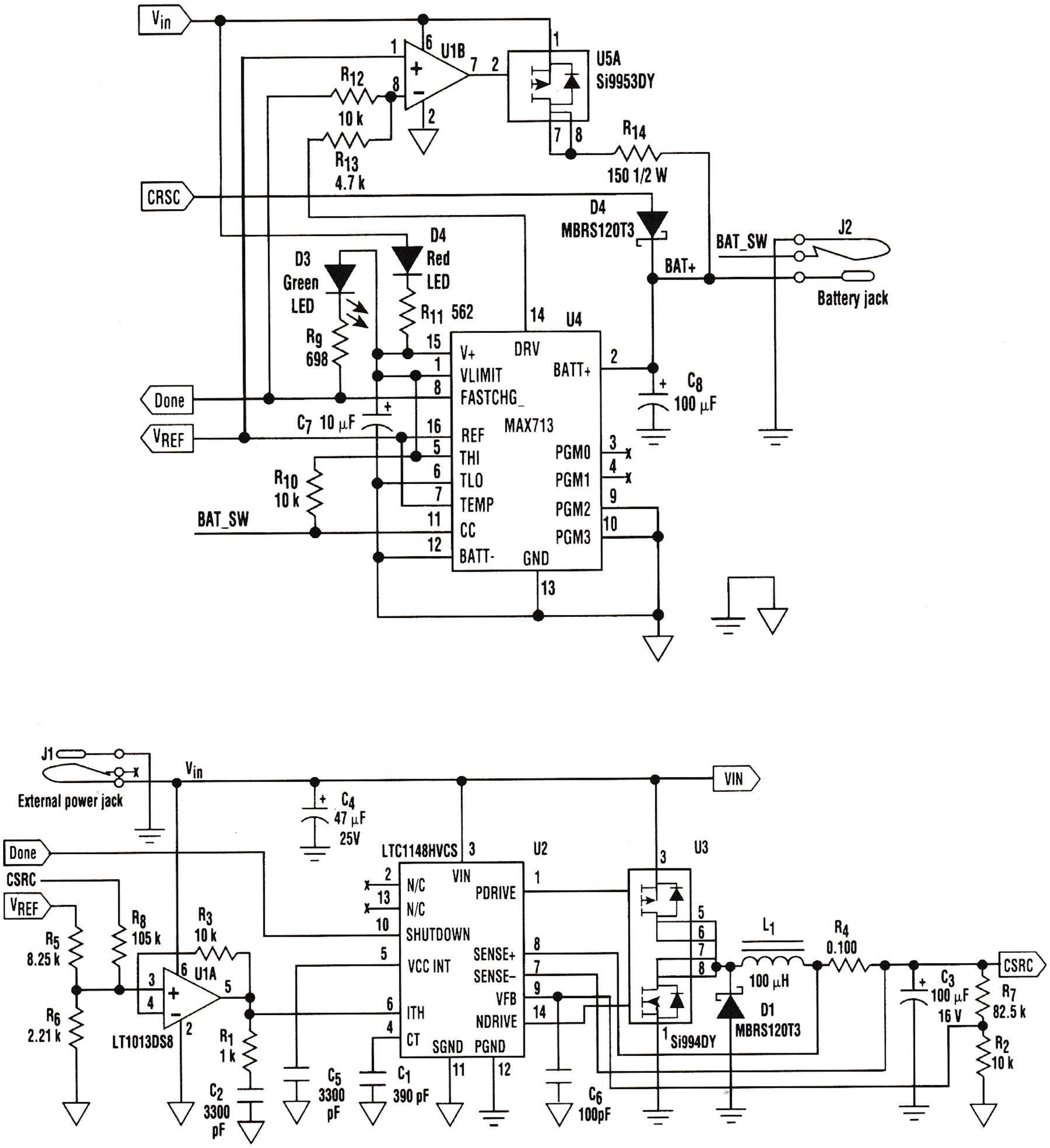
ELECTRONIC DESIGN

Fig. 14-4

This current-source battery charger can source 2.5 A with up to 96 percent efficiency. It can operate from an ac adapter or directly from a car battery. By sensing current on the high side of the battery being charged, it preserves the low impedance of the automobile's ground-return system. The charger handles battery stacks of 5 to 15 cells, and its input voltage can range from 28 V down to a level 1.5 V above the terminal voltage of a fully charged battery. Charging current is generated by the current-mode, buck-regulator controller IC1, operating with an external power switch (Q1) and a synchronous rectifier (Q2). Both are N-channel MOSFETs, whose low on-resistance (vs. P-channel types) contributes to high efficiency in the circuit. The IC includes a charge pump for generating the required positive gate voltage for Q1. It also senses the Q1 current (via R1) and shuts down if this current becomes excessive.

The current-sense transformer (T1) saves power by diverting a fraction of Q1's current through R1. Operating on the output's high side is the current-sense amplifier IC2. Its OUT current (1/2000 of the current flowing internally from RS+ to RS−) flows through R2 to produce a feedback signal for IC1. Digital control of the charging current can be introduced by switching among different-switching FETs like the 2N7002; its 7.5-Ω on-resistance is not a problem because its drain current—no greater than 1.25 mA—introduces an error no greater than 0.5 percent. Circuit efficiency ranges up to 96 percent. Efficiency and power output both increase with output voltage, because the circuit's power consumption (associated mainly with IC1 and the switching MOSFETs) is almost constant. This buck regulator's output cannot rise about V_{in}, in most cases, overvoltage protection is not required. V_{out}, which supplies power to IC2, must not go below 4 V.

MORE-EFFICIENT BATTERY CHARGER



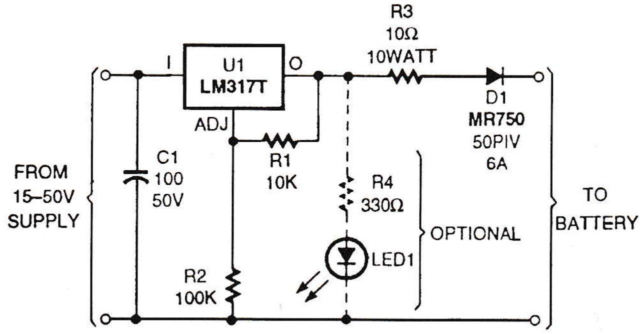
ELECTRONIC DESIGN

Fig. 14-5

MORE-EFFICIENT BATTERY CHARGER *(Cont.)*

The project at hand was to build a small, efficient, inexpensive, full-function battery charger that could charge 2 to 10 NiCd or NiMH cells. A switching regulator that could be set up as a constant-current source was needed. Connecting the negative end of the battery directly to ground provides more voltage and reduces IR losses. Linear Technology's LTC1148HV synchronous step-down switching regulator fills this role because it is more than 90 percent efficient, and it features two current sense inputs (Sense+ and Sense−) and a current control pin (I_{th}) that has a dc input linearly related to the maximum coil current (Fig. 1). For example, with a low, commonly available 0.1-Ω sense resistor and I_{th} connected to the 2-JV reference output of the MAX713, the peak coil current is set to 1.55 A. The average current will still vary with output voltage, but this can be compensated for by feeding back some of the output voltage to I_{th}. The constant-voltage regulation loop of the LTC1148 is disabled once the voltage divider (R2 and R7) for V_{FB} is set above the highest voltage that the battery is going to reach during charge. With the battery above the constant voltage regulation point, the switching regulator will supply no current. If a trickle charge current is desired, a switch (U5A) and a resistor (R14) can be added that supply the desired current directly from the primary dc source (V_{in})—a simple wall cube—when the MAX713 controller terminates fast charge or during battery undervoltage condition at startup.

BATTERY TRICKLE CHARGER

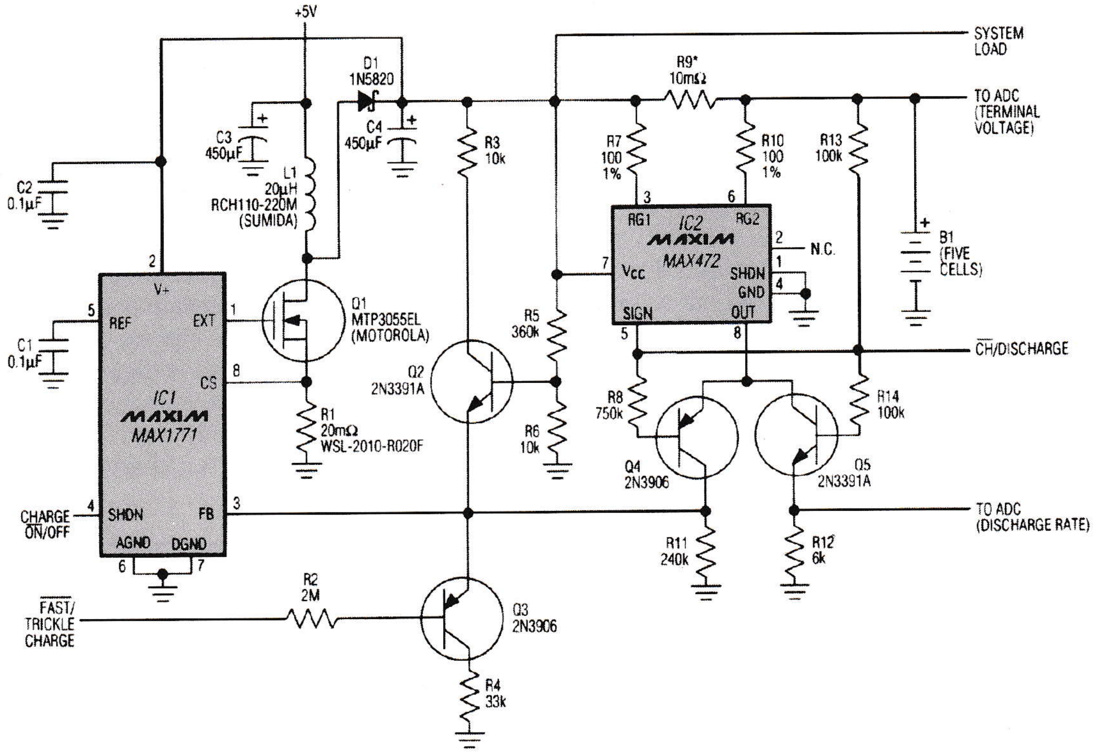


POPULAR ELECTRONICS

Fig. 14-6

The circuit is built around an LM317T adjustable voltage regulator. Its output voltage (V_{OUT}) is determined by the formula $V_{OUT}=1.25\ (1+R_2/R_1)$. I chose a 10-kΩ resistor for R1 and a 100-kΩ resistor for R2 to allow for a little wasted current flow (around 125 μA). This will develop 13.75 V between the output terminal and ground. R3 and a diode prevent burnout if the terminals are shorted or reversed, and prevent battery discharge in the event that the regulator is disconnected from the main power supply. The capacitor is optional but will make life easier on the chip under an extreme charging cycle. With proper heat sinking, the IC is capable of carrying 1.5 A to the battery. The circuit can be left hooked to the battery all of the time and will not overcharge it.

STEP-UP SUPPLY BATTERY CHARGER



MAXIM ENGINEERING JOURNAL

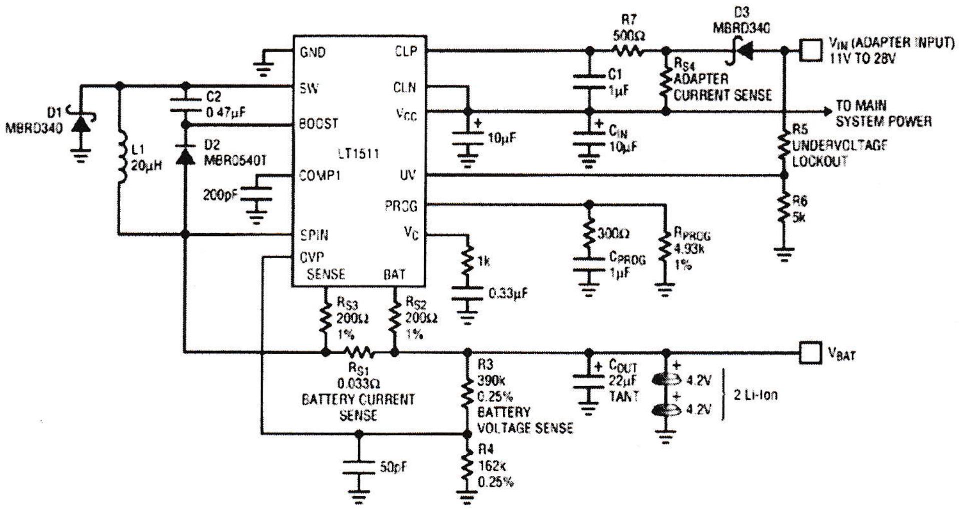
Fig. 14-7

IC1 is a step-up switching regulator that boosts V_{in} (nominally 5 V) as necessary to supply the combination of charging current and load current. The 5-V source must include short-circuit protection. IC2 is a high-side current-sense amplifier that monitors the charging current. Commands from the processor include CHARGE ON/OFF and FAST/TRICKLE CHARGE. IC2 produces an output current (OUT) equal to 10^{-4} of the current through sense resistor R9. Q3 and Q4 are on during a fast-charge operation, so this output current flows through the parallel combination of R11 and (approximately) R4. The resulting feedback to IC1 (pin 3) maintains the fast-charge current through R9 at 500 mA. This feedback also enables the regulator to supply as much as 500 mA of load current in addition to the fixed 500 mA of charging current. Q2 limits the battery voltage to 10 V (2 V/cell). During the fast charge, an external processor and multichannel A/D converter (ADC) must monitor the battery's terminal voltage. When the ADC senses a change of slope in this voltage, the processor terminates the fast charge by asserting a high on FAST/TRICKLE CHARGE. Q3 turns off, causing a rise in the feedback (FB) that lowers the charging current to the trickle charge rate (approximately 60 mA). If IC1 shuts down or if the load current plus charging current exceeds the capability of IC1, the R9 current reverses as current flows out of the battery. IC2 indicates the reversal by allowing R13

STEP-UP SUPPLY BATTERY CHARGER *(Cont.)*

to pull its open-collector SIGN output high, turning off Q4 and turning on Q5. Current through R12 then produces a voltage proportional to the battery's discharge current (5 A through R9 produces a full-scale response of 3 V across R12). By integrating this voltage over time (sampling at fixed intervals and multiplying by the time interval), the A/D-processor system can monitor energy removed from the battery. Based on this measurement and the terminal-voltage measurement, the processor can then reinitiate a fast charge (by asserting FAST/TRICKLE CHARGE low) before the battery reaches its end of life.

3-A BATTERY CHARGER FOR Li-ION OR NiCd

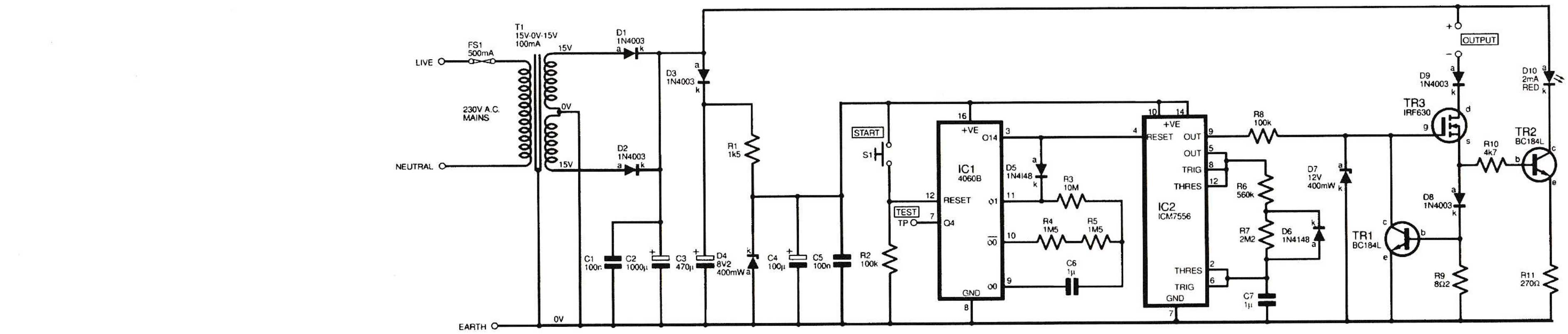


LINEAR TECHNOLOGY

Fig. 14-8

The LT1511 is a high-efficiency switched-mode current source designed for battery charging in portable applications. The LT1511 implements the constant-voltage/constant-current profile required for lithium-ion (Li-ion) batteries. It can also charge nickel-cadmium (NiCd) and nickel-metal-hydride (NiMH) batteries by using an external charge-termination method. Full charging current can be programmed by resistors or a DAC. An input current regulating loop on the LT1511 allows simultaneous equipment operation and battery charging without overloading the wall adapter. The charging current is automatically reduced to keep the wall adapter current within specified levels.

TIMED NiCd CHARGER

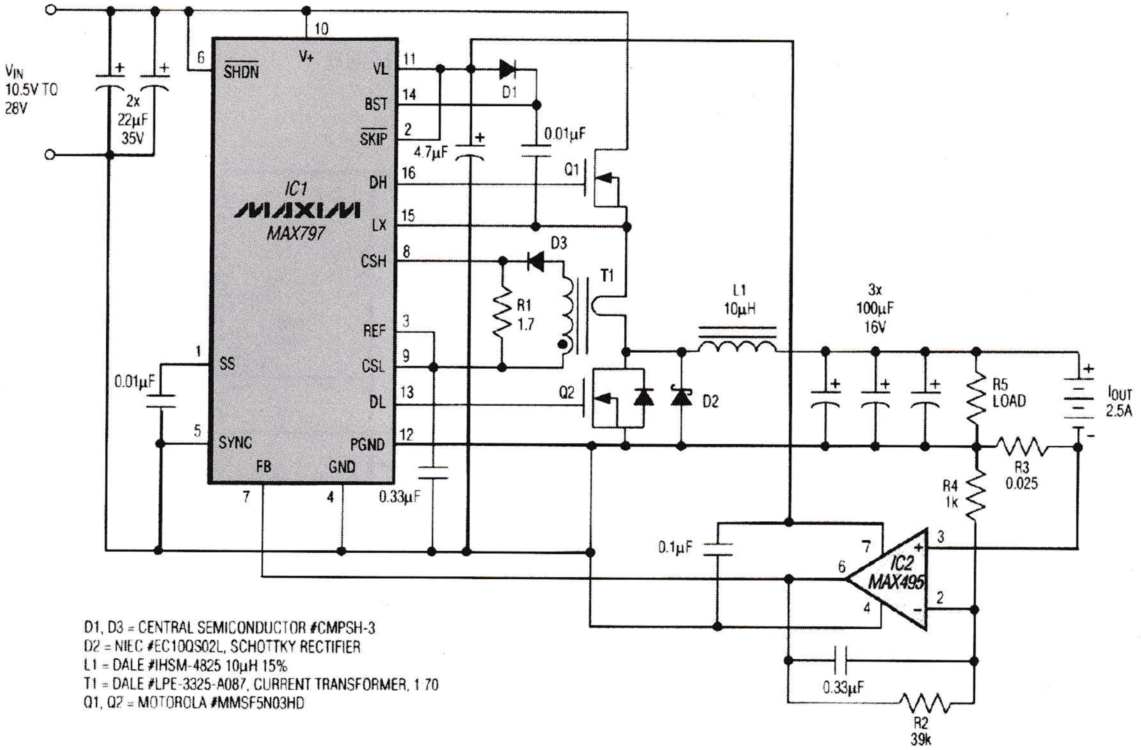


EVERYDAY PRACTICAL ELECTRONICS

Fig. 14-9

The primary supply is provided by 230 V through transformer T1, diodes D1 and D2, and reservoir capacitor C2. A supply for the timing circuit is provided through diode D3, with resistor R1 and zener diode D4 to keep it to a safe voltage for the CMOS devices used. These CMOS devices, IC1 and IC2, use so little current that the timer will keep going for up to 30 s if the power fails, preventing the charge period from being restarted by every minor glitch in the supply. IC1 is a 4060B 14-stage divider with built-in oscillator. Pressing switch S1 sets all its outputs low, so diode D5 is reverse-biased and the oscillator operates. With the component values shown, it runs at about 0.17 Hz, so the last output of the divider, pin 3, goes high after about 14 h. This applies forward bias to D5, which stops the oscillator. The first timer of the 7556 dual CMOS timer IC2 is connected to operate as an oscillator with a frequency of about 0.5 Hz with a duty cycle of about one to five. Pin 4 is an "active low" reset for this timer, so although the input to this from IC1 is low, its output is also low. The second timer is used as an inverter to convert this to a high output, which, via resistor R8, activates the output constant-current generator. When IC1 times out, the oscillator in IC2 starts running, and the current generator is then pulsed for about 400 ms every 2 s. NiCds have quite a high self-discharge rate: about 10 percent of capacity per week. If left on this charger, they will be kept fully topped up ready for use without overcharging, and by flashing in time with the current pulses, LED D10 will let the user know that the main charge period is complete.

2.5-A BATTERY CHARGER

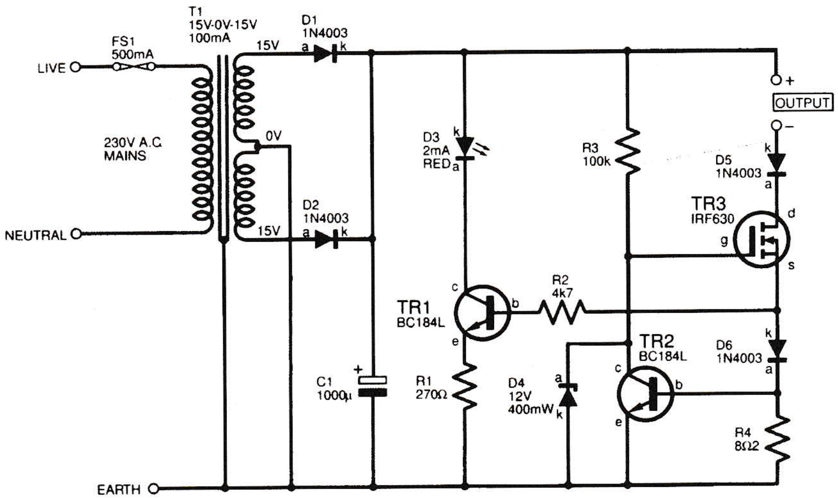


D1, D3 = CENTRAL SEMICONDUCTOR #CMPSH-3
D2 = NIEC #EC10QS02L, SCHOTTKY RECTIFIER
L1 = DALE #IHSM-4825 10μH 15%
T1 = DALE #LPE-3325-A087, CURRENT TRANSFORMER, 1:70
Q1, Q2 = MOTOROLA #MMSF5N03HD

MAXIM ENGINEERING JOURNAL ***Fig. 14-10***

Battery chargers are usually designed without regard for efficiency, but the heat generated by low-efficiency chargers can present a problem. For those applications, the charger shown in the figure delivers 2.5 A with efficiency as high as 96 percent. It can charge a battery of one to six cells while operating from a car battery. IC1 is a buck-mode switching regulator that controls the external power switch, Q1, and the synchronous rectifier. IC1 includes a charge pump for generating the positive gate-drive voltage required by Q1. The battery-charging current develops a voltage across the 25-MΩ resistor (R3) that is amplified by the op amp and presented as positive-voltage feedback to IC1. This feedback enables the chip to maintain the charging current at 2.5 A. While charging, the circuit can also supply current to a separate load, up to a limit set by current-sense transformer T1 and sense resistor R1. T1 improves efficiency by lowering power dissipation in R1. The transformer turns ratio (1:70) routes only 1/70 of the total battery-plus-load current through R1, creating a feedback voltage that enables IC1 to limit the overall current to a level compatible with the external components.

CONSTANT-CURRENT NiCd CHARGER

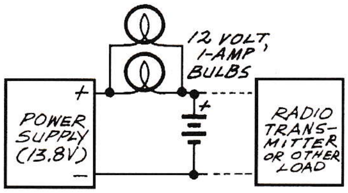


EVERYDAY PRACTICAL ELECTRONICS

Fig. 14-11

A tapped transformer (T1) with two rectifier diodes (D1 and D2) and capacitor C1 provides the primary dc supply from the 230 Vac. The power MOSFET device TR3 is initially biased into conduction by a positive gate voltage from resistor R3. Current flowing through the load flows through current-sensing resistor R4, developing a voltage. When this reaches about 0.5 V, transistor TR2 begins to conduct, reducing the gate (g) voltage of TR3. The circuit stabilizes at the load current that gives 0.5 V across R4. Zener diode D4 prevents excessive gate voltage from being applied to power MOSFET TR3, which might happen if the circuit was powered without the load connected. Diode D6 compensates for the base-emitter voltage drop of transistor TR1 so that the voltage across R4 is duplicated across resistor R1, controlling the current flow through LED D3. The apparent brightness of LED D3 therefore depends on the charging current, so any problems with connection to the cells on charge will be immediately apparent to the user. Diode D5 prevents any "back feeding" of current from the batteries power supply fails while the batteries are still connected.

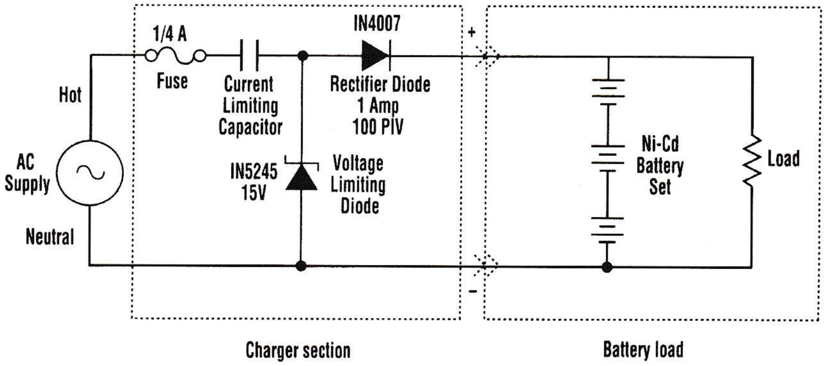
FLOAT-CHARGING CIRCUIT



To float-charge a 12-V lead-acid battery, all you need is an accurately regulated 13.8-Vdc power supply. You could connect the power supply directly to the battery, but it is safer to make the connection through a couple of 12-V, 1-A automotive light bulbs. The light bulbs serve as current limiters; they guarantee that no matter what happens, the power supply will never have to deliver more than 2 A. Resistors can also serve as current limiters, but light bulbs are better because their resistance varies with current in a useful way. It's nearly zero at low current, but as the current through each bulb approaches 1 A, the bulb lights and the resistance increases. Thus, the bulb limits the current, but doesn't waste energy when the current is low. This setup is a good way to power a heavy load that operates intermittently, such as a ham radio transmitter. The battery delivers heavy current when necessary and the power supply keeps the battery charged.

ELECTRONICS NOW *Fig. 14-12*

SIMPLE CHARGER



ELECTRONIC DESIGN *Fig. 14-13*

Built with just four components, this battery charger for small NiCd batteries is useful as a compact travel charger or in "floating" simple battery-backed projects. It is small enough to fit in a 35-mm film canister.

Warning: This circuit is not isolated from the ac line and presents a shock hazard if there is any contact between it and a person or another device.

LEAD-ACID BATTERY TEMPERATURE-COMPENSATED CHARGER

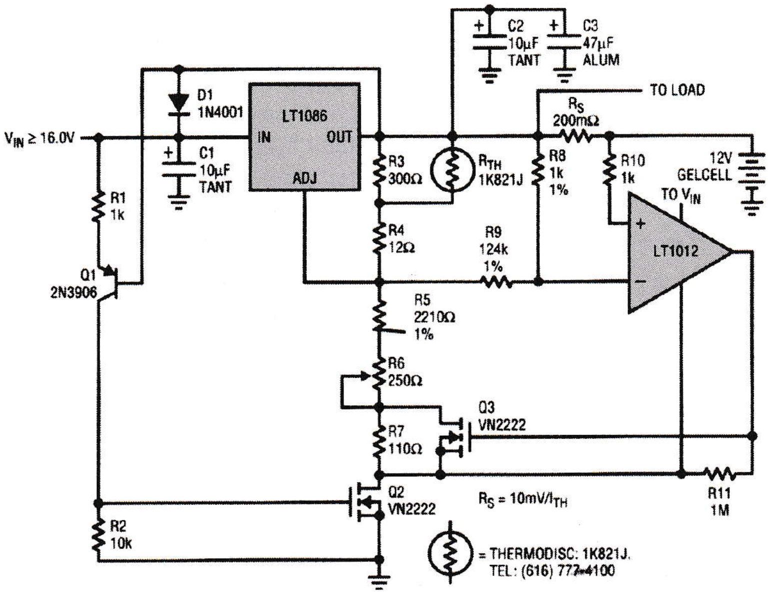


Table 1. The Regulator Should Be Chosen to Provide at Least C/4 Charging Current

Battery Capacity	Device	Maximum Charging Current	Float Current Threshold	Sense Resistor (Shunt)
≤3Ah	LT1117	0.8A	20mA	500mΩ
3–6Ah	LT1086	1.5A	50mA	200mΩ
6–12Ah	LT1085	3.2A	100mA	100mΩ
12–24Ah	LT1084	5.5A	200mA	50mΩ
24–48Ah	LT1083	8.0A	400mA	25mΩ

LINEAR TECHNOLOGY POWER SOLUTIONS

Fig. 14-14

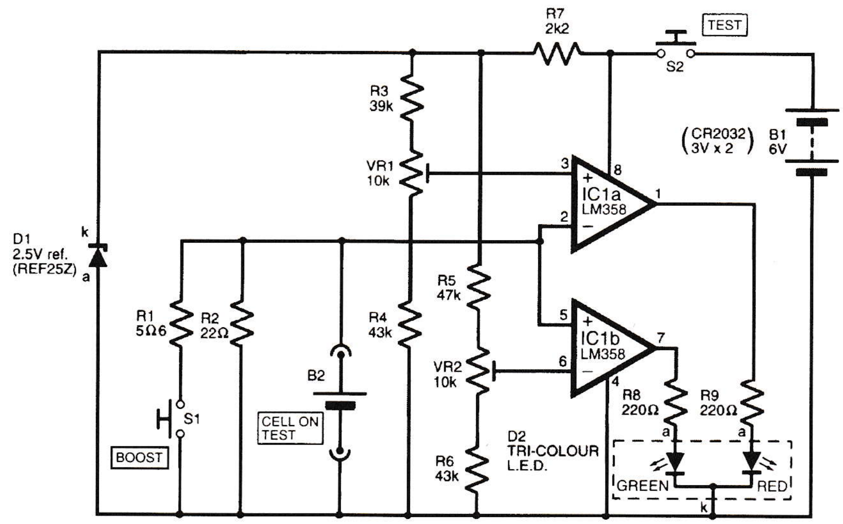
The charging characteristics of lead-acid cells are strongly linked to the ambient temperature. To prevent over- or undercharging of the battery during periods of extended low or high temperatures, temperature compensation is desirable. This circuit incorporates a low-dropout linear regulator, temperature compensation, dual-rate charging, and true negative ground, and consumes zero standby current. The LT1086 linear regulator is used to control the charging voltage and limit maximum charging current. If the input supply is removed, Q1 and Q2 turn off and all charger current paths from the battery to ground are interrupted, resulting in zero shutdown current draw. Diode D1 provides reverse current flow protection for the regulator should the input fall below the battery voltage or be shorted. The temperature compensation employed in this circuit follows the true curvature of a lead-acid cell. Temperature compensation is provided by R_{TH}, which is a Tempsistor, in parallel with R3. Changes in temperature alter the resistor divider ratio of the regulator. The match is within 100 mV for a 12-V battery over a range of −10 to +60°C. The best location for the Tempsistor is directly under the battery, with the battery resting on a pad of Styrofoam. Dual-rate charging is implemented by comparator LT1012, which senses the charging current through current-sense resistor R_S. When the current is greater than 10 mV/R_S, the high-rate charging voltage is 14.4 V at 25°C; when the current is less than this threshold, the float charging voltage is 13.8 V.

15

Battery Test and Monitor Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

TRICOLOR LED NiCd CHECKER

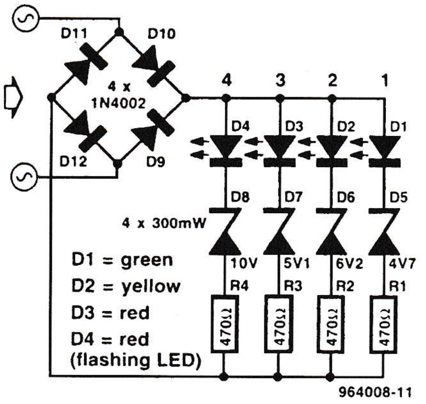


EVERYDAY PRACTICAL ELECTRONICS

Fig. 15-1

This circuit uses a window comparator and a bicolor LED. VR1 and VR2 set the high and low trip points of the comparators, respectively. The LED shows green for highest voltage (good), yellow for intermediate, and red for low voltage (bad). The circuit can be calibrated for other voltages and is generally useful as a voltage indicator.

LED BATTERY MONITOR FOR 12-V SYSTEMS

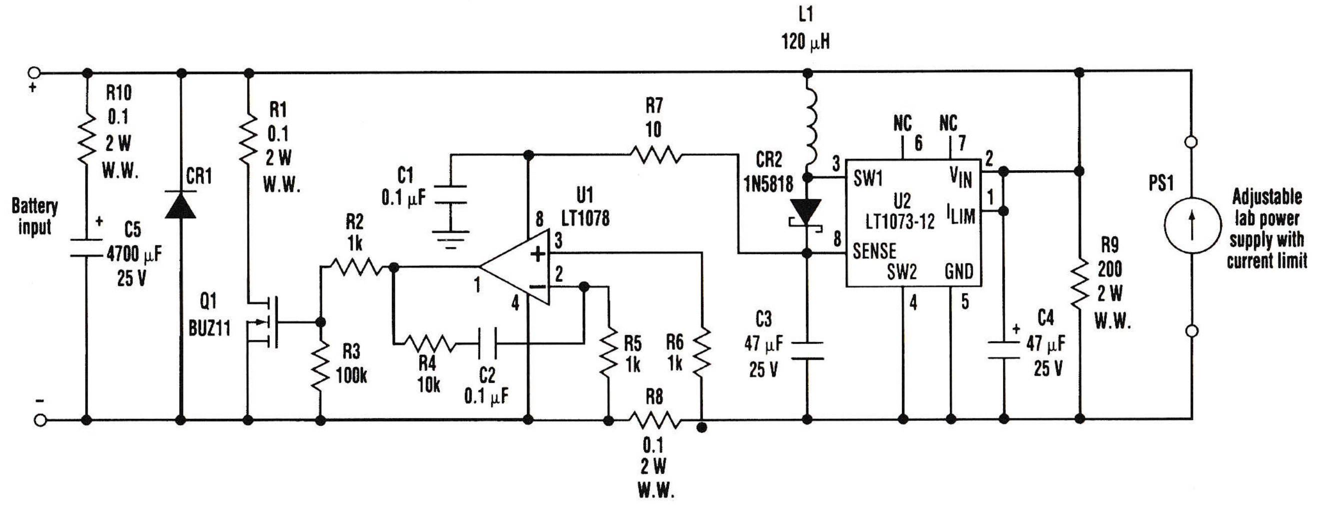


ELEKTOR ELECTRONICS

Fig. 15-2

This monitor is handy in cars and is particularly suitable for radio amateurs who power their equipment from a car battery. Bridge rectifier D9–D12 ensures that the battery cannot be connected with incorrect polarity. The zener voltage of diodes D5–D8 increases in standard steps, so the battery voltage needs to be higher to cause successive LEDs to light. In other words, the higher the battery voltage, the more LEDs will light. The component values are chosen so that at a battery voltage of 9 V—battery poor—only D1 lights; when it is about 11 V—battery doubtful—D1 and D2 light; when it is 13 V—battery fine—D1, D2, and D3 light. Diode D4 is a flashing LED. The value of zener diode D8 is such that the LED begins to flash when the battery voltage approaches 15 V—that is, an overvoltage situation.

BATTERY SIMULATOR CIRCUIT

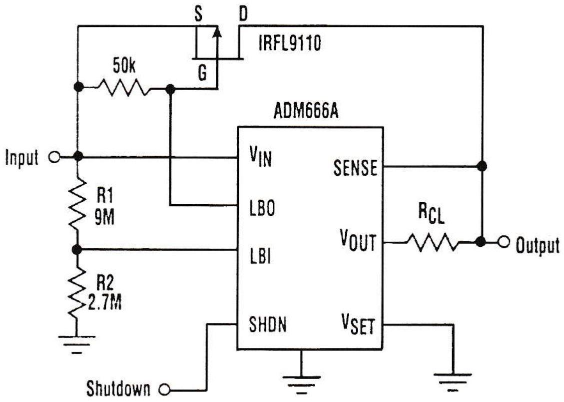


ELECTRONIC DESIGN

Fig. 15-3

When developing a battery charger, using a real battery might be inconvenient. The battery simulator circuit described here is an alternative. The battery input positive and negative terminals should be connected in place of the battery in the charger circuit. Also, a current-limited lab-type power supply must be connected to the simulator circuit (as shown). In Discharge mode, the battery simulator uses the current-limited lab power supply PS1 as a source, and the simulator is inactive. In Charge mode, charge current is forced through the battery input terminals. Low voltage that develops across R8 is amplified by U1 and causes Q1 to shunt the charge current while maintaining the power-supply (PS1) voltage. U2, L1, CR2, C3, and C4 produce an internal 12-V power supply that is required to operate U1 and drive Q1. The PS1 voltage range is 1.5 to 15 V. Diode CR1 protects the circuit from reverse polarity and is needed if the maximum charge current is too high for the body diode of Q1 (Q1 must be heat sunk). R1 is a sense resistor for measuring the charge current. R10 and C5 simulate the ac characteristics of the battery.

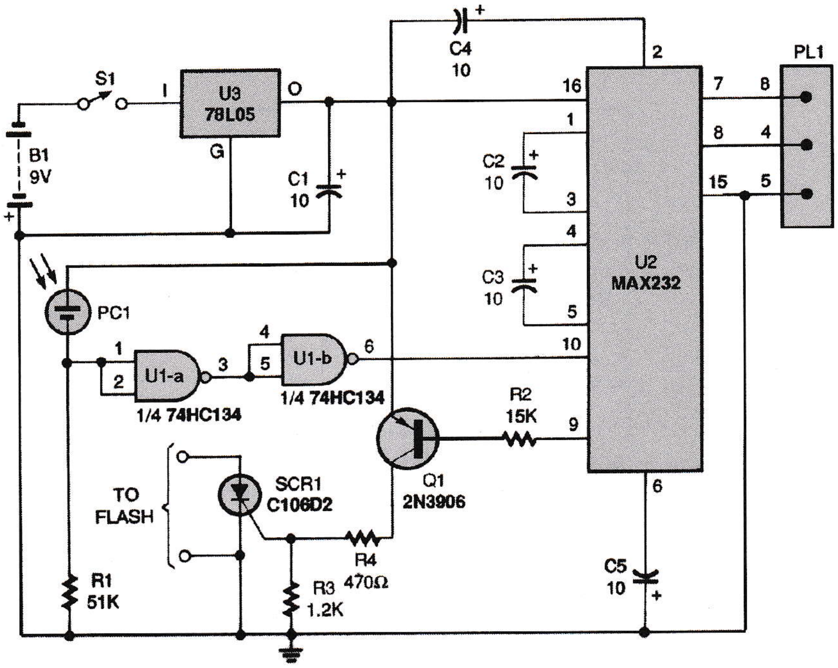
DUAL-MODE BATTERY-LIFE EXTENDER



ELECTRONIC DESIGN *Fig. 15-4*

Most voltage regulators stop functioning when the differential voltage between the input and output is reduced below a certain level. At this level, the regulator's output voltage begins to drop at an accelerated rate, resulting in a much lower voltage's being available to the circuit. To prevent this from happening, the battery voltage is monitored and a low-battery warning signal is issued, indicating the approaching end of battery life. In the circuit presented here, the voltage regulator is bypassed when a low battery level is detected—the battery is connected directly to the circuit. At high battery voltage levels, the output voltage is regulated by the linear regulator, and the low-battery indicator (LBI) comparator output is off. Also, the LBO pin is pulled to V_{batt} (input), keeping the power MOSFET off. As the input voltage drops and approaches the regulator's dropout voltage, the base current to the regulator's pass transistor reaches its maximum, turning it on very hard. Lowering the input voltage any further will result in an increase in the pass transistor's saturation voltage and a reduction in the regulator's output voltage. The input level detector's crossover voltage should be set to $V_{\text{out}} + V_{\text{sat}}$ of the pass transistor. When the input voltage falls below the crossover point, the comparator output is turned on. This pulls the gate voltage to ground, which turns on the power MOSFET. From this point, the voltage available to the circuit is the battery voltage minus the voltage across the power FET, which is insignificant.

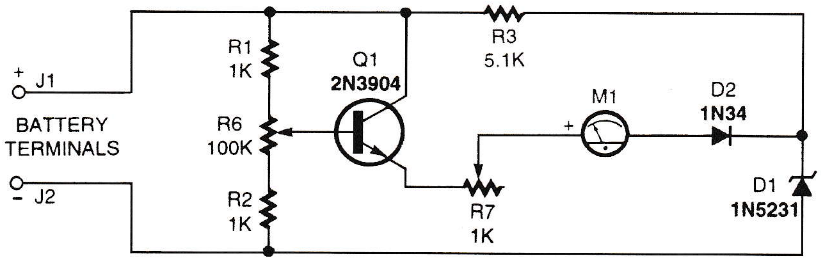
FLASH BATTERY TESTER



POPULAR ELECTRONICS *Fig. 15-5*

Power from a 9-V battery (B1) is fed to a 78L05 regulator (U3). The IC then produces a regulated 5 V to power the rest of the circuit. A cadmium sulfide photocell, PC1, conducts when a connected flash's ready light comes on and illuminates it. When current flows through PC1, U1-a, and U1-b, two sections of a 74HC134 quad Schmitt trigger NAND gate produce a sharp-edged TTL high. A MAX232, U2, converts the high to an RS233 low that is compatible with the PC's serial port. The MAX232 also takes an incoming serial-port pulse and converts it to TTL levels to fire the flash via SCR1, a C106D2 silicon-controlled rectifier. The circuit works with a BASIC program. That program fires the flash by sending a brief pulse through plug PL1 to the serial port's DTR pin. The program then starts timing how long it takes for the flash to recycle. In other words, the program "looks" at the CTS pin over and over until it sees that it went low. That happens when the photocell is lit by the flash's ready light. The program records the elapsed time and continues counting until 1 minute elapses. At that time, the DTR pin is cycled again to fire the flash, and the process is repeated. The test concludes when the recycle time exceeds 45 seconds.

BATTERY CAPACITY INDICATOR

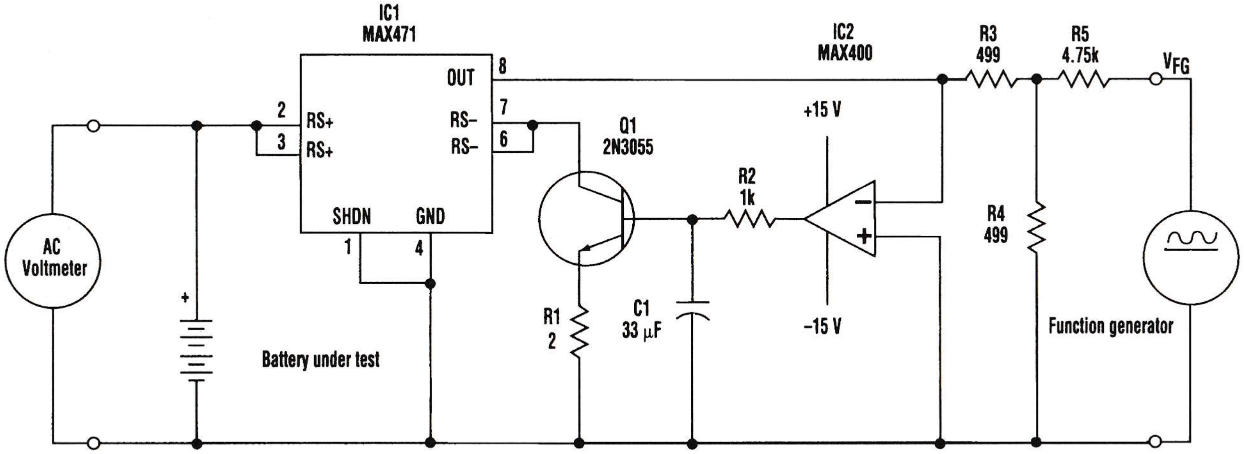


ELECTRONICS NOW

Fig. 15-6

Zener diode D1 creates a reference voltage to which the battery voltage is compared. The diode specified has a breakdown voltage of 5.1 V. That rating will work fine with most six- or seven-cell NiCd battery packs, as well as with 12-V lead-acid batteries. The circuit can be customized for a particular battery by selecting a unit for D1 that has a voltage rating about 1 V below the completely discharged voltage of the battery pack that you wish to measure. Transistor Q1, an emitter-follower amplifier, greatly increases the sensitivity of the circuit over what it would be if R7 were connected directly to the wiper of R6. A further advantage to that arrangement is that it reduces the current drain that flows through R1, R2, and R6. By amplifying the current flowing through the resistors, the resistance value can be increased to a very high value, lowering the total current draw of the circuit. Resistor R6 adjusts the meter to read 0 mA when the battery is completely discharged and R7 adjusts the meter to read 1 mA when the battery is fully charged. If the circuit were accidentally connected backward to the battery, current would flow through D1 and M1. The transistor would become reverse-biased, allowing a complete path back to the battery. That situation would allow excessive current to flow through D1, M1, and Q1, destroying them in the process. D2, R1, and R2 are included to prevent any current flow in case the battery is reversed.

BATTERY IMPEDANCE MEASURER

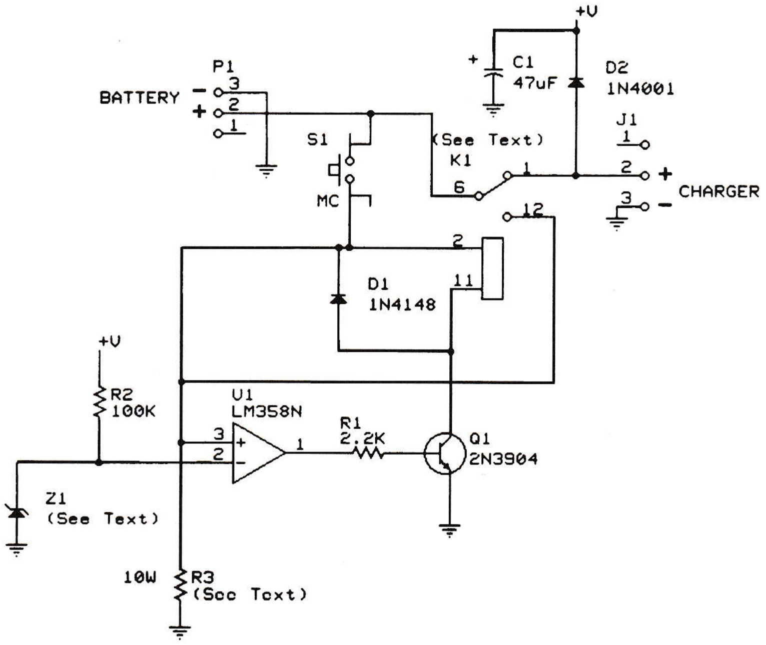


ELECTRONIC DESIGN ANALOG APPLICATIONS

Fig. 15-7

By applying an ac voltage superimposed on a ten times larger negative dc voltage (at V_{FG}), the function generator determines the battery current drawn by Q1 (see the figure). The generator voltage causes the op-amp (IC2) output to go high and turn Q1 on, which allows battery current to flow through the high-side current-sensing amplifier (IC1). The output current of IC1, on pin 8, is equal to 1/2000 of this battery current. As a result, IC1, IC2, and Q1 form a loop in which the op amp forces a virtual ground at the IC1/IC2 end of R3. The op amp's extremely low-voltage offset (10 µV maximum) ensures accuracy. This virtual-ground condition enables the voltage divider (R5, and R3 in parallel with R4) and the function generator to determine the voltage across R3. The resulting current in R3 is $i_{R3}=R_P \times V_{FG}/[(R_P+R_5)R_3]$, where R_P is the parallel combination of R3 and R4. Substituting resistor values and noting that battery current (i_B) is 2000 times i_{R3}, $i_B=-V_{FG}/5$. To operate the circuit, set the function generator's ac voltage to approximately 10 percent of its dc component. The equation then gives the resulting ac current in the battery (i_B). Using an ac voltmeter, you can measure the ac voltage across the battery (v_B) and calculate the average cell impedance as v_B/Ni_B, where N is the number of cells. The circuit easily accommodates battery voltages of 3 V or more.

NiCd BATTERY CYCLER

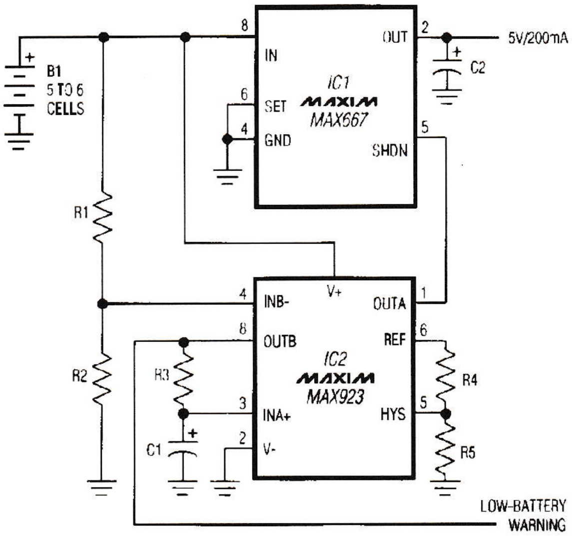


NUTS AND VOLTS MAGAZINE

Fig. 15-8

The battery cycler works with NiCd configurations of between three and nine cells. Cell combinations are accommodated by selecting Z1, K1, and R3 based upon the number of cells in the battery pack. This circuit is basically composed of a voltage comparator (U1), a voltage reference (Z1), and a switch (Q1 and K1). The op amp (U1) compares the reference voltage generated by the zener diode (Z1) and the battery. When the battery voltage matches (or is less than) the reference, the switch is turned off and the battery is allowed to charge. While the battery voltage is above the reference voltage, it is discharged through resistor R3. The resistor has been selected to discharge the battery at a rate between 200 and 300 mA. This rate keeps the power dissipation in R3 below 3 W and reduces the risk of opening any fuses in the battery circuitry located in the portable equipment. The push-button switch (S1) initiates the discharge process. If the battery voltage is below the reference when S1 is pressed, the unit will not discharge the battery because the lower operating limit of the battery has already been exceeded. If your batteries are in this condition, charge them for 18 hours and measure the voltage. If the batteries are still below the cutoff voltage, the problem is with one or more cells in the battery pack.

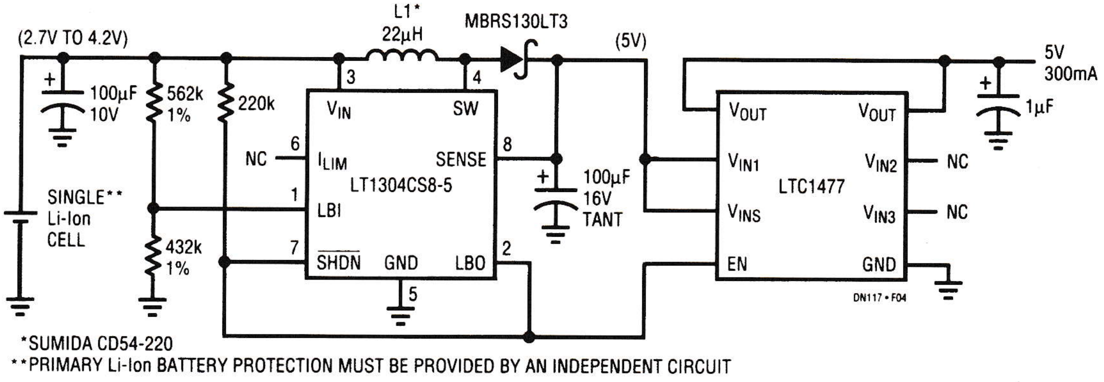
LOW-BATTERY MONITOR



MAXIM ENGINEERING JOURNAL ***Fig. 15-9***

This circuit gives an early warning of declining battery voltage. Then, to allow a controlling processor time for emergency housekeeping chores, such as the storage of register data, the circuit delays system shutdown by a specified time interval (rather than waiting for battery voltage to decline further, to a specified lower level). Circuit components are chosen for low quiescent current, which protects discharged cells by minimizing the battery drain during shutdown: IC1 draws 1 μA, IC2 draws 3 μA, and R1 and R2 draw 3 μA, for a total shutdown current of about 7 μA. R1 and R3=1 MΩ, R2=280 kΩ, R4=49.9 kΩ, R5=2.4 MΩ, and C1=3.9 μF.

LOW BATTERY DETECTOR

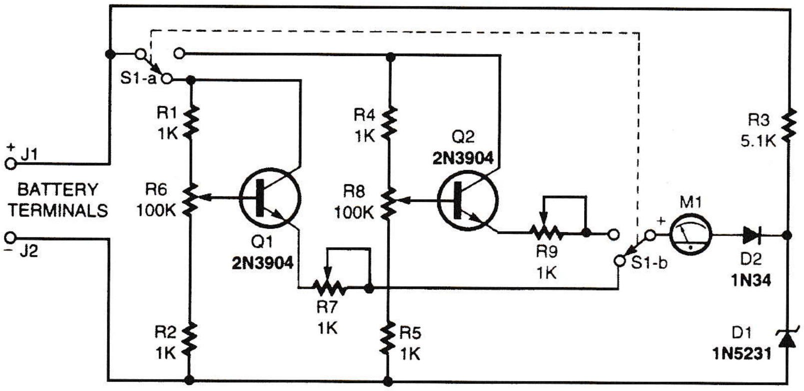


*SUMIDA CD54-220
**PRIMARY Li-Ion BATTERY PROTECTION MUST BE PROVIDED BY AN INDEPENDENT CIRCUIT

LINEAR TECHNOLOGY ***Fig. 15-10***

Low-voltage cutoff is desirable in battery-operated systems to prevent deep discharge damage to the battery. The LT1304 micropower boost regulator contains a low-battery detector which is active even when the regulator is shut down. The output of the detector controls both the LTC1477 and the LT1304 5-V boost regulator. In this application, the LTC1477 serves to protect against short circuits (850-mA limit selected) and completely disconnects the load under a low-battery condition. In shutdown, the circuit draws less than 25 µA from the battery.

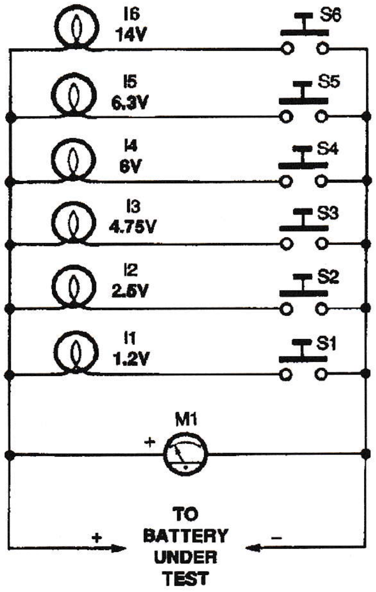
DUAL BATTERY CAPACITY INDICATOR



ELECTRONICS NOW ***Fig. 15-11***

This indicator circuit uses two separate expanded meter scale circuits and can be calibrated for use with two different types of batteries.

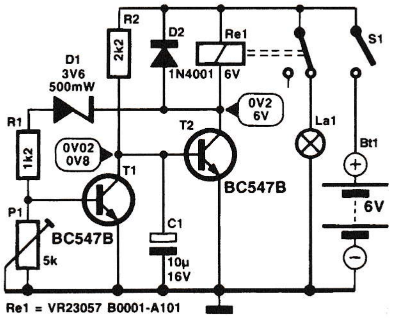
BATTERY TESTER



POPULAR ELECTRONICS *Fig. 15-12*

Although deceptively simple, this battery tester can help you weed out marginal cells that might otherwise test good. Six incandescent lamps, chosen for their voltage and current ratings, are selected as a load for the battery under test. The meter (M1) and the lamp's brightness will give a good indication of a battery's output capacity. In addition, because the inrush current that occurs when the lamp is first connected across the battery is much higher than the rated operation value, the circuit makes it easy to spot marginal cells. To use the circuit, connect a battery and observe the measured voltage on M1. Then close the switch that corresponds to the meter's reading and/or the battery's rated voltage and observe the brightness of the appropriate lamp. Be careful to select the right lamp for testing. Never test using a lamp whose voltage rating is more than 30 percent lower than the battery's rating. Otherwise, damage to the lamp could result if the battery under test is good.

CAMCORDER BATTERY PROTECTOR



ELEKTOR ELECTRONICS *Fig. 15-13*

Many camcorder enthusiasts use their spare battery for powering video lights. Many such lights give no indication when the battery has gone flat. This can be avoided by the use of this protection circuit. When it gets switched on, the potential across C1 is zero, so that T2 is cut off, the relay is inactive, and the indicator lamp lights. As long as the battery voltage remains above a certain level, T1 is on and holds the base of T2 at earth potential. In this state, only a small current is drawn. When the battery voltage is no longer higher than the sum of the zener voltage, the potential set by divider R2-P1, and the drop across the base-emitter junction of T1, this transistor is cut off, whereupon C1 is charged via R2. When the potential across C1 has risen to a value high enough for T2 to be switched on, the relay is energized, and its contact disconnects the lamp from the battery. Because the current drain (≤70 mA) is then determined almost entirely by the relay, it is essential to remove, or disconnect, the battery from the light unit. The switch-off voltage level, set with P1, should be about 1 V per battery cell.

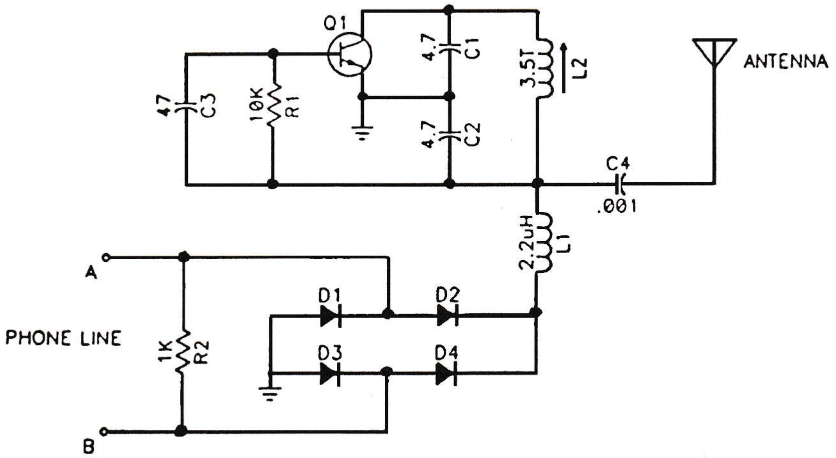
16

Bugging Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Low-Power FM Telephone Bug
FM Telephone Bug
Telephone Bug

LOW-POWER FM TELEPHONE BUG

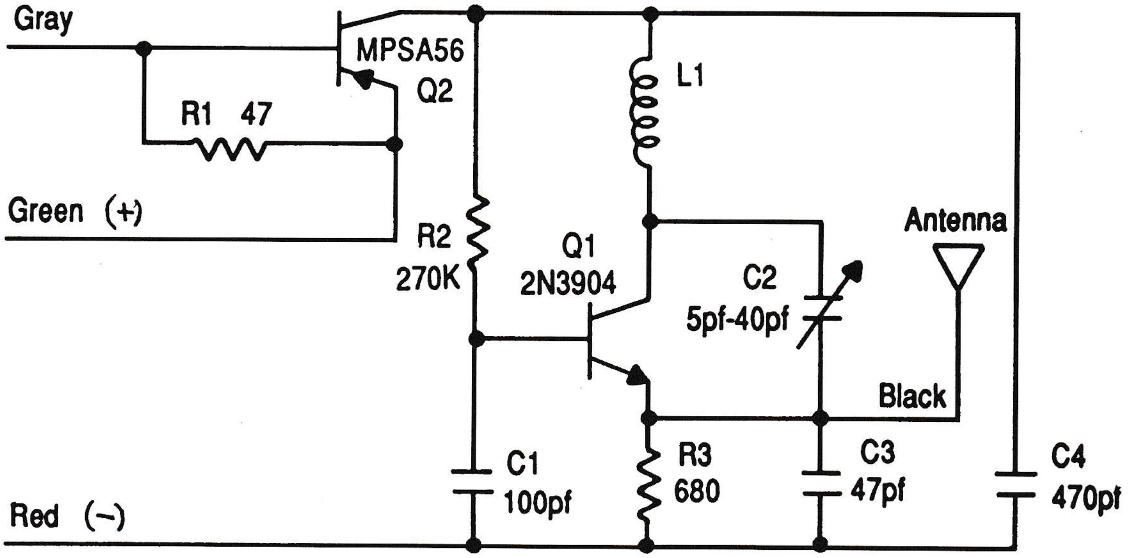


NUTS AND VOLTS MAGAZINE ***Fig. 16-1***

Q1 (2N3904) is an oscillator tuned to a quiet spot in the FM broadcast band. D1 through D4 (1N914) ensure proper polarity. Dc from the line powers the bug. Audio on the line causes incidental FM, which can be heard on an FM receiver tuned to the frequency of the oscillator.

Warning: Use of this device for certain purposes could violate federal and/or state laws and subject the violator to prosecution.

FM TELEPHONE BUG



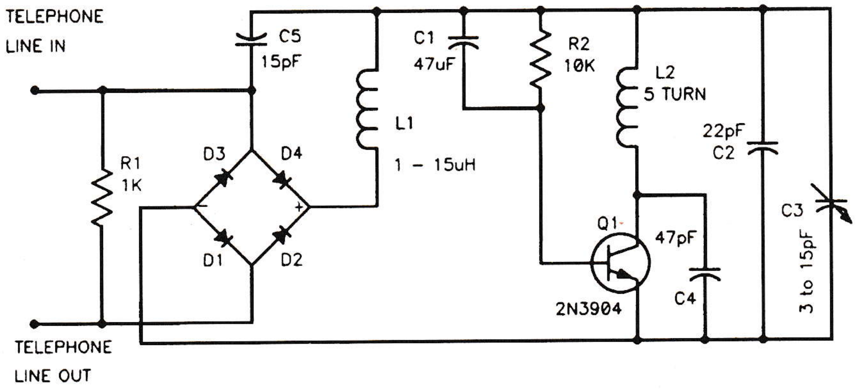
NUTS AND VOLTS MAGAZINE

Fig. 16-2

Q1 is an oscillator tuned to a quiet spot in the FM broadcast band. Dc from the line powers the bug. Connect the gray wire to the phone in place of the green wire, and the green wire on the bug to the green line wire. The red wire goes to the red phone line wire. Audio on the line causes incidental FM, which can be heard on an FM receiver tuned to the frequency of the oscillator. Because this device "sees" the full line voltage, Q2 is a high-voltage PNP MPSA56 transistor.

Warning: Use of this device for certain purposes could violate federal and/or state laws and subject the violator to prosecution.

TELEPHONE BUG



NUTS AND VOLTS MAGAZINE *Fig. 16-3*

Q1 is an oscillator tuned to a quiet spot in the FM broadcast band. Dc from the line powers the bug. Diodes D1 through D4 ensure proper polarity. R1 maintains a suitable voltage drop for the bug. Audio on the line causes incidental FM, which can be heard on an FM receiver tuned to the frequency of the oscillator.

Warning: Use of this device for certain purposes could violate federal and/or state laws and subject the violator to prosecution.

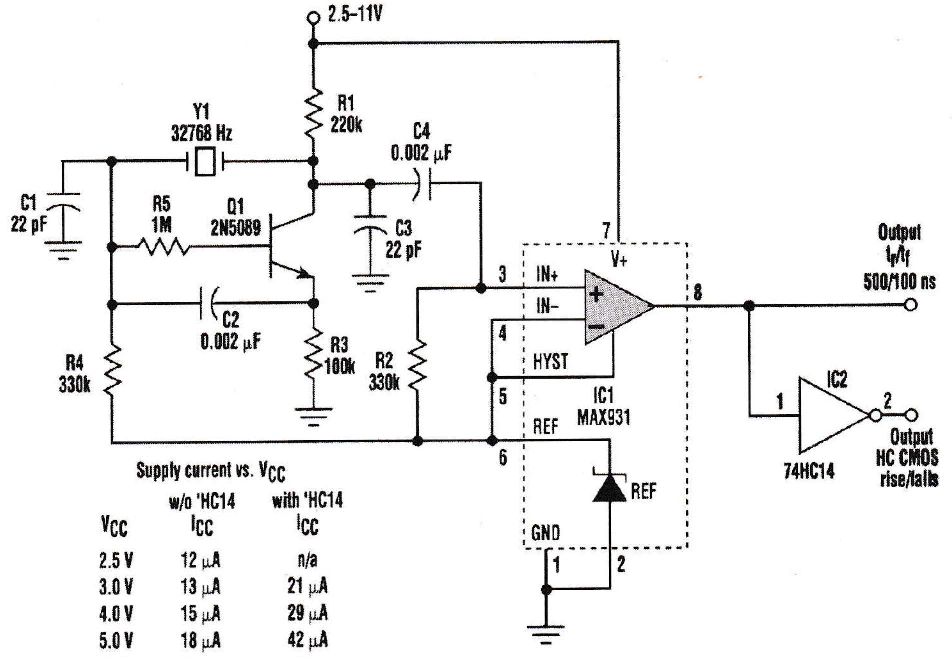
17

Clock Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Low-Power Wide-Supply-Range Clock
Simple 5.2-kHz Clock

LOW-POWER WIDE-SUPPLY-RANGE CLOCK



Supply current vs. V_{CC}

V_{CC}	w/o 'HC14 I_{CC}	with 'HC14 I_{CC}
2.5 V	12 μA	n/a
3.0 V	13 μA	21 μA
4.0 V	15 μA	29 μA
5.0 V	18 μA	42 μA
6.0 V	23 μA	59 μA
7.0 V	24 μA	n/a
8.0 V	28 μA	n/a
9.0 V	31 μA	n/a
10.0 V	35 μA	n/a

ELECTRONIC DESIGN

Fig. 17-1

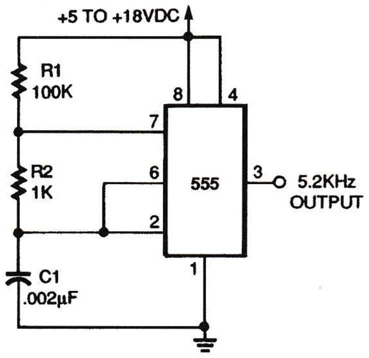
This 32-kHz, low-power clock oscillator offers numerous advantages over conventional oscillator circuits based on a CMOS inverter.

Many times, 32-kHz oscillators are used to generate a system clock or an auxiliary sleep clock in low-power instruments and microcontrollers. The typical implementation uses a CMOS inverter (74HC04 or CD4049UB type). Inverter circuits present problems, though. Supply currents fluctuate widely over a 3- to 6-V supply range, and currents below 250 μA are difficult to attain. Operation can be unreliable for wide variations in supply voltage. A very low power crystal oscillator solves these problems. Drawing only 13 μA from a 3-V supply, it consists of a single-transistor amplifier/oscillator (Q1) and a low-power comparator/reference device (IC1). Q1's base is biased at 1.25 V via R5, R4, and the reference in IC1. V_{BE} is about 0.7 V, placing the emitter at approximately 0.5 V. This constant voltage across R3 sets the transistor's quiescent current at 5 μA, which fixes the collector voltage at about 1 V below V_{CC}. The amplifier's nominal gain (R_1/R_2) is approximately 2 V/V. The crystal and load capacitors (C1 and C3) form a feedback path around Q1, whose 180° of phase shift causes the oscillation. C4 cou-

LOW-POWER WIDE-SUPPLY-RANGE CLOCK *(Cont.)*

ples this signal to the comparator input; the input's quiescent voltage (1.25 V) is set by the reference via R2. The comparator's input swing is thus centered around the reference voltage. Operating at 3 V and 32 kHz, IC1 draws about 7 μA.

SIMPLE 5.2-kHz CLOCK



This circuit will produce a clock signal of 5.2 kHz using a NE555 timer.

ELECTRONICS NOW

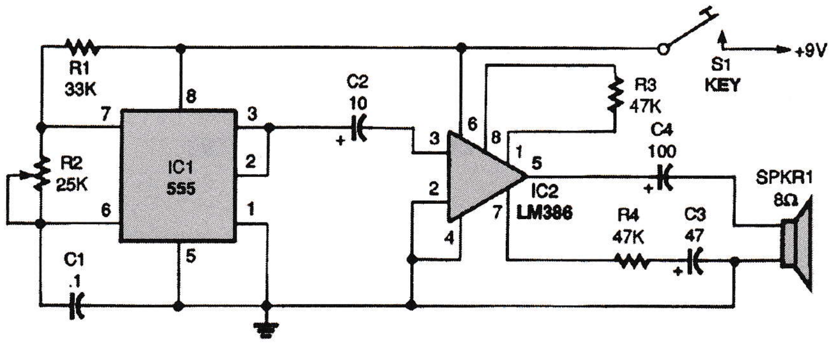
Fig. 17-2

18

Code-Practice Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

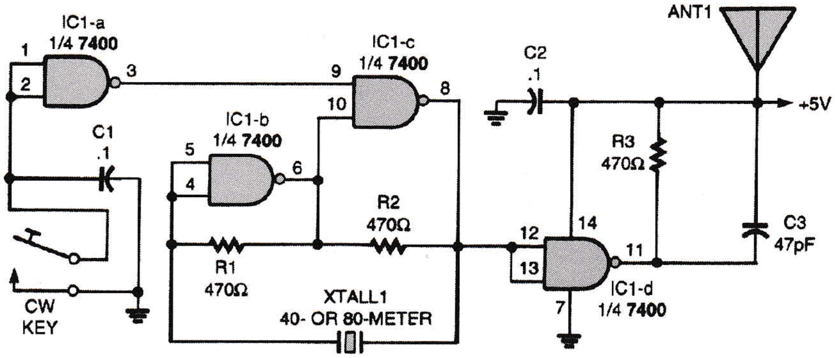
MORSE CODE OSCILLATOR



POPULAR ELECTRONICS *Fig. 18-1*

The circuit is built around a 555 oscillator (IC1) and an LM386 audio amplifier (IC2). The 555 circuit is an astable oscillator, with the chip output retriggering the circuit. When the key (S1) is pressed, it activates the circuit. The 555 oscillates at a frequency determined by R1, R2, and C1. Potentiometer R2 is used to adjust the tone frequency of the oscillator. Some of the output current of IC1 is coupled to IC2 via a 10-°F capacitor, C2, so that it will be sufficient to drive a loudspeaker. Because the circuit has no gain control, the volume depends on the size and wattage of the speaker.

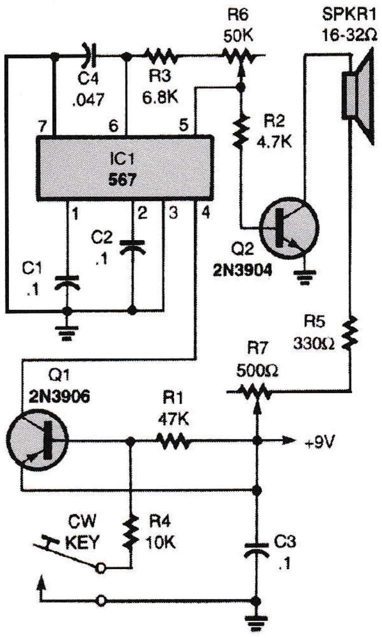
CRYSTAL-CONTROLLED CODE-PRACTICE TRANSMITTER



POPULAR ELECTRONICS *Fig. 18-2*

When the CW key is closed, IC1-a's output goes high, allowing IC1-b and IC1-c to oscillate. The crystal supplies the feedback path setting the oscillator's operating frequency. The circuit will operate on the 40- and 80-m bands. Section IC1-d isolates the oscillator from the short antenna, ANT1. A clip lead should do here to get the signal out and about for operation. Tune your ham-band receiver to the crystal's frequency and key down. If the receiver doesn't have a CW mode, turn on the BFO and tune for the desired CW tone.

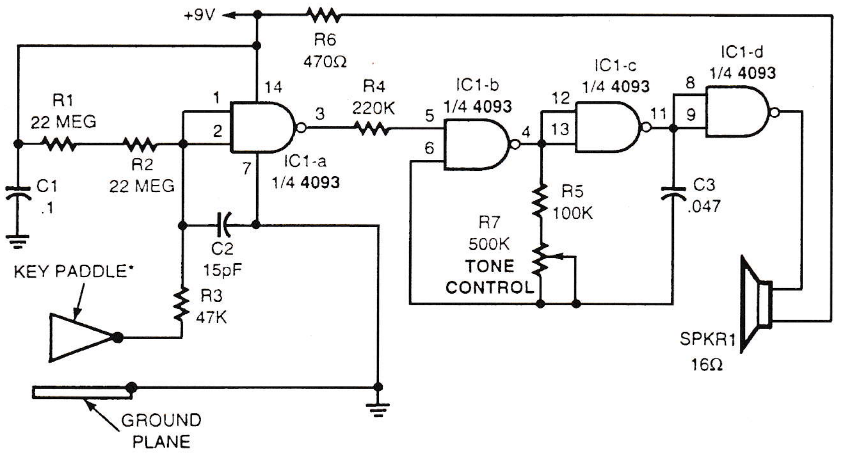
PLL CODE-PRACTICE OSCILLATOR



POPULAR ELECTRONICS *Fig. 18-3*

This CPO uses a 567 phase-locked loop, IC1, as the variable tone generator. The oscillator's frequency is set by R6, and the frequency range can be changed by selecting a different-value capacitor for C5. To lower the oscillator's frequency range, make the value of C_5 larger, and to increase the frequency range, reduce C_5. A general-purpose 2N3906 PNP transistor, Q1, supplies power to the 567 through pin 4 each time that the CW key is closed. Meanwhile, Q2, a general-purpose 2N3904 NPN transistor, buffers the oscillator's output and drives the speaker. Potentiometer R7 sets the output volume.

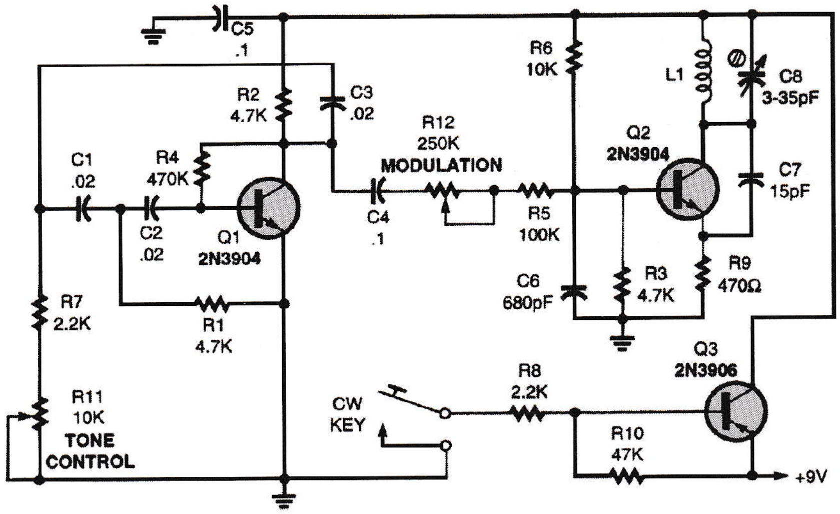
TOUCH-OPERATED CODE-PRACTICE OSCILLATOR



POPULAR ELECTRONICS ***Fig. 18-4***

A touch-operated CPO is shown in the figure. The gates of IC1-a are biased high through the two 22-MΩ resistors (R1 and R2), keeping its output low. Gates IC1-b and IC1-c are connected in an audio oscillator circuit that can operate only when pin 5 of IC1-b is high. The last gate of the 4093, IC1-d, adds isolation to the oscillator's circuit and drives the speaker (SPKR1). Touching the key paddle and ground plane lowers IC1-a's input gate voltage to near zero, allowing the output at pin 3 to go high. The tone generator then turns on and sends out an audio note. The touch key paddle and ground plane can be made from a circuit board or any other conductible material. Note that the ground plane should lie flat for a hand rest and the key paddle should be positioned for ease of touch.

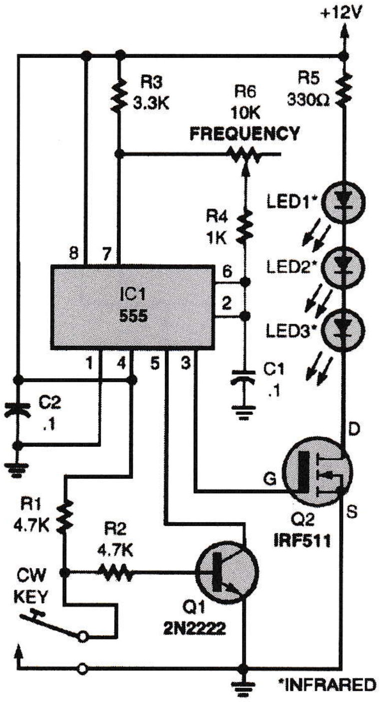
WIRELESS FM CODE-PRACTICE TRANSMITTER



POPULAR ELECTRONICS *Fig. 18-5*

The circuit shown is a low-power, tone-modulated FM transmitter that can be used with any FM broadcast receiver for code practice. Transistor Q1 and its associated components make up a phase-shift audio-frequency generator circuit. Potentiometer R11 sets the tone frequency. Transistor Q2 is connected in a high-frequency RF oscillator circuit that operates in the FM broadcast band. Potentiometer R12 sets the modulation level. Transistor Q3 operates as a switch, turning on the FM transmitter each time the CW key is closed. Coil L1 is a homemade air-wound coil. Take a 6½-in length of 20-gauge enamel-covered wire and close-wind it around a ¼-in-diameter form; leave about ¼ in free at each end. Remove the insulation from the ends and slide the coil off the form. The overall length of the finished coil should be about ¼ in. Set R11 and R12 to midposition and close the CW key. Then set your FM receiver to a clear spot on the low end of the dial and slowly adjust C8. Once the tone is heard, R11 can be set for the desired tone frequency and the tone level set by R12. If your oscillator won't tune to the top end of the band, carefully stretch the windings of L1 and retune. The circuit's operating range can be increased by adding a very short antenna to the emitter of Q2.

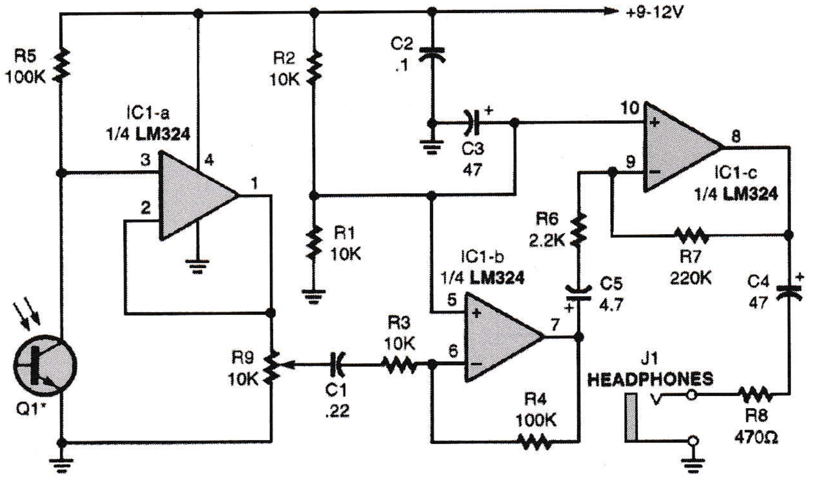
INFRARED CODE-PRACTICE TRANSMITTER



POPULAR ELECTRONICS *Fig. 18-6*

A 555 timer, IC1, is connected in an audio-oscillator circuit with its frequency set by potentiometer R6. Transistor Q1, with the CW key up, is biased on, thereby holding pin 5 of IC1 low and keeping it turned off. The 555 timer's output, at pin 3, ties to the gate of a power hexFET, Q2, which drives the three IR emitters, LED1 to LED3. Placing the CW key in the down position turns the 555 oscillator on. That sends out the audio tone signal via IR.

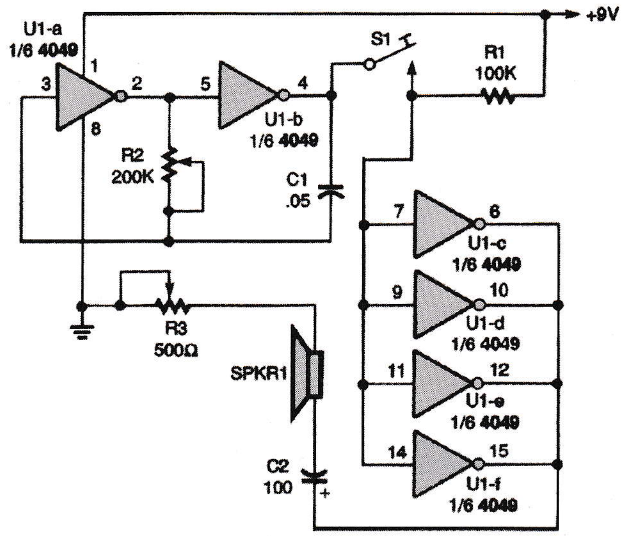
INFRARED CODE-PRACTICE RECEIVER



POPULAR ELECTRONICS *Fig. 18-7*

An IR phototransistor, Q1, is directly-coupled to the input of op amp IC1-a. The output of IC1-a is fed through the gain-control potentiometer R9 to the input of op amp IC1-b, which has a voltage gain of 10. Section IC1-b's output drives IC1-c, which has a voltage gain of 100. The output of IC1-c supplies audio to the headphones via J1. The IR phototransistor can be mounted in reflectors to increase the CPO's operating range.

CODE-PRACTICE OSCILLATOR



POPULAR ELECTRONICS *Fig. 18-8*

This versatile code-practice oscillator has a variable frequency and volume control. The unit is especially suitable for use by small groups that are interested in learning and practicing code. A single 4049 CMOS hex inverting buffer is the heart of the oscillator, with inverters U1-a and U1-b making up the variable audio-oscillator circuit. The oscillator's output is coupled to the speaker-driver circuit through the CW (Morse code) key S1. The audio frequency of the oscillator (hence, its tone) is varied by the potentiometer. R3 is used to vary the speaker's volume.

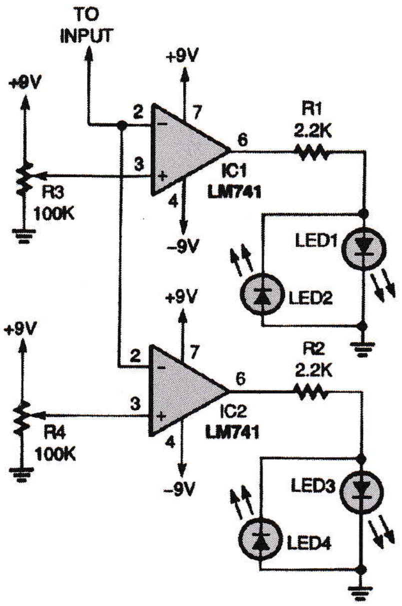
19

Comparator Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Dual-Voltage Comparator
Voltage Window Comparator
Four-Level Voltage Comparator
Adjustable Comparator
Fast TTL-Compatible Comparator
Voltage Comparator

DUAL-VOLTAGE COMPARATOR

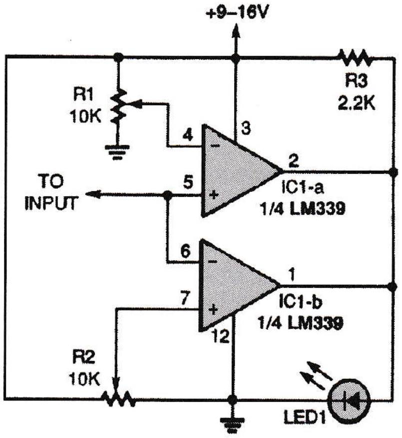


POPULAR ELECTRONICS *Fig. 19-1*

Use this dual comparator to monitor a battery while it's charging; the circuit will let you check for under- and overvoltage conditions.

R3 and R4 set the trip levels at which the LEDs are activated. Almost any standard LEDs can be used. LED current is about 3 to 4 mA, as determined by the op-amp capability and resistors R1 and R2.

VOLTAGE WINDOW COMPARATOR

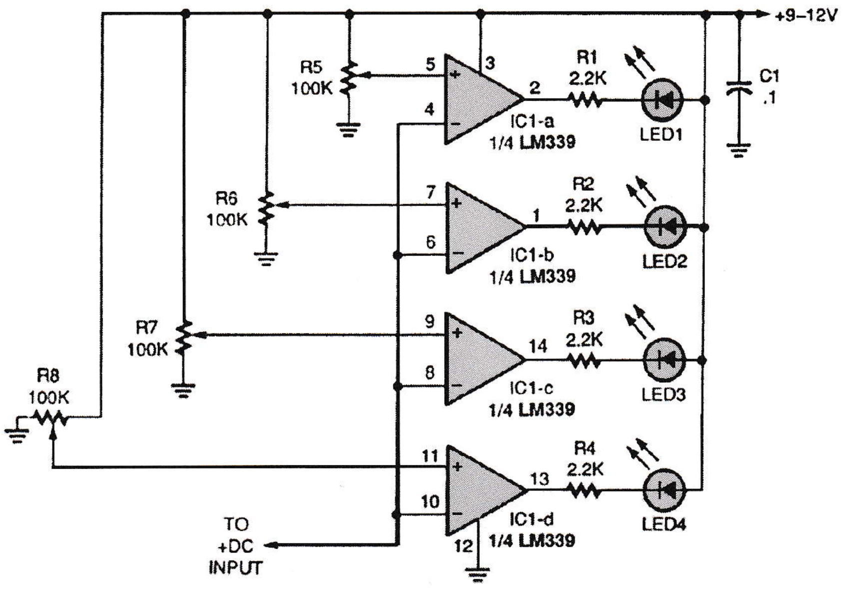


POPULAR ELECTRONICS *Fig. 19-2*

This window comparator determines if a voltage is between two limits, upper and lower.

Using a digital voltmeter, set the reference voltages in this voltage window to the same values. Then vary one to set the width of the window; when the input voltage is within the window area, LED1 will light.

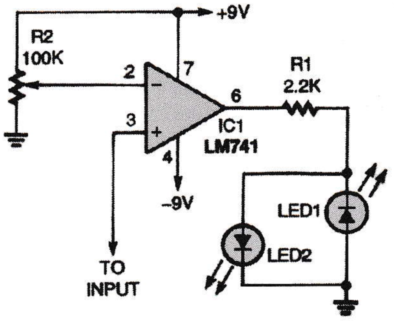
FOUR-LEVEL VOLTAGE COMPARATOR



POPULAR ELECTRONICS *Fig. 19-3*

This four-level voltage detector can be used as a bar-graph voltmeter. Simply set each potentiometer (R5 to R8) for a specific voltage.

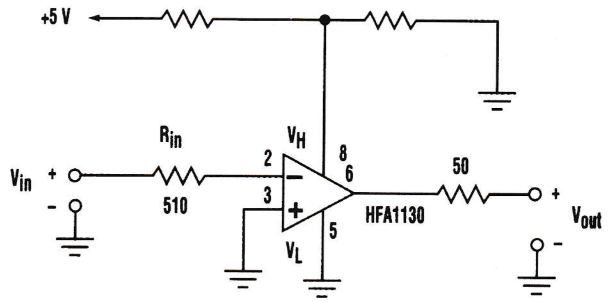
ADJUSTABLE COMPARATOR



The setting of potentiometer R2 determines the level at which this comparator circuit will switch. The output can be used to drive any device needing a comparator signal, within the drive capabilities of the particular op amp used (741 is shown).

POPULAR ELECTRONICS *Fig. 19-4*

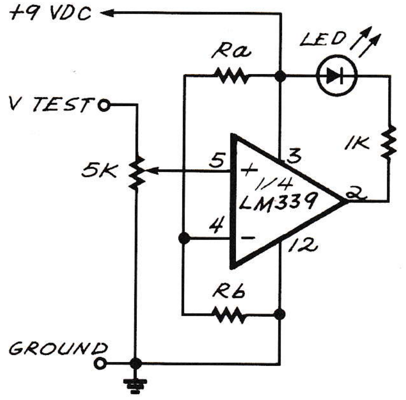
FAST TTL-COMPATIBLE COMPARATOR



ELECTRONIC DESIGN ANALOG APPLICATIONS *Fig. 19-5*

The HFA1130 by Harris Semiconductor is useful as a comparator. Depicted is an inverting 2-ns comparator with TTL-compatible output levels that are realized by using the HFA1130 output-limiting, current-feedback amplifier.

VOLTAGE COMPARATOR



The LED turns on when the input voltage at pin 5 of the LM339 falls below the reference voltage at pin 4.

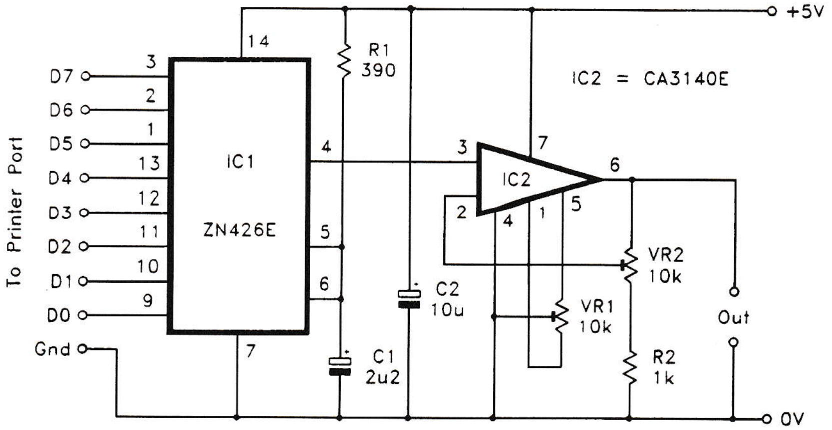
ELECTRONICS NOW *Fig. 19-6*

20

Computer-Related Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

PRINTER-PORT D/A CONVERTER

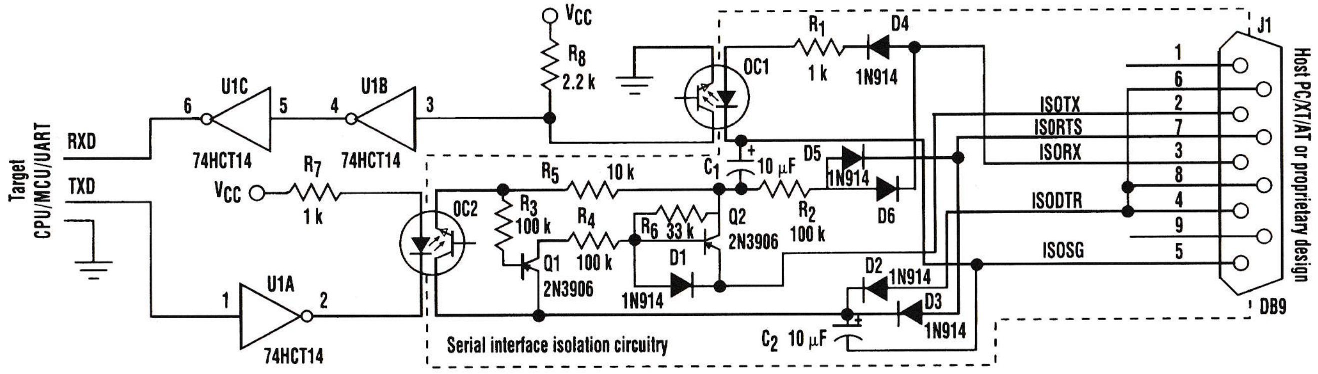


EVERYDAY PRACTICAL ELECTRONICS ***Fig. 20-1***

Where eight latching outputs are available, the Ferranti ZN426E probably represents the simplest means of providing an analog output. The figure shows the circuit diagram for a PC analog output port based on this chip. The full-scale output voltage is equal to the reference voltage fed to pin 5. This terminal can be fed from an external reference voltage of up to 3 V, but, in most cases, the built-in 2.55-V reference is perfectly adequate. The output voltage from IC1 (in volts) is equal to the value written to the printer port multiplied by 0.001. In most practical applications, this output-voltage range will have to be modified using an amplifier or an attenuator. In virtually all cases it will be a small amount of amplification that is required. This is the purpose of IC2, which also provides output buffering. The noninverting-mode amplifier IC2 can have its closed-loop voltage gain varied from unity to about 11 times by means of preset VR2.

The maximum output voltage of IC2 is about 2 V less than its supply potential (about 3 V) if it is powered from a 5-V supply. Therefore, maximum output voltages of more than 3 V require IC2 to be powered from a higher supply potential of up to about 30 V. This means using a separate supply for IC2 because the converter circuit must be powered from a 5-V supply. If preset VR1 is included, the best way to find the correct setting is to first write a low value to the port and adjust VR1 for the correct output voltage. Then write a high value to the port and adjust VR2 for the appropriate output voltage. Repeat this process a few times until no further adjustment is needed. If VR1 is omitted, write a value of 255 to the port and then adjust VR2 for the required maximum output voltage. Reasonable accuracy should then be obtained over the full range of output voltages. Using GW BASIC, it is just a matter of writing the values to the appropriate address using the OUT command. For example, OUT &H378,123 would write a value of 123 to a digital-to-analog converter connected to printer port LPT1.

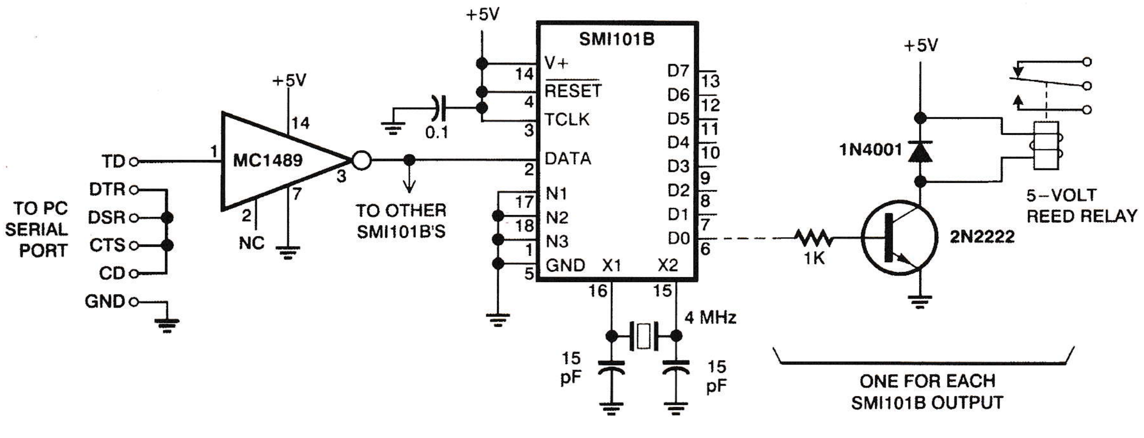
ISOLATED RS232 INTERFACE



ELECTRONIC DESIGN *Fig. 20-2*

Electrical isolation of 1500 V or higher is possible with this cost-effective RS232 interface. It is ideal for various data-communication designs, including medical instrumentation and devices within harsh electrical environments. The interface uses the host's TXD (transmit data), RXD (receive data), DTR (data terminal ready), and RTS (request to send) lines to provide power. For fully duplexed operation, the host's communications port should be set up so that its RTS is off (at negative voltage). Half-duplex operation can use the host's TXD negative voltage, available through D6, to run the circuitry. Sending a low bit (space state) to the host is just the opposite. This time, the required positive voltage is supplied from the host via diodes D2 and D3, and is routed through Q1 and D1 to DB9-2.

COMPUTER SERIAL PORT RELAY CONTROLLER



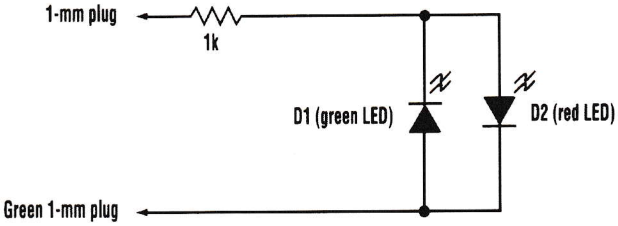
```
10 OPEN "COM1:9600,N,8,1" FOR OUTPUT AS #1   ' open serial port
20 PRINT #1,"0N1" + CHR$(13)                 ' turn on relay 1 of processor 0
30 FOR I=1 TO 10000: NEXT I                  ' pause a moment
40 PRINT #1,"0F1" + CHR$(13)                 ' turn it off again
```

ELECTRONICS NOW

Fig. 20-3

Decoding RS-232 signals is a job for a microcontroller (single-chip computer). Fortunately, you don't have to program the microcontroller yourself; you can get a PIC 16C54A microcontroller already programmed for exactly this job from Stone Mountain Instruments. Shown is the circuit and the BASIC program to demonstrate how it works. Each SMI101B has eight logic-level outputs. Further, you can connect up to seven SMI101Bs to a single serial port. The three N pins give each SMI101B a distinctive identifying number, from 0 to 6. If all three are grounded, the identifier is 0; if N1 is connected to +5 V, the identifier is 1, etc. At power-up, all the data outputs are off (logic 0). To turn an output on, send a command of the form "xNy, where x is the identifier of the SMI101B and y indicates which data output you want to switch. To turn the outputs back off, use an F in place of an N (e.g., 0F3). All communication is done with 8 data bits and no parity bits. The baud rate is 9600 baud with a 4-MHz crystal, or 1200 baud with a 500-kHz ceramic resonator. As shown in the diagram, each relay requires a transistor to drive it, along with a resistor and a protective diode. To cut down the total number of components, you can use a relay driver chip, such as the Allegro UDN2987, which contains everything necessary to drive eight small relays from logic-level signals.

ULTRA-SIMPLE RS232 TESTER

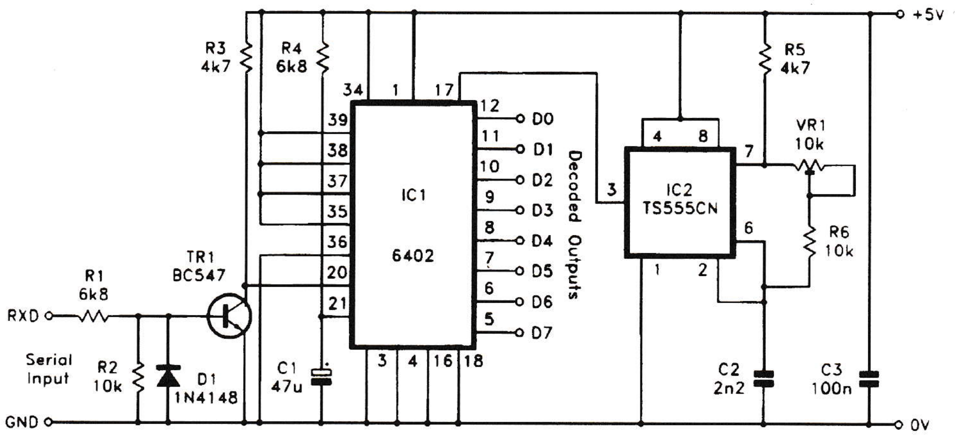


ELECTRONIC DESIGN

Fig. 20-4

The tester consists of no more than a two-color LED (or a red and a green LED connected in anti-parallel) in series with a 1-kΩ resistor. The free ends of the resistor and the LEDs should preferably be terminated in 1-mm plugs. One of the free ends should be covered in green sleeving, or use a green 1-mm plug. This is touched on pin 7 (signal ground) of the connector under test. The other end is touched on each pin to be tested, in turn. The LED (or LED pair) is connected so that a positive voltage emits a red glow and a negative voltage causes a green glow. Sometimes, an RS232 input will be found that has an internally connected pull-up to drive a particular default RS232 level when unconnected. Although this will cause the tester to glow as if the pin were an output, it will do so with markedly less brightness. Bearing this in mind, the tester can be used to diagnose most RS232 problems at the electrical level.

RS232-TO-PARALLEL DATA CONVERTER

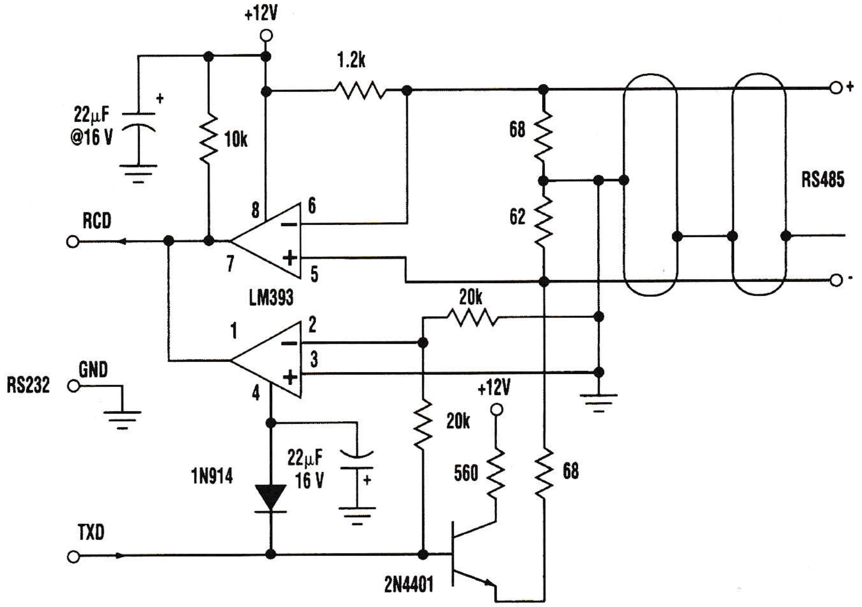


EVERYDAY PRACTICAL ELECTRONICS

Fig. 20-5

A simple serial decoder circuit based on a 6402 UART (IC1) is shown in the figure. The RS232C input signal is at signal levels of about ±12 V; these must be converted to standard 5-V logic levels before being applied to the serial input of IC1. A simple common-emitter switching stage based on transistor TR1 is used to provide the conversion to normal logic levels, and it also produces the necessary inversion of the input signal. Resistor R4 and capacitor C1 provide IC1 with a positive reset pulse at switch-on. The inputs at pins 35 to 39 program the word format; the method of connection shown in the figure provides a format on 1 start bit, 8 data bits, 1 stop bit, and no parity. Pin 34 is connected to the +5-V rail so that the binary pattern on pins 35 to 39 is loaded into IC1's control register. The decoded bytes of parallel data are available at pins 5 to 12, and pin 4 is connected to the 0-V rail so that these outputs are permanently enabled. In a stand-alone application, the tristate capability of these outputs is not of great value, but, if necessary, this facility can be utilized by applying a control signal to pin 4 of IC1.

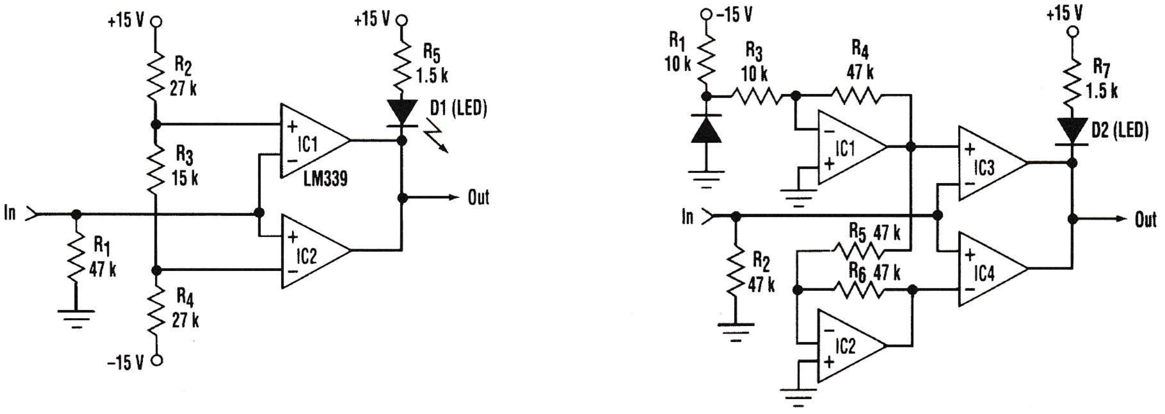
THREE-WIRE RS232-TO-RS485 CONVERTER



ELECTRONIC DESIGN *Fig. 20-6*

This circuit needs only a minimal three-wire RS232 implementation plus one +10- to +15-V supply voltage to provide a transparent link capable of sending data at transmission rates up to tens of kbaud. Circuit operation is as follows: When both the 232 and the 485 are idle (232 port in MARK state and no 485 device active), the 485 link is held in the 1 state by the 1200-Ω pullup. This causes the top comparator to hold the 232 RCD line negative and therefore in MARK state. When a character is transmitted by the 232 port, it begins with a positive-going (SPACE state) START bit on the TXD line. In response, the 2N4401 pulls the "−" 485 conductor more positive than the "+" wire, thus transmitting the START down the 485 cable. Meanwhile, the bottom comparator holds the "wire-or" (LM393s have open-collector outputs) 232 RCD low, blocking the 232 port from "hearing" its own transmission. The receive side of the 232 port remains idle. The rest of the bits of the character follow along in the same fashion. When a character originates somewhere along the 485 bus, it begins with a 485 transceiver going active and driving the "−" line above the "+." This causes the upper half of the LM393 comparator to release RCD, and this time the bottom comparator doesn't prevent it from being pulled high. The data bits are thus allowed to arrive at the RS232 port, where they appear at standard RS232 bipolar voltage levels. The common-mode voltage range and noise-rejection capabilities of this circuit are compatible with standard 485 specifications. The converter's speed is mainly limited by the loading of the comparator outputs because of cable capacitance.

RS232 TEST CIRCUIT

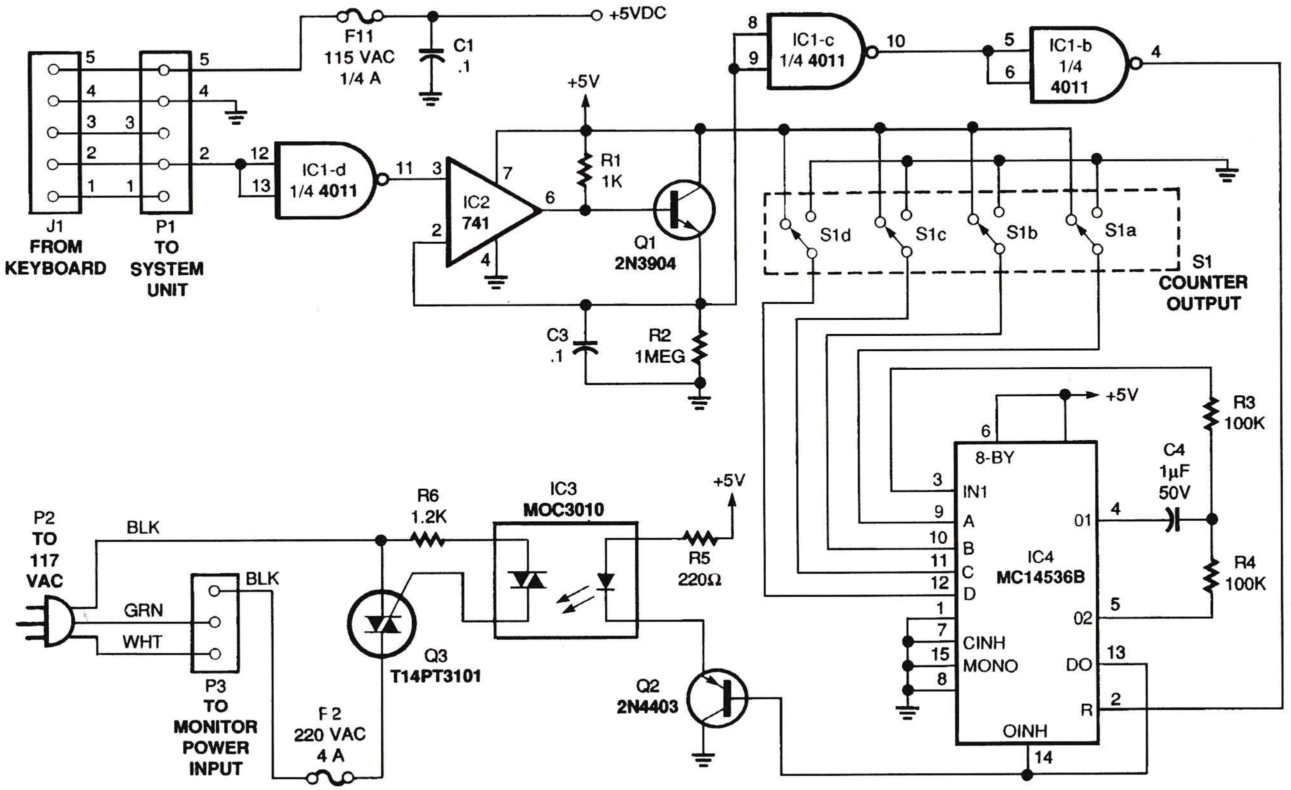


ELECTRONIC DESIGN

Fig. 20-7

The tester is basically a window comparator, in which the low and high levels are set at +3.0 V and −3.0 V, respectively, by resistors R2, R3, and R4. Resistor R1, when not driven by an RS232 output, will have a low voltage across it (approximately 0 V), and the LED D1 at the output of the comparators is turned off. If the unknown wire of the cable that is tested is an RS232 output, then it will drive the In point to a voltage either between +3 and +12 V or between −3 and −12 V. In both cases, one of the two comparator outputs will be driven low. This turns the LED on, indicating the presence of a wire connected to an RS232 output. The comparator should be an LM339 type or equivalent (with an open-collector output). The disadvantage of this scheme is that the thresholds are very sensitive to the supply variations. To eliminate this problem, the thresholds at the inputs of the comparators can be created using the normal forward drop on a simple diode and then be brought to the necessary levels by IC1 (+3 V at its output) and IC2 (a simple inverter).

PC POWER PINCHER

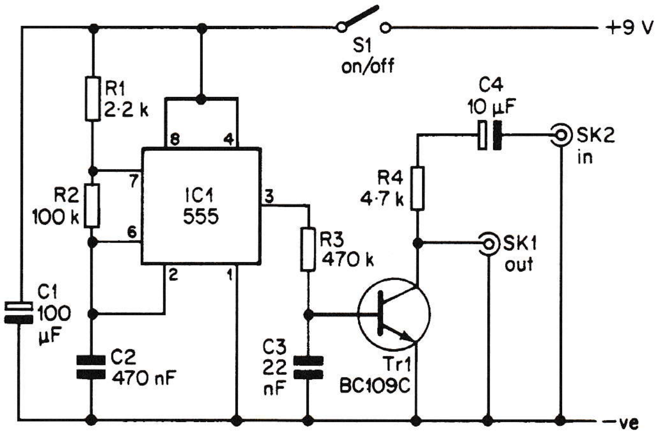


ELECTRONICS NOW

Fig. 20-8

The figure is a diagram of the circuit, in which a low-frequency oscillator continually drives the input of a multistage binary counter. Whenever the count reaches the setting selected by DIP switch S1, the circuit turns triac Q3 off, thereby interrupting the flow of 120-Vac to the monitor. A keyboard-monitoring circuit keeps the video monitor powered up during active use by resetting the counter every time a key is pressed. As long as a key-press occurs before the time delay expires, the counter keeps resetting. Hence, it never times out, and the monitor continues to receive power. When the computer turns on, a routing in its basic input/output system (BIOS) polls the keyboard. The keyboard, in turn, sends a series of data pulses back to the microprocessor to indicate its status. The data line is normally high (+5 V), and the pulses are low-going transitions. The first stage of the power pincher inverts the sense of the logic to normally low with high-going transitions.

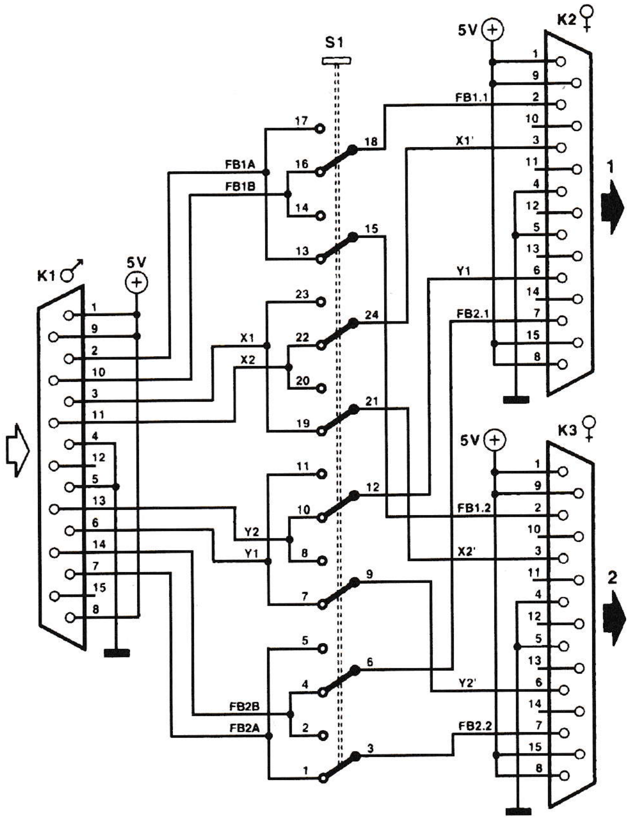
COMPUTER VOICE



ELECTRONIC EXPERIMENTERS HANDBOOK ***Fig. 20-9***

This circuit will enable one to simulate the "computer voice" effect commonly heard in films, ads, and TV programs. It consists of two sections: an oscillator to provide the modulation signals, and the modulator itself. The oscillator uses a 555 timer chip in the astable multivibrator mode, and the frequency of operation has been set at about 10 Hz by the values given to R1, R2, and C1. A very simple modulator is used, but this is quite acceptable. Distortion produces new frequencies that help to change the voice signal and make it sound less like the original. A large amount of distortion is obviously not desirable because it would severely impair the intelligibility of the output signal. Transistor TR1 is used as a sort of voltage-controlled resistor, and, in conjunction with R4, it forms a voltage-controlled attenuator.

JOYSTICK CHANGEOVER

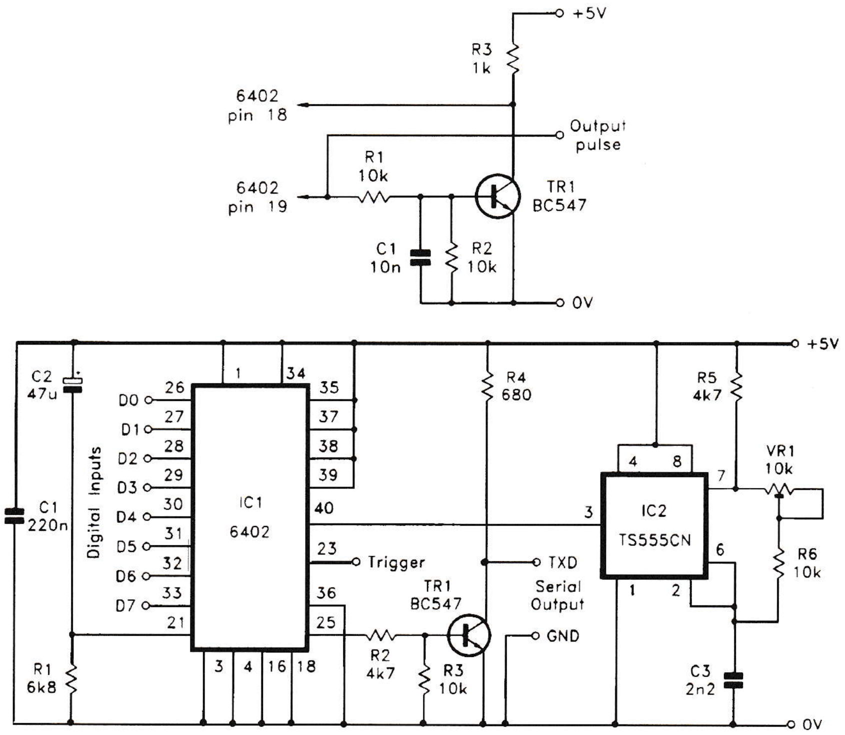


ELEKTOR ELECTRONICS

Fig. 20-10

Many I/O cards and sound cards have a standard provision of a 15-way connection for two joysticks. Unfortunately, many programs use the connections for only one joystick. Because often several kinds of joystick are used (in particular, modern flight simulators have provision for very advanced, specialized joysticks), it is frequently necessary to change over connectors. As the joystick connectors are invariably found at the back of the computer, this can be a tedious operation. Moreover, in the long term, it does not do the connectors any good. The present circuit replaces this changing over of connectors by a simple push on a button. In this way, two joysticks can be connected to the computer in a simple and user-friendly way. An eight-pole switch arranges the interconnection of controls X and Y and fire button 1 and fire button 2.

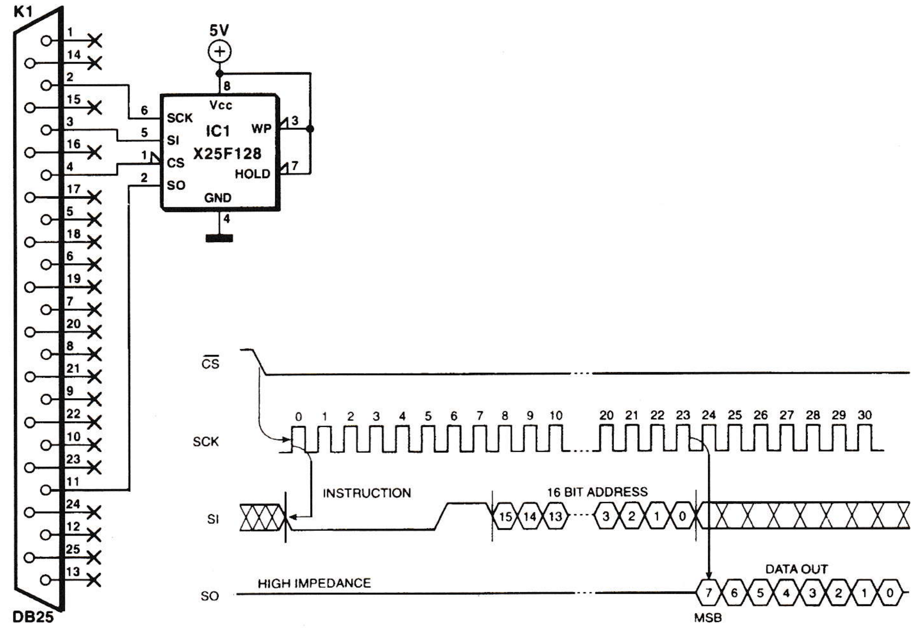
SERIAL TRANSMITTER CIRCUIT



EVERYDAY PRACTICAL ELECTRONICS ***Fig. 20-11***

This circuit provides basic parallel-to-serial conversion, with the control inputs connected to provide a word format of 1 start bit, 8 data bits, 1 stop bit, and no parity. VR1 should provide operation at 1200 baud. Adjusting VR1 is just a matter of using trial and error to locate a setting that enables the computer to reliably decode the serial data. If a frequency meter is available, adjust VR1 for an output frequency of 19.2 kHz at pin 3 of IC2.

FLASH EEPROM COMMUNICATOR

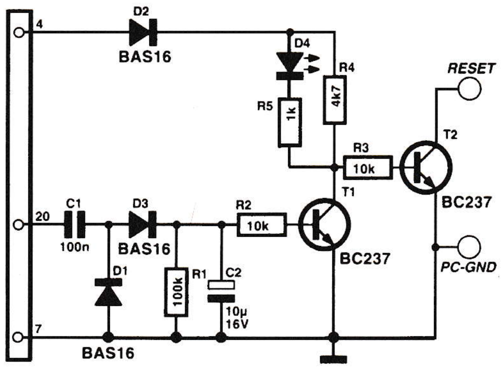


ELEKTOR ELECTRONICS

Fig. 20-12

Modern equipment frequently uses serial EEPROMS to store data that must not be lost. With the circuit shown, it is possible to program or read such an IC via the Centronics port of a computer. Because the serial interface of a flash EEPROM is identical to that of an EEPROM, the two devices can communicate with each other. This means that the present circuit can be used for either device. The IC is enabled via CS (Chip Select). The command "read" followed by the address that needs to be read is set on to the high level is a little low, some 4.7 kΩ pull-up resistors can be added between the Centronics outputs and the positive supply line (not the SO line).

PC WATCHDOG

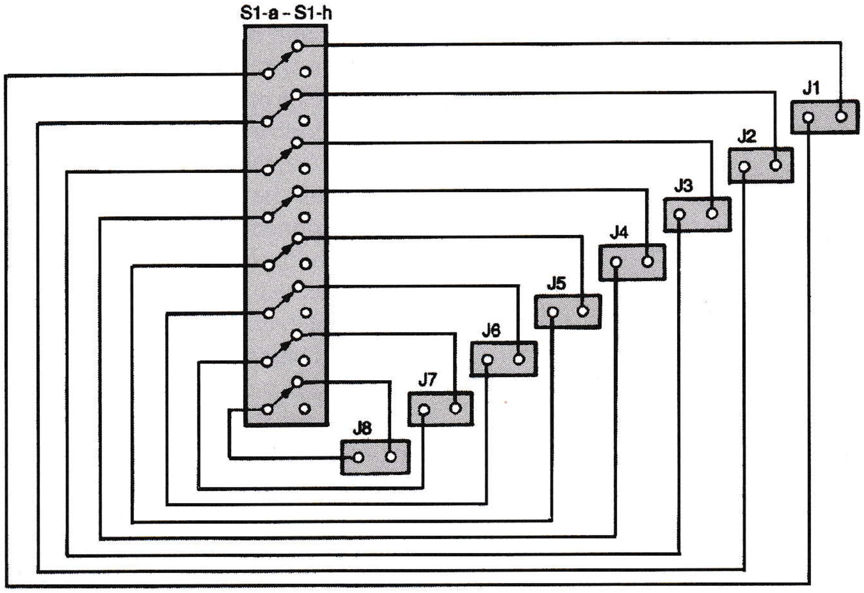


The watchdog is intended to monitor a microprocessor and determine whether it functions correctly or not. It and its software are suitable for use in the background with any PC that runs under DOS or Windows. The hardware is linked to the serial interface, which is then controlled by the software. After the computer has been switched on, the data connections at the serial interface are low. The watchdog software is started at the same time as the selected application program. It provides a permanent rectangular signal at pin 20, which results in C2 being charged and T2 conducting. Pin 4 is made high so that the computer cannot receive a RESET signal. This condition is stable as long as the program runs. If the computer fails (crashes), the rectangular signal falls out and C2 is discharged via R1. This causes T1 to be switched off, whereupon the base of T2 goes high. This transistor is then on and pulls the RESET line of the computer to ground. The computer then restarts. Note that the circuit works only if a computer RESET also causes the serial interface to be reset because that is essential for the high level at pin 4 to be removed. It is only when this pin is at ground level that the RESET pulse is terminated and the computer can reboot.

ELEKTOR ELECTRONICS

Fig. 20-13

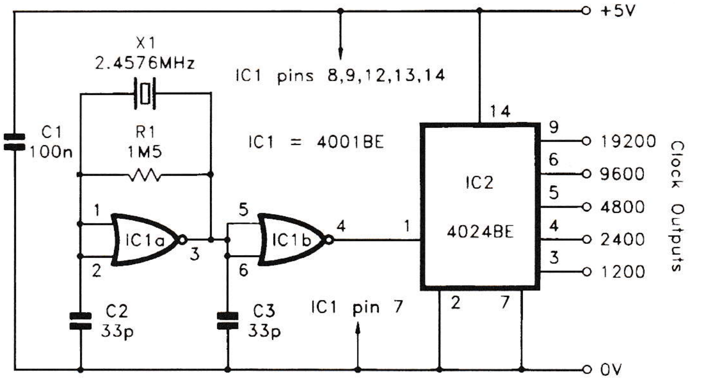
SCSI SWITCH



POPULAR ELECTRONICS *Fig. 20-14*

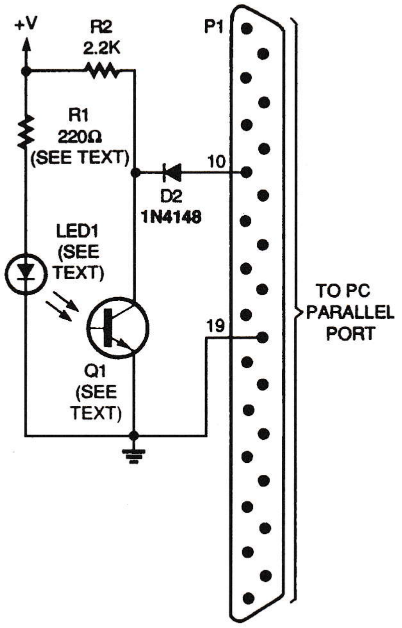
The SCSI switch consists of an eight-position DIP switch, about 24 inches of ribbon cable, and eight female header blocks. A schematic of the switch is shown. The header blocks plug onto the ID pins of the SCSI hard disks. Through the DIP switch, those IDs can be reassigned at will. In any given configuration, whichever physical drive has the lowest SCSI ID becomes the boot drive. The others are allocated in order by SCSI ID.

BAUD-RATE GENERATOR



EVERYDAY PRACTICAL ELECTRONICS ***Fig. 20-15***

Gate IC1a is used in a conventional crystal oscillator circuit and IC1b acts as a buffer stage. IC2 is a CMOS 4024BE seven-stage binary counter and its clock input is fed with the 2.4576-MHz signal from IC1b. The first two stages of IC2 are not used, but the other five outputs provide baud rates from 1200 to 19,200 baud. Of course, the clock frequency is 16 times the baud rate and output frequencies from IC2 range from 19.2 to 307.2 kHz.



LISTING 1—MAIN PROGRAM

```
REM**************************************************
REM** SWIPE.BAS V950121 (c) 1995, JJ Barbarello *****
REM** NOTICE: This is a non-compilable version *****
REM***************************************************
CLEAR : CLS : DEFINT A-X: DEFSTR Y-Z: DIM x(16)
DEF SEG = 64: ON ERROR GOTO errortrap
OPEN "R", 1, "BITPORT.DAT": FIELD 1, 4 AS a$
IF LOF(1) = 0 THEN
a1 = PEEK(8) + 256 * PEEK(9) + 1
ELSE
GET 1, 1: a1 = VAL(a$) + 1
END IF
CLOSE 1
REM************ MAIN PROGRAM LOOP
start1:
GOSUB screenlayout
WHILE (INP(a1) AND 64) = 0
a$ = INKEY$: IF a$ <> "" THEN GOTO readytoend
WEND
x = 0: j = 0: start! = TIMER
readholes:
WHILE (INP(a1) AND 64) = 64: WEND
x = 0: WHILE (INP(a1) AND 64) = 0: x = x + 1: WEND
j = j + 1: x(j) = x
IF x = 0 OR (TIMER - start!) > 2 THEN ERROR 6
IF j < 16 THEN GOTO readholes
done1:
VIEW PRINT 3 TO 24: CLS : VIEW PRINT: BEEP
stat = 0: ttl = 0
FOR i = 2 TO 16
SELECT CASE stat
CASE IS = 0
IF x(i) > 1.5 * x(i - 1) THEN
ttl = ttl + 2 ^ (i - 2): stat = 1
ELSE
stat = 0
END IF
CASE IS = 1
IF x(i) < .667 * x(i - 1) THEN
stat = 0
ELSE
ttl = ttl + 2 ^ (i - 2): stat = 1
END IF
CASE ELSE
ERROR 6
END SELECT
NEXT
LOCATE 14, 3
LOCATE 10, 35: PRINT "ID SENSED:"; ttl
GOSUB screenlayout
GOTO start1
readytoend:
IF a$ = CHR$(27) THEN CLS : LOCATE 18, 1, 1: END
BEEP: GOTO readholes
REM**
REM** SCREEN LAYOUT
REM**
screenlayout:
LOCATE 1, 34, 0: PRINT "Pc SWIPE CARD";
LOCATE 2, 1: PRINT STRING$(79, 220)
LOCATE 18, 35: COLOR 23, 0: PRINT "Waiting........"; :
COLOR 7, 0
LOCATE 21, 33: PRINT "(Press ESC to end)"
RETURN
REM**
REM** ERROR TRAP
REM**
errortrap:
IF ERR = 6 THEN
```

LISTING 1—MAIN PROGRAM

```
SOUND 500, 1
CLS : LOCATE 1, 34: PRINT "Pc SWIPE CARD";
LOCATE 2, 1: PRINT STRING$(79, 220): COLOR 0, 7
LOCATE 9, 25: PRINT SPACE$(34)
LOCATE 10, 25: PRINT " Error In Reading Swipe Card. "
LOCATE 11, 25: PRINT " Wait For The Beep and Try Again.
"
LOCATE 12, 25: PRINT SPACE$(34): COLOR 7, 0
start! = TIMER
WHILE (TIMER - start!) < 1: WEND: CLS
END IF
BEEP
RESUME start1
```

LISTING 2—TEST PROGRAM

```
REM**************************
REM** SWIPETST.BAS 1/20/95 *
REM**************************
CLEAR : CLS: DEFINT A-X: DEF SEG = 64
a1 = PEEK(8) + 256 * PEEK(9) + 1
LOCATE 1, 34, 0: PRINT "PcSWIPE TEST"
LOCATE 2, 1: PRINT STRING$(79, 220)
LOCATE 4, 31: PRINT "(Press ESC To End)"
previous = (INP(a1) AND 64) / 64
LOCATE 10, 39
IF previous = 1 THEN PRINT "HI" ELSE PRINT "LO"
loop01:
a = (INP(a1) AND 64) / 64
a$ = INKEY$: IF a$ <> "" THEN GOTO endit
LOCATE 10, 39
IF a = 1 AND previous = 0 THEN
SOUND 600, 1
PRINT "HI"
previous = 1
ELSEIF a = 0 AND previous = 1 THEN
SOUND 100, 1
PRINT "LO"
previous = 0
END IF
GOTO loop01
endit:
END
```

PC IR CARD READER *(Cont.)*

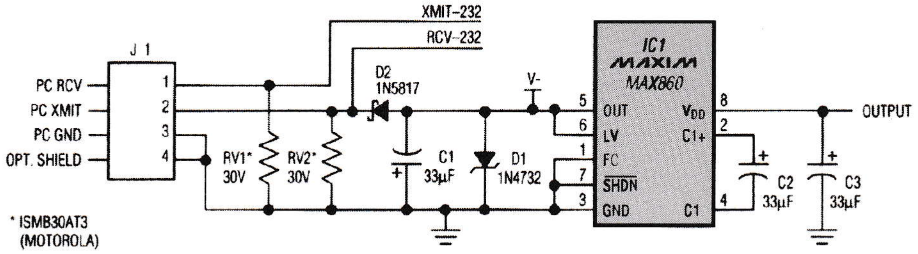
LISTING 3—DECIMAL TO BINARY CONVERSION

```
REM******************************
REM** SWIPENOS.BAS 1/20/95 **
REM******************************
CLEAR : CLS : DIM n$(14)
LOCATE 1, 23: PRINT "PC SWIPE DECIMAL TO BINARY
CONVERSION"
LOCATE 2, 1: PRINT STRING$(79, 220)
loop1:
LOCATE 6, 23: INPUT "Enter Decimal Number (0 to
32767)..": n
IF n < 0 OR n > 32767 THEN
BEEP
LOCATE 6, 20: PRINT SPACE$(50)
GOTO loop1
END IF
number = n
FOR i = 14 TO 0 STEP -1
bin = 2 ^ i
IF bin <= n THEN n = n - bin: n$(i) = CHR$(79) ELSE
n$(i) = CHR$(248)
NEXT
LOCATE 10, 1
LOCATE 10, 23: PRINT CHR$(218); STRING$(33, 196);
CHR$(191)
FOR i = 11 TO 15
LOCATE i, 23
PRINT CHR$(179); SPACE$(33); CHR$(179)
NEXT i
LOCATE 16, 23: PRINT CHR$(192); STRING$(33, 196);
CHR$(217)
LOCATE 13, 25: PRINT "Ref"; : LOCATE 14, 25: PRINT
CHR$(179);
LOCATE 15, 25: PRINT CHR$(248); " ";
FOR i = 0 TO 14
PRINT n$(i); " ";
NEXT i
LOCATE 12, 35: PRINT USING "ID: #####"; number
LOCATE 20, 23: PRINT "Press a key to try again, ESC to
end...";
LOCATE 6, 23: PRINT SPACE$(50)
a$ = INPUT$(1)
IF ASC(a$) = 27 THEN END
LOCATE 20, 23: PRINT SPACE$(50)
GOTO loop1
```

ELECTRONICS NOW *Fig. 20-16*

The LED is a high-output infrared emitter. It receives its power through current-limiting resistor R1. With a 9-V power supply and a value of 220 Ω for R1, the diode will receive about 25 mA of current. With a 5-V supply, R_1 should be 150 Ω to keep diode current in the 25-mA range. The LED energizes NPN phototransistor Q1, which is configured as a simple inverting amplifier. As more light shines on Q1, the output voltage at its collector decreases. With a value of 2.2 kΩ for R2, the circuit provides TTL-compatible logic levels. The output of Q1 feeds one bit of a PC's parallel port. Diode D2 allows the use of power sources greater than 5 V, thereby maintaining TTL level compatibility—even with high supply voltages. If the voltage at the collector of Q1 ever exceeds 5 V, D2 will block the voltage, thereby protecting the port. On the other hand, when Q1 goes logic low, D2 becomes forward-biased, so the low level can be sensed by the port.

5-V SUPPLY FROM THREE-WIRE RS232 PORT



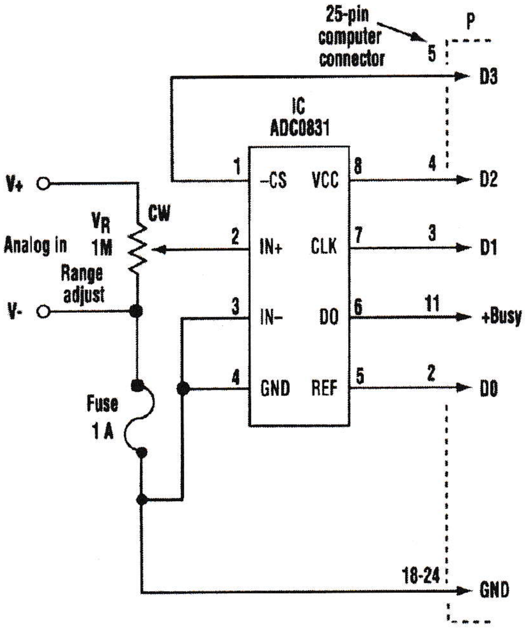
MAXIM ENGINEERING JOURNAL ***Fig. 20-17***

This circuit produces a semiregulated 5-V output from an RS232 port. The output current—about 8 mA—is sufficient for CMOS microcontrollers and other low-power circuits. IC1 is a switched-capacitor, charge-pump voltage converter that can either invert an input voltage or double it. The connections shown provide a doubler configuration in which the normal input voltage is reversed: A positive input voltage normally connects between GND and OUT, but this circuit connects a negative input between OUT and GND. The IC then doubles the negative V_{in} in the positive direction, producing a positive output (at $V_{D}D$) equal to [V_{in}]. The zener diode D1 acts as a shunt regulator that "semiregulates" V_{in} to −5 V (actually to −4.7 V). The 33-µF capacitor values shown are larger than normal to support the output voltage during worst-case (all-zero) patterns of transmission. At 9600 baud, for example, an all-zeros character causes an output droop of about 0.2 V. For lower baud rates, substitute a proportionally higher value for C_1.

COMPUTER-CONTROLLED A/D CONVERTER

TABLE 2: ADC COMMANDS

Parallel port data	ADC operation
0 0 0 0 0	All off
0 0 1 0 0	Select ADC
0 0 1 0 1	Clock low
0 0 1 1 1	Clock high
0 1 1 0 1	Deselect ADC



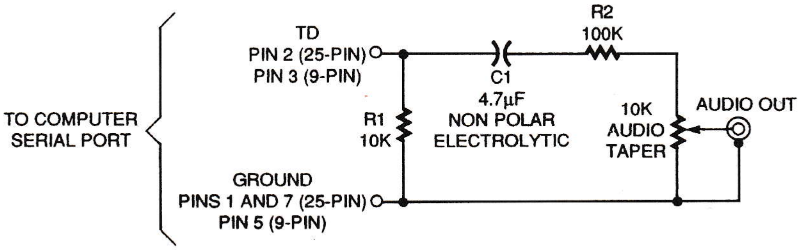
```
'**********************************************************************
'program EDCCADC written in BASIC  Barry Voss
'for use with the computer-controlled ADC pc board
**********************************************************************
'define variables
     DIM addout AS INTEGER
     DIM addin AS INTEGER
'graph
     DIM graph(3000)
'variables used
    'bitin input bit for building a digital word
    'word is the binary built from bitin
    'lastvoltage is the previous voltage value. used for determining
         'the number of characters in the previous display
    'voltage is the calculated voltage to be displayed
'**********************************************************************
'SETUP                                                                *
'**********************************************************************
'setup display
    SCREEN 2: WIDTH 80: CLS
'header
    LOCATE 1, 10: PRINT "Computer Controlled Analog to Digital Converter"
    LOCATE 2, 58: PRINT "voltage ="
'footer
    LOCATE 24, 1: PRINT "<ESC> to quit";
'draw the graph box
    LINE (1, 59)-(601, 161),,B
'**********************************************************************
'address of parallel port                                             *
'the next line should read:                                           *
'addout = 888 if you have a PC clone                                  *
'addout = 956 if you have an IBM (type computer)                      *
'addout = 632 if you are using LPT2                                   *
'**********************************************************************
    addout = 888
    addin = addout + 1
```

```
'**************************************************************************
'main program                                                             *
'**************************************************************************
DO UNTIL INKEY$ = CHR$(27): 'do until escape key pressed
 'get data from ADC
   'clear the old data
       REDIM bitin(8) AS INTEGER
       word = 0
   'select the ADC
       OUT addout, 5
   'clock the chip this starts the conversion
       OUT addout, 7
       OUT addout, 5
   'get the 8 bit word
       FOR a = 7 TO 0 STEP -1
   'clock the chip high
       OUT addout, 7
   'the bit is present after the negative clock edge
       OUT addout, 5
   'get the status word
       bitin(a) = INP(addin)
       NEXT a
   'de-select the ADC
       OUT addout, 13
   'reconstruct the word MSB is first
       FOR r = 7 TO 0 STEP -1
       IF bitin(r) < 128 THEN word = word + (2 ∧ r)
       NEXT r
   'calculate the voltage
       voltage = 50 * word/255
   'printing the voltage with formatting
      IF LEN(lastvoltage) > LEN(STR$(INT(voltage * 100)/100)) THEN LOCATE 2, 69: PRINT "  "
       voltage = INT(voltage * 100)/100
       LOCATE 2, 69
       PRINT voltage
       lastvoltage = voltage
    'update the graph
       GET (3, 60)-(600, 168), graph
       PUT (2, 60), graph, PSET
       PSET (599, (160 - (100 * (voltage/50)))
LOOP
'escape pressed end the program
   'clear the parallel port
      OUT addout, 0
END
```

ELECTRONIC DESIGN ***Fig. 20-18***

This simple, inexpensive computer-controlled A/D converter (ADC) plugs into a PC parallel port. The 8-bit peripheral device requires only seven components to implement and is completely controlled by a short BASIC program.

PC SIGNAL GENERATOR



ELECTRONICS NOW ***Fig. 20-19***

This circuit will produce audio from your PC. The trick is U—the ASCII character "U," that is. The hexadecimal value of U is 55, which in binary is 01010101 (with 8 data bits and no parity, or 7 data bits and even parity). The RS232 protocol specifies that the bits of an ASCII character are transmitted from least to most significant, preceded by a start bit (always 0) and followed by a stop bit (always 1). So, after adding the requisite start and stop bits, the result is 1010101010. Now, suppose a string of Us is generated at the serial port at some steady rate. The result is a continuous series of alternating 1s and 0s—a square wave. The frequency of the signal will be half the baud rate, which by definition is the number of transitions per second. Each cycle of a square wave comprises two transitions, so, for example, a 9600-bps baud rate produces a 4800-Hz square wave. In practical terms, just about any computer should be able to deliver frequencies of 55, 150, 300, 600, 1200, 2400, and 4800 Hz, corresponding to the standard baud rates from 110 to 9600. The output of a serial port is nominally 24 V p-p, which is much too high a voltage to feed to the input of an audio amplifier. The circuit attenuates the signal to a more useful level, a variable 2-V p-p. The circuit also protects the computer from static electricity and voltage surges. Capacitor C1, a nonpolar unit, blocks dc because the serial port, when idling, outputs approximately −12 V.

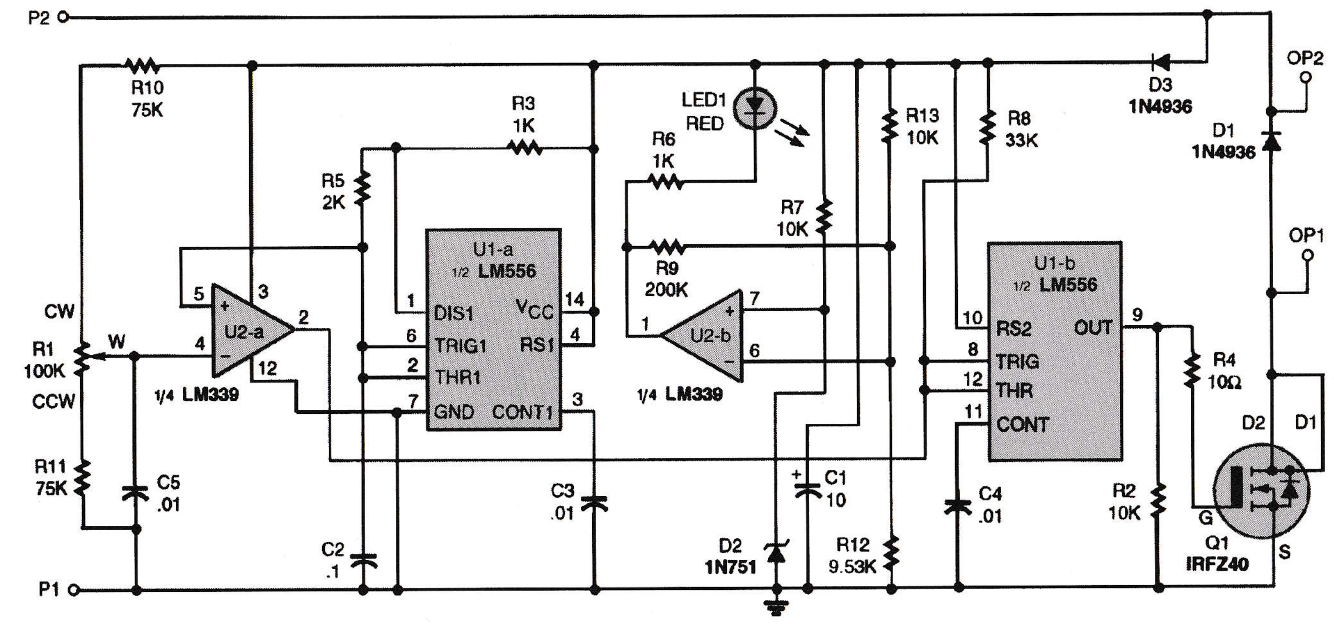
21

Controller Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Low-Voltage Power Controller
Ten-Step Counter for Controllers
Four-Output Controller
Two-Function Controller

LOW-VOLTAGE POWER CONTROLLER

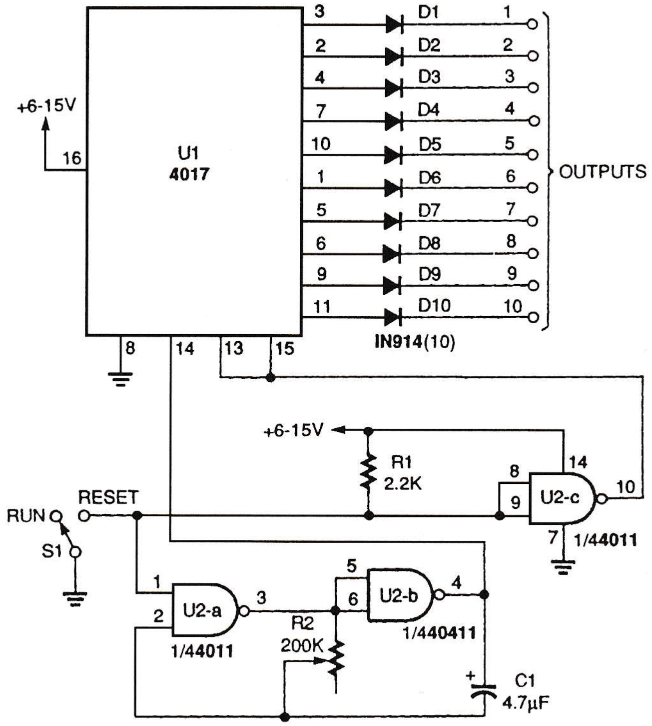


POPULAR ELECTRONICS

Fig. 21-1

The circuit has a duty-cycle generator that produces an output varying from fully off to fully on and pulses of any duty cycle in between the two extremes. The circuit can be fed from any dc supply source of between 10 and 15 V. U1-a and U2-a combine to form a voltage-to-pulse-width converter. The first half of the dual oscillator/timer is configured as an astable oscillator, generating a continuously oscillating ramp voltage. Op amp U2-a compares the voltage at its noninverting input to the voltage at its inverting input. The op amp will give a low output if R1's wiper voltage is higher than the instantaneous voltage present at pins 2 and 6 of U1-a. The output of U2-a at pin 2 will have an on/off ratio that is proportional to the voltage at R1's wiper. Because the output of U2-a does not have enough power-handling capacity to drive the MOSFET, its output is fed to U1-b, which is used to buffer the signal. The low-impedance, pulsed output of U1-b at pin 9 is fed to the gate of MOSFET Q1, driving it hard on or off. Diode D1 is used to suppress the reverse-voltage spikes generated by inductive loads during turn-off. If the circuit will not be used to drive inductive loads (motors), D1 can be eliminated. *Note:* This controller can be used only with incandescent lamps and permanent-magnet dc motors.

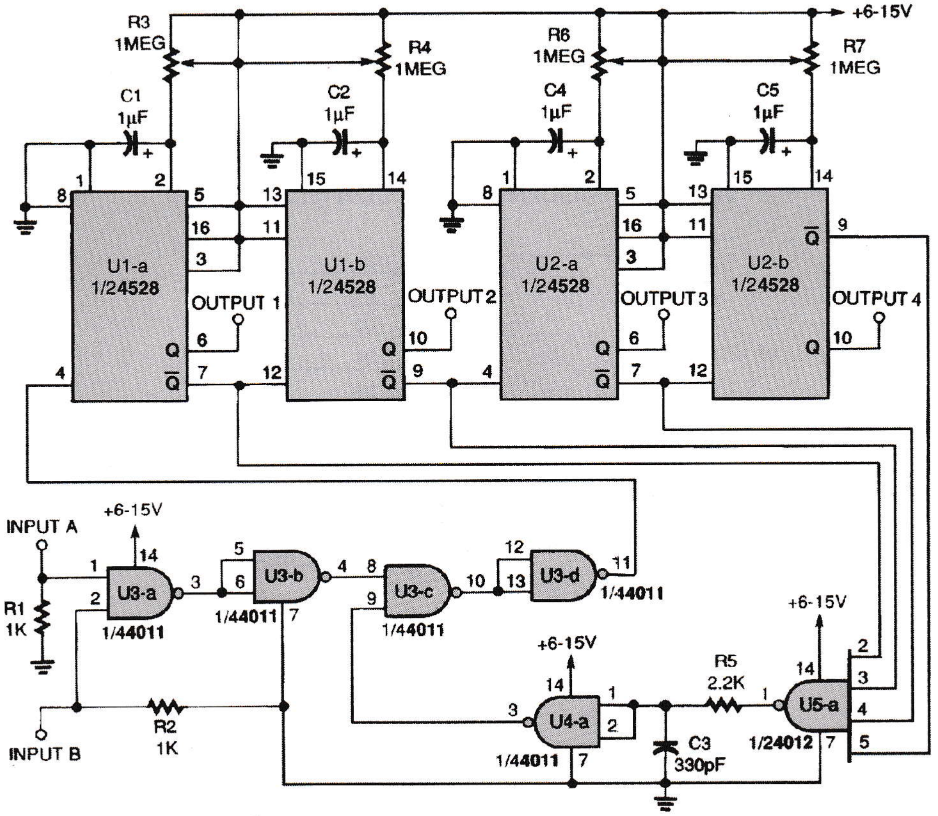
TEN-STEP COUNTER FOR CONTROLLERS



POPULAR ELECTRONICS *Fig. 21-2*

A 4017 divide-by-10 counter IC is the heart of this simple 10-output controller circuit. Two gates of a 4011 quad two-input NAND gate IC are connected in an astable oscillator circuit to clock the divide-by-10 counter U1. The step time is set by R5. With the RUN/RESET switch in the RUN position, U1 takes 10 equal steps and then stops. Momentarily switching S1 to RESET starts the cycle over.

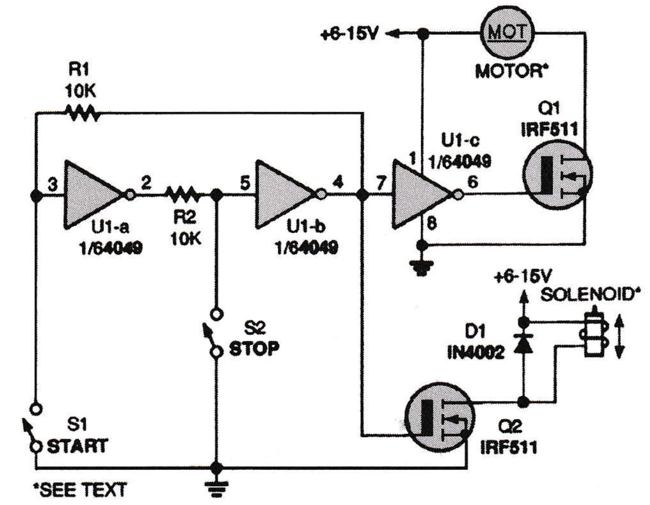
FOUR-OUTPUT CONTROLLER



POPULAR ELECTRONICS *Fig. 21-3*

This controller offers up to four timed outputs that can be used to operate motors, air valves, solenoids, relays, etc. The timer sections are cascaded so that as one timer times out, it triggers the next timer, and so on, until the last timer times out. The intended application for the controller required a two-sensor input that would start only when both inputs occur simultaneously. Note, however, that the start-signal logic could be modified to accommodate a combination of any number of input sensors, or even a single switch closure. The controller also includes an inhibit circuit that keeps the sequence from restarting before a cycle is completed.

TWO-FUNCTION CONTROLLER



POPULAR ELECTRONICS *Fig. 21-4*

This two-function controller operates a motor when started, then energizes a solenoid, relay, etc., when stopped.

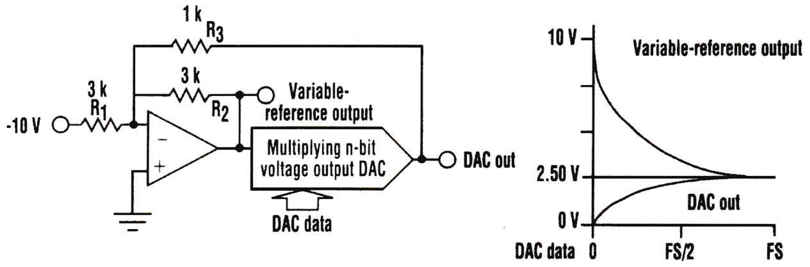
22

Converter Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Linear DAC with Nonlinear Output
8-Bit Binary-to-Decimal Converter
Audio-to-Dc Converter Circuit
Ratiometric 20-kHz V-F Converter
Multiswitch Charge Pump Boost Converter
Isolated 3-V–to–5-V DAC
Voltage Converter

LINEAR DAC WITH NONLINEAR OUTPUT



ELECTRONIC DESIGN

Fig. 22-1

When controlling a nonlinear device, such as an incandescent lamp, it is desirable to have fine resolution at the high end, where a small change in current can cause a large change in brightness. At the low end, coarser resolution is quite adequate. Using the circuit shown, any desired compression can be produced using just about any multiplying DAC. A negative 10-V reference is fed through R1 to inverting amplifier A1, which has an initial gain set to unity by R2. A1's output supplies a positive variable reference to the DAC. The DAC output provides additional feedback through R3, reducing the amplifier's gain as the DAC data increase. The variable reference is gradually reduced so that each step is progressively smaller than the one before. With the values shown, as the DAC data approaches full-scale, the reference approaches $\frac{1}{4}$ of its original value. This produces output with four times as much resolution at the high end as at the low end. By decreasing the value of R_3, greater compression and higher resolution can be achieved. The variable-reference output also can be useful in some applications.

8-BIT BINARY-TO-DECIMAL CONVERTER

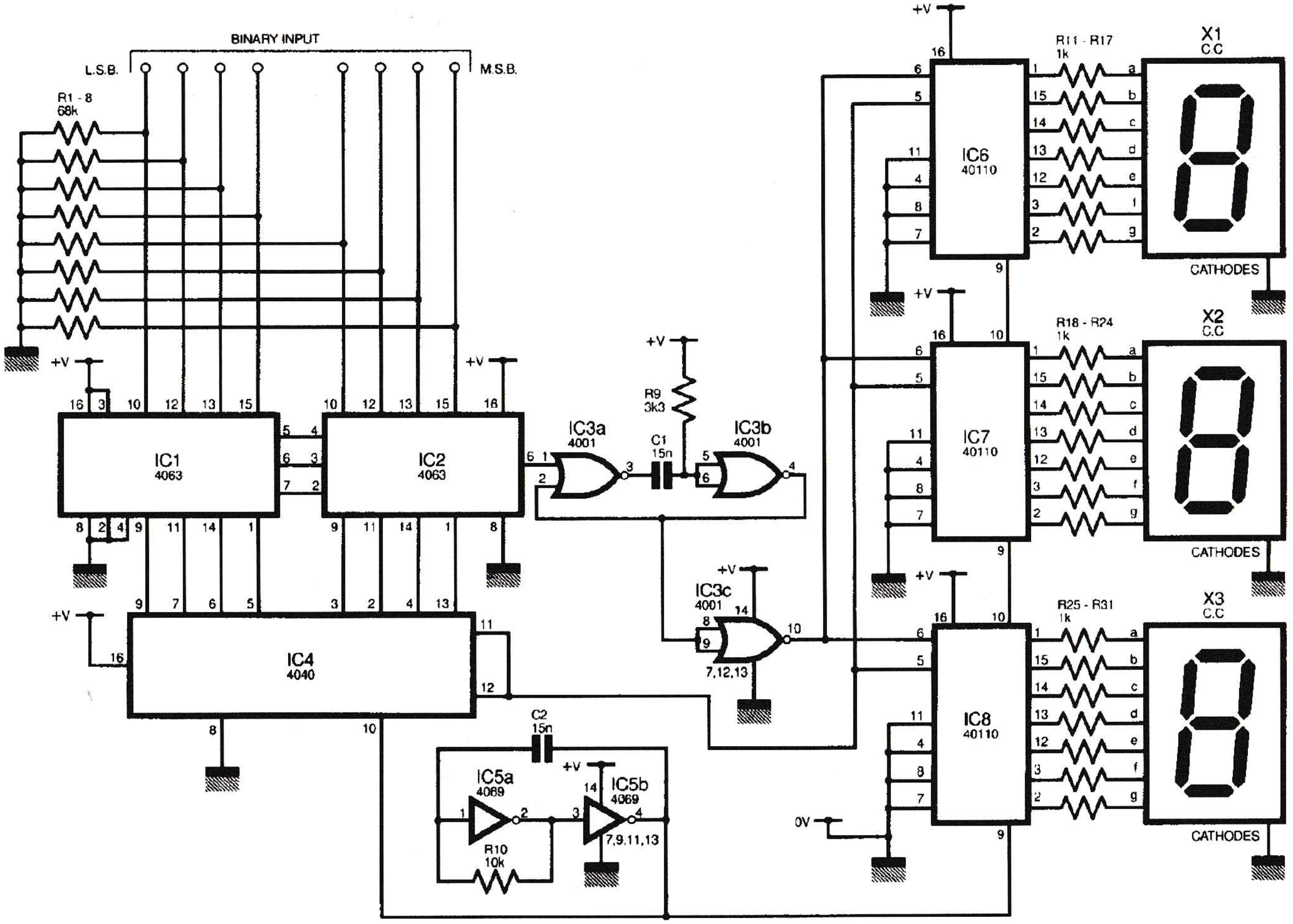
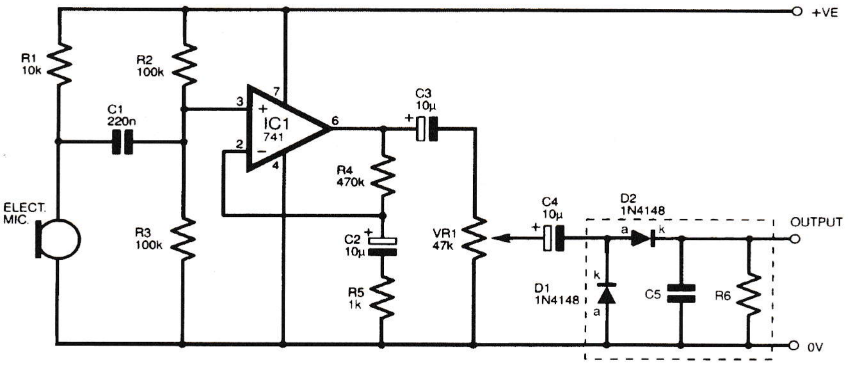


Fig. 22-2

8-BIT BINARY-TO-DECIMAL CONVERTER *(Cont.)*

The decimal value of the eight input lines is displayed on three seven-segment displays. Although chips exist to perform this function for single displays, none include the possibility of displaying numbers greater than 9. No EPROM is necessary in this design. It operates by using two synchronized counters, one that generates an 8-bit binary output, and a second that drives the display. If the display is updated only when the binary counter is at the same value as the input, then the display will show the decimal value of the input. IC4 is the binary counter, and IC6 to IC8 form the display/counter section. IC5a and IC5b form the astable, which clocks both counters at 5 kHz. The minimum display refresh rate is, therefore, 20 times per second. IC1 and IC2 are two 4-bit comparators, ganged to form an 8-bit comparator. This compares the output of the binary counter (IC4) with the binary input taken from the circuit under test. Resistors R1 to R8 pull down the input lines to prevent them from floating when no input is connected. When the comparator inputs are equal, pin 6 of IC2 goes high, triggering the monostable (IC3ab), which outputs a brief pulse. This latches the value of the display counters (IC6 to IC8) to the display. When IC4 reaches a value of 256, the link between pins 11 and 12 resets the chip, and this resets the display counter also.

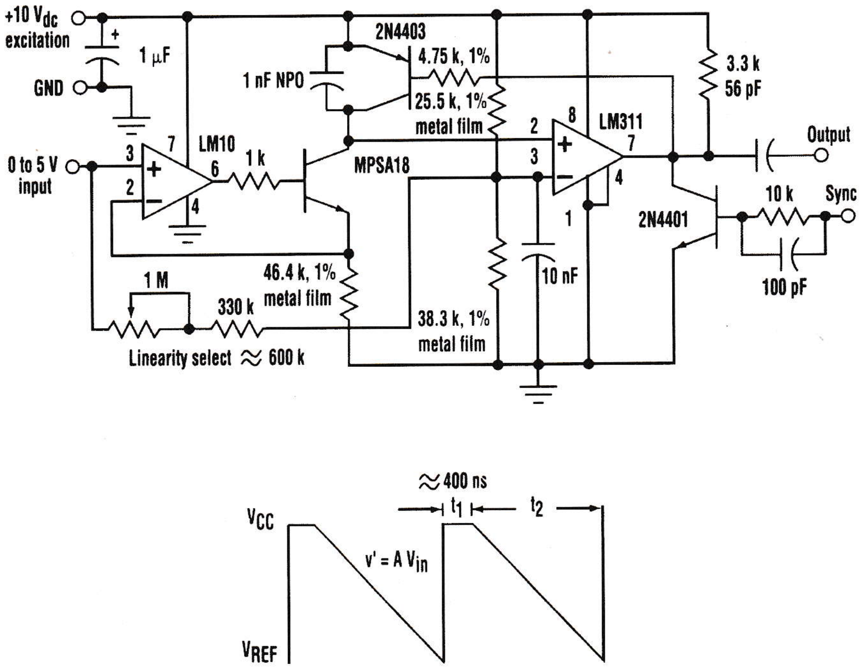
AUDIO-TO-DC CONVERTER CIRCUIT



EVERYDAY PRACTICAL ELECTRONICS *Fig. 22-3*

The circuit diagram for the audio input module, which produces a dc output voltage relative to the input signal amplitude.

RATIOMETRIC 20-kHz V-F CONVERTER



ELECTRONIC DESIGN

Fig. 22-4

This ratiometric 20-kHz voltage-to-frequency converter (VFC) provides superior performance with strain gauges and other ratio-responding transducers—even with noisy, unregulated excitation voltages. Feedback isn't used to achieve the excellent 4-Hz linearity, so there is very-low-frequency jitter—period measurements can be used to get several digits of resolution—even when operating at a fraction of full scale. An optional synchronizing transistor starts the VFC with zero charge at the beginning of each count cycle, eliminating the characteristic digit-jumping often encountered with VFC designs. Good linearity is attained by making the comparator's reference voltage vary with the input voltage, which precisely compensates for the finite capacitor reset time:

$$\begin{aligned} Period &= t_1 + t_2 \\ &= t_1 + (V_{CC} - \Omega_{\rho\epsilon\phi})/A\Omega_{\iota\nu} \\ &= (t_1AV_{in} + V_{CC} - \Omega_{\rho\epsilon\phi})/A\Omega_{\iota\nu} \end{aligned}$$

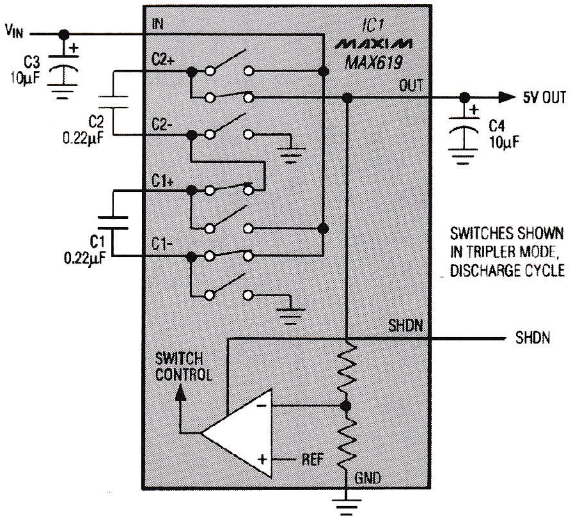
where $AV_{in} = \Delta V/\Delta t$. If V_{ref} is made to include the amount t_1AV_{in}, then the effect of t_1 is eliminated:

RATIOMETRIC 20-kHz V-F CONVERTER *(Cont.)*

$$Period = [t_1 AV_{in} + V_{CC} - (\tau + A\Omega_{\iota\nu} + V_{ref})]/AV_{in} = (V_{CC} - \Omega_{\rho\epsilon\phi})/A\Omega_{\iota\nu}$$

The MPSA18 is a remarkably high-gain transistor, even at low currents, producing good current-source linearity down to 0 Hz. In addition, bipolar transistors work well with the low collector voltages encountered in this single-supply 10-V design. Moreover, most single-supply op amps will work in place of the LM10. But the LM10 also has a reference amplifier that could be used to construct a 10-V excitation regulator. The LM311 propagation delay gives a reset pulse width near 400 ns, which gives the transistor time to discharge the capacitor. Also, the 311's bias current produces a small negative offset that ensures a 0-Hz output for 0 V_{in}.

MULTISWITCH CHARGE PUMP BOOST CONVERTER

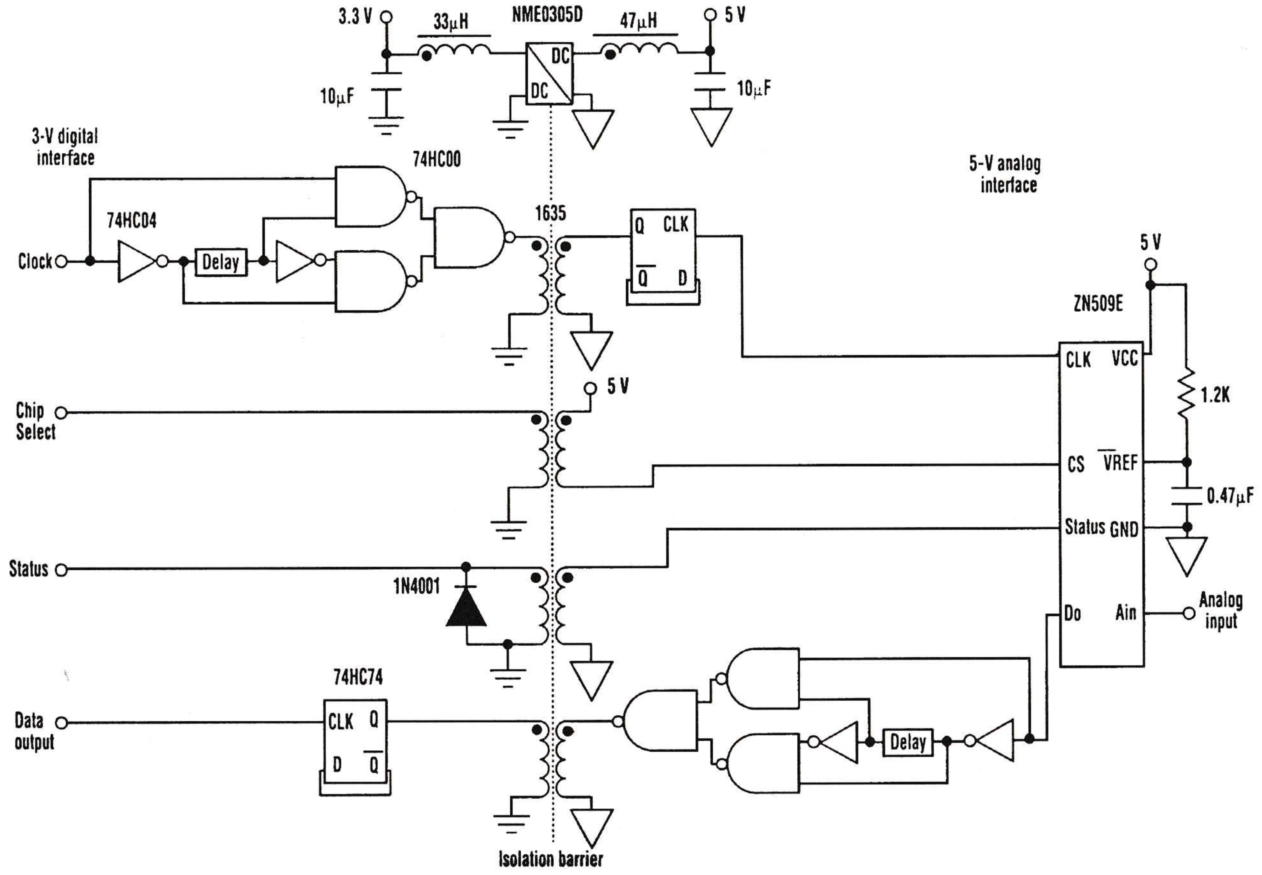


MAXIM ENGINEERING JOURNAL

Fig. 22-5

This device is useful both in main supplies and in backup supplies. It generates a regulated 5-V output for load currents to 20 mA and inputs ranging from 1.8 to 3.6 V. For input voltages no lower than 3 V, the output current can reach 50 mA. The circuit accomplishes regulation without a linear pass element, but its losses are the same as those of an unregulated doubler or tripler feeding into a linear regulator.

ISOLATED 3-V–TO–5-V DAC



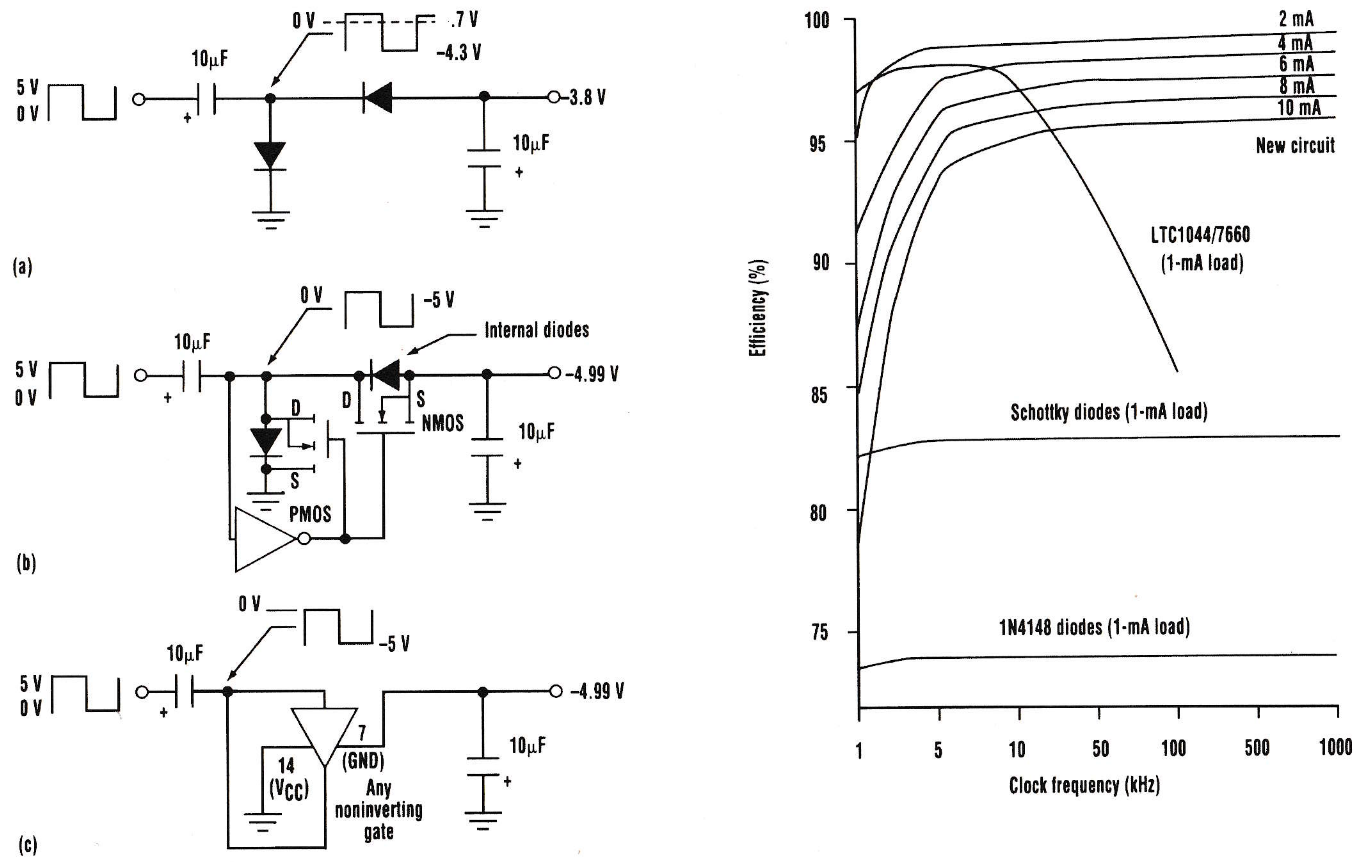
ELECTRONIC DESIGN

Fig. 22-6

ISOLATED 3-V–TO–5-V DAC *(Cont.)*

The circuit uses a low-power (1 W) dc-to-dc converter for the power isolation and a transformer isolator/translator for the data interface. The transformer isolator not only provides the galvanic isolation required, but also converts the data signals between 3-V and 5-V levels. As a result, no additional level conversion is required. The ADC can run at 1-MHz clock rates. To allow the 50 percent duty cycles (clock and data signals) to pass through a transformer isolator requires an edge-detection and conversion technique. The edge detector is built from simple logic gates (two inverters and three NAND gates) and a short delay (either a delay line or a passive RC circuit can be used). The signal is rebuilt with a D-type flip-flop. Using a four-channel isolator allows full control over the ADC to be exercised. Conversion is requested by pulling the Chip Select pin low, and a Status high for one clock cycle is reported back to acknowledge conversion start. The first data bit (MSB) then is presented onto the data line, and all eight bits are transferred with a further Status signal at the end of conversion. Conversion can be requested asynchronously with the system clock, if necessary, and the Status flag can be used to poll the controlling logic circuitry. Filtering is placed on either side of the dc-to-dc converter to reduce power-supply ripple and prevent noise on the logic power supply from affecting the analog system. Although not shown, all ICs have 0.22-μF decoupling capacitors.

VOLTAGE CONVERTER



ELECTRONIC DESIGN

Fig. 22-7

This bootstrap voltage converter begins with the basic diode inverter circuit (a). Placing a MOSFET across each diode will improve efficiency (b). The final step involves using a single noninverting CMOS digital gate to replace the diodes (c).

The performance curves depict the bootstrap voltage converter's efficiency, which is 99 percent from 5 to 500 kHz using 10-µF capacitors and a 1-mA load. A typical commercial unit operates at only 94 percent efficiency.

23

Counter Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Simple 25-MHz Counter
Digital Counter Circuit
Four-Mode Frequency Counter
Up/Down Counter with XOR Gates
Four-Digit Counter

SIMPLE 25-MHz COUNTER

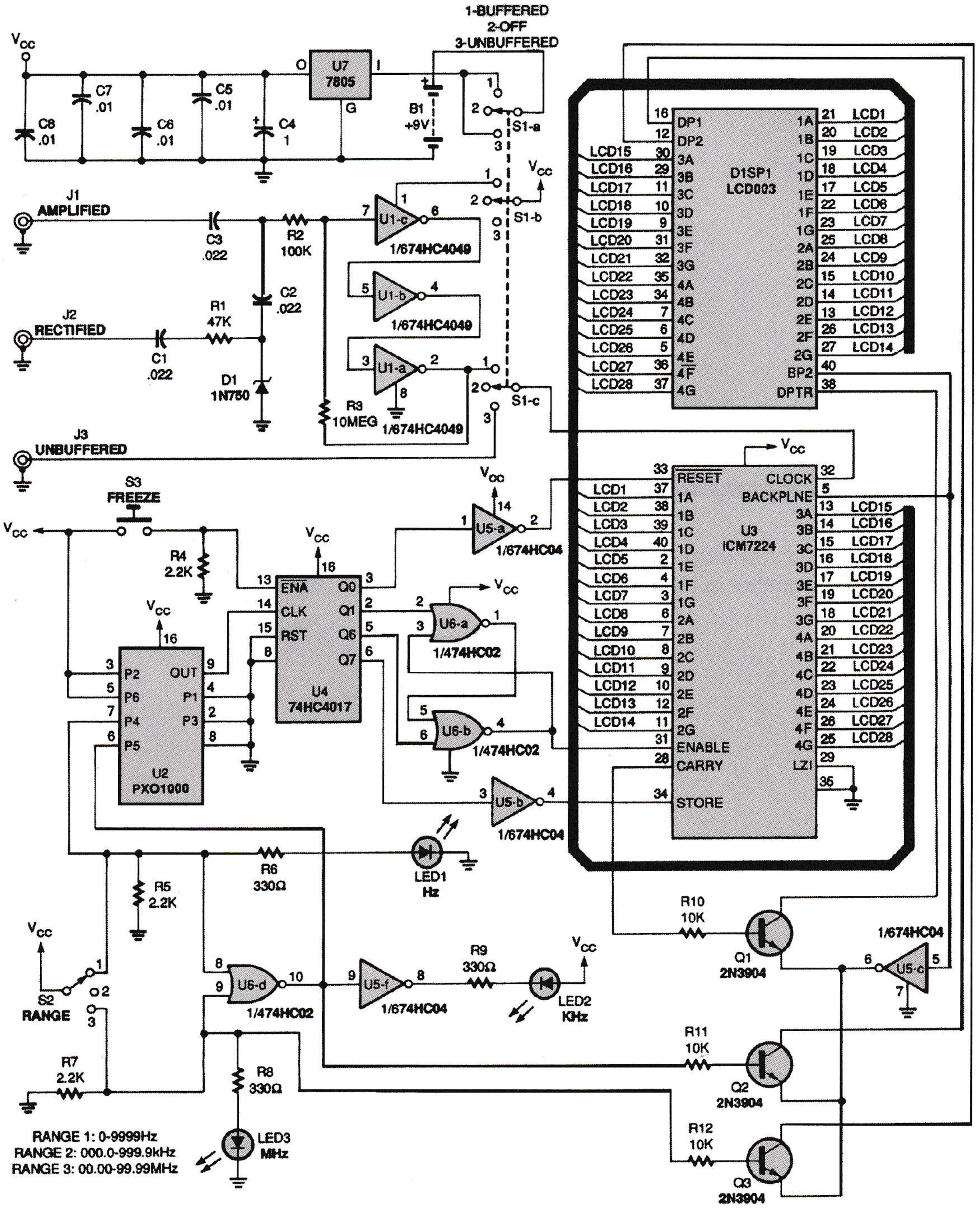
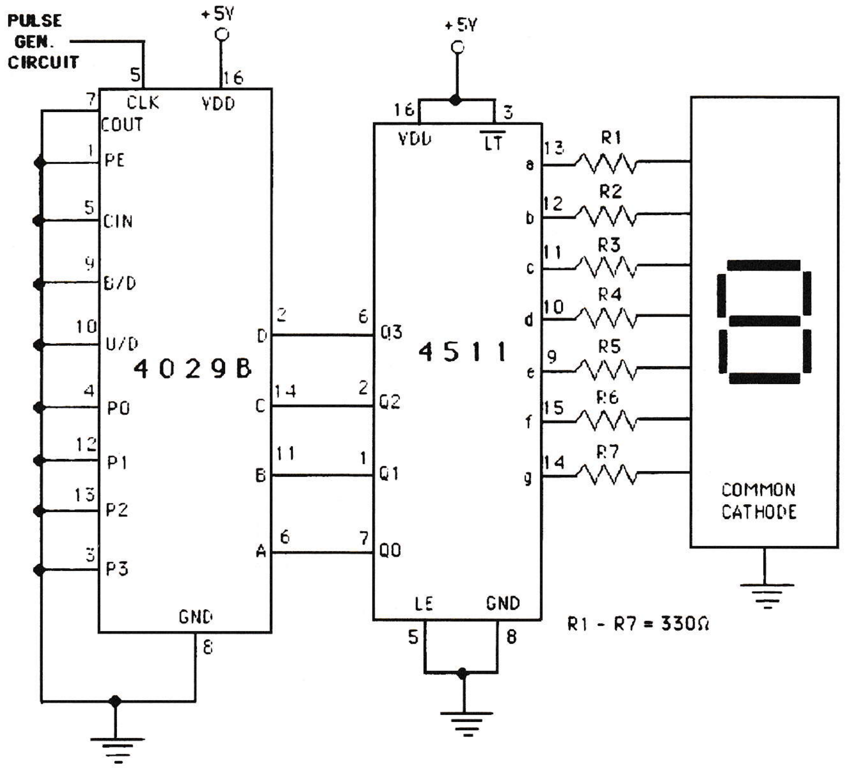


Fig. 23-1

SIMPLE 25-MHz COUNTER *(Cont.)*

An Intersil ICM7224 is used to drive an LCD003 four-digit LCD display unit. Three inputs are provided, which add signal conditioning, either gain, rectification, or unbuffered input. A Statek PX0-1000 1-MHz clock is used as a frequency reference. S2 selects gate time and hence range, with LED1, LED2, and LED3, indicating Hz, kHz, or MHz, respectively.

DIGITAL COUNTER CIRCUIT

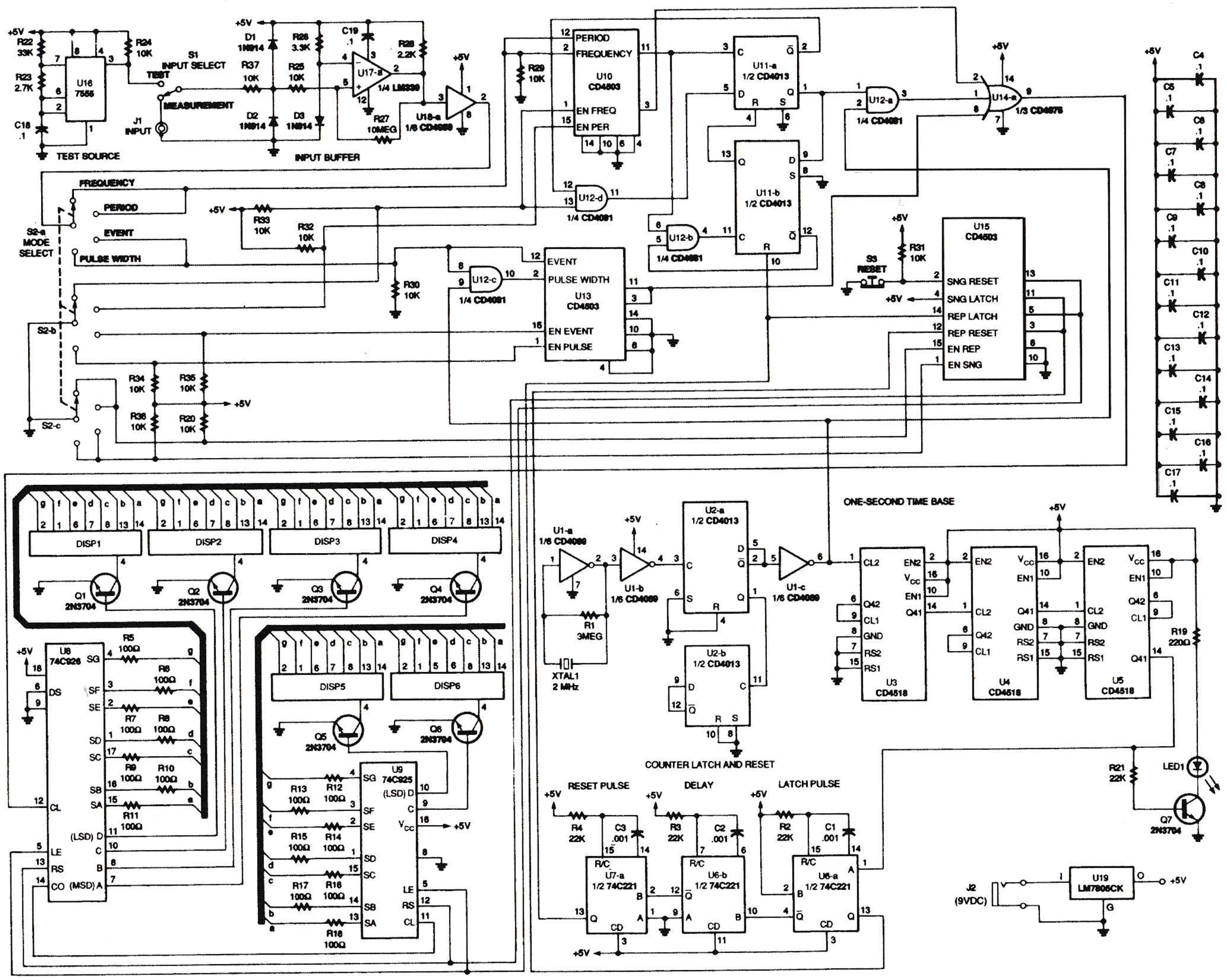


NUTS AND VOLTS

Fig. 23-2

This circuit shows how a simple digital counter can be implemented. A CD4029B drives a DC4511 decoder and LED driver. A common-cathode LED display is used.

FOUR-MODE FREQUENCY COUNTER



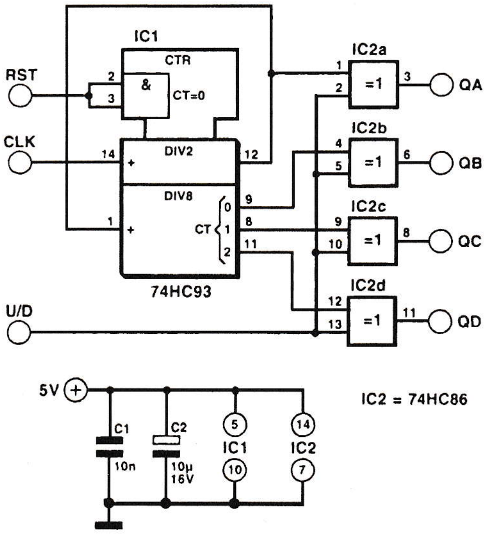
POPULAR ELECTRONICS

Fig. 23-3

FOUR-MODE FREQUENCY COUNTER *(Cont.)*

This counter can measure frequencies from 2 Hz to 1 MHz, time interval, and period, and count random events. A 74C926 and 74C925 are used as the counter, and these will drive a multiplexed LED display. A 2-MHz time base is used, and a divider chain is used to derive a 1-s gate. An LM339 op amp serves as the input buffer, and CD4000 series logic is used for gating and switching functions.

UP/DOWN COUNTER WITH XOR GATES

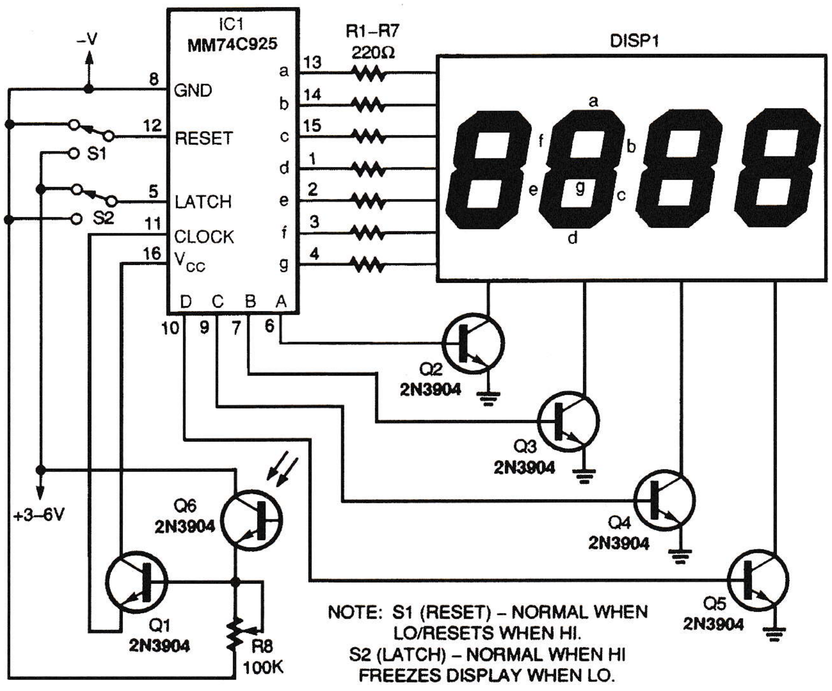


ELEKTOR ELECTRONICS

Fig. 23-4

This circuit shows how a regular 4-bit binary counter can be extended with an up/down function just by adding four XOR (exclusive-OR) gates. The principle is simple: The level at the common inputs of the XOR gates determines whether the gates invert the counter's Q_A to Q_D output levels or not. In this way, the outputs of the XOR gates can be made to cycle from 1111 down to 0000 instead of from 0000 to 1111. The disadvantage of this circuit over a real up/down counter is the jump, which occurs when the level on the U/D control input is changed. The sum of the "old" state and the "new" state is always 15. For example, if the counter is at state 3 in count-up mode, the state becomes 12 when the U/D line is made logic high to initiate down counting.

FOUR-DIGIT COUNTER



ELECTRONICS NOW *Fig. 23-5*

A general-purpose four-digit counter can be made from a 74C925 IC and a few external components. That IC contains the counter, multiplexer, and seven-segment digit drivers, all in one convenient package. A couple of important notes about the circuit: The seven 220-Ω resistors (R1 to R7) are used as dropping resistors between the driver outputs and the segments of the display to protect the LEDs and keep the 74C925 from overheating. The four 2N3904 transistors (Q2 to Q5) act as amplifiers for the digital drivers to keep the display at full illumination. Switches S1 and S2, for reset and latch, respectively, are not crucial, but are highly recommended. The latch will freeze the count if needed. If the switches are not used, pin 12 needs to go to ground, and pin 5 to +*V* (the circuit's voltage supply). If more than four digits are needed, use the MM74C926 IC. The functions are the same, but it has a "carry out" to cascade more than one chip and four-digit display.

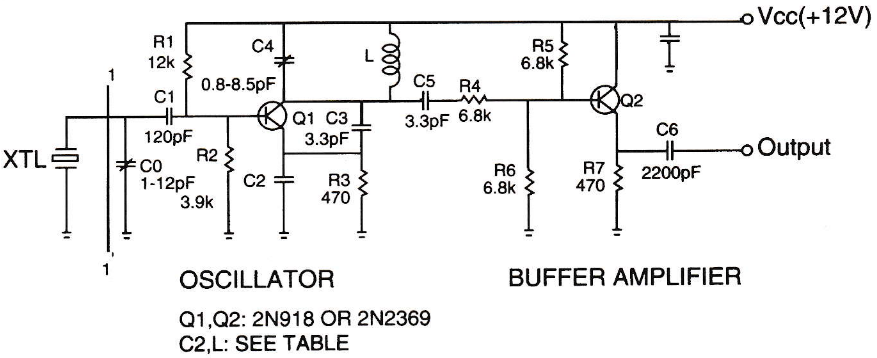
24

Crystal Oscillator Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Versatile Wideband Crystal Oscillator
CMOS Crystal Oscillator
Pierce Crystal Oscillator
NE602 Overtone Crystal Oscillator
NE602 Third-Overtone Crystal Oscillator
NE602 Adjustable Crystal Oscillator
Basic NE602 Colpitts Crystal Oscillator
32.768-kHz Micropower Oscillator
TTL Crystal Oscillator
Colpitts Crystal Oscillator

VERSATILE WIDEBAND CRYSTAL OSCILLATOR

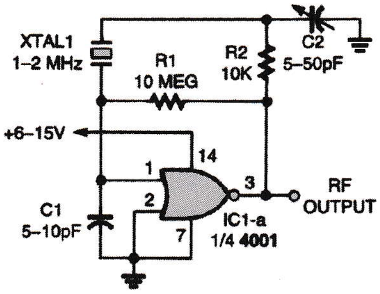


freq. MHz	L μH	C2 pF
6.4	5.6	4700
12.0	3.4	4700
20.0	1.98	470
34.29	0.78	470
45.454	0.78	47
73.0	0.39	47
104.0	0.16	47
120.0	0.1	47

RF DESIGN *Fig. 24-1*

The crystal oscillator operates from 6 to 120 MHz by changing only C2 and L. The table lists component vaues for crystal oscillator at different frequencies.

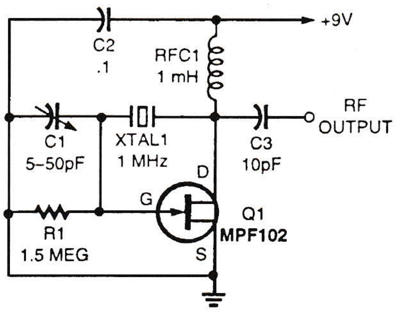
CMOS CRYSTAL OSCILLATOR



POPULAR ELECTRONICS *Fig. 24-2*

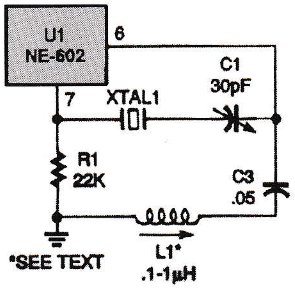
This single CMOS two-input NOR-gate crystal oscillator circuit has one major limitation: It lacks high-frequency performance. Otherwise, it is a solid performer.

PIERCE CRYSTAL OSCILLATOR



POPULAR ELECTRONICS *Fig. 24-3*

NE602 OVERTONE CRYSTAL OSCILLATOR

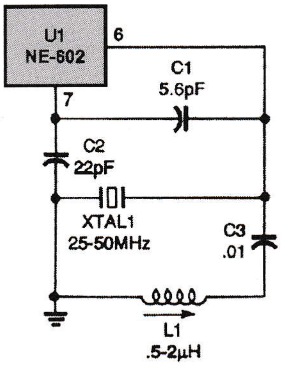


POPULAR ELECTRONICS

Fig. 24-4

For higher frequencies, use an overtone crystal oscillator like the one shown here. The circuit is a Butler oscillator. The overtone crystal is connected between the oscillator emitter of the NE602 (pin 7) and a capacitive voltage divider that is connected between the oscillator base (pin 6) and ground. An inductor is also in the circuit (L1), and it must resonate with C1 to the overtone frequency of crystal XTAL1. The circuit can use either third- or fifth-overtone crystals up to about 80 MHz.

NE602 THIRD-OVERTONE CRYSTAL OSCILLATOR

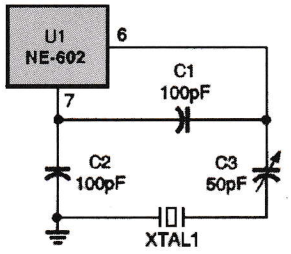


POPULAR ELECTRONICS

Fig. 24-5

This overtone crystal oscillator uses third-overtone crystals and will work from 25 to 50 MHz.

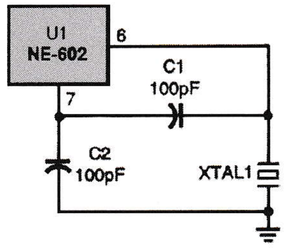
NE602 ADJUSTABLE CRYSTAL OSCILLATOR



Here, a variable capacitor is added to the circuit to make it easier to obtain the desired frequency.

POPULAR ELECTRONICS *Fig. 24-6*

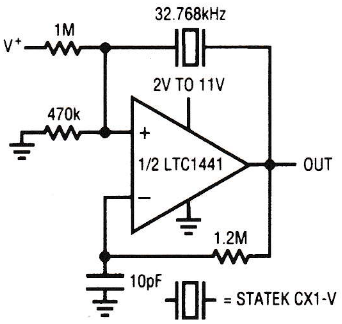
BASIC NE602 COLPITTS CRYSTAL OSCILLATOR



This basic Colpitts crystal oscillator will work with fundamental-mode crystals up to 20 MHz.

POPULAR ELECTRONICS *Fig. 24-7*

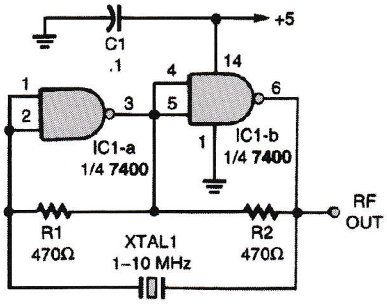
32.768-kHz MICROPOWER OSCILLATOR



Using an LTC1441, this oscillator pulls 9 µA at a supply voltage of 2 V. The circuit has no spurious modes.

LINEAR TECHNOLOGY *Fig. 24-8*

TTL CRYSTAL OSCILLATOR

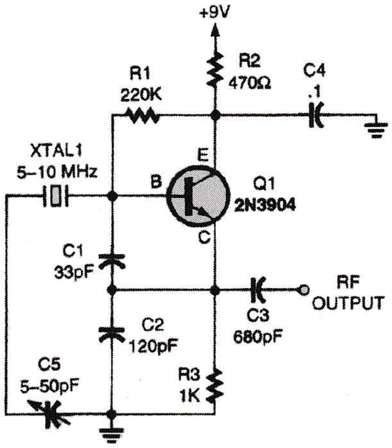


POPULAR ELECTRONICS

Fig. 24-9

Here is an oscillator circuit that uses no L/C components. It uses two sections of a 7400 TTL IC, two resistors, and a crystal to make up a simple and stable oscillator circuit.

COLPITTS CRYSTAL OSCILLATOR



POPULAR ELECTRONICS

Fig. 24-10

This circuit is commonly called a *Colpitts oscillator*. C_1 and C_2 determine the feedback ratio that maintains oscillation. To obtain maximum frequency stability and output level, C_1 and C_2 should be selected for a given frequency.

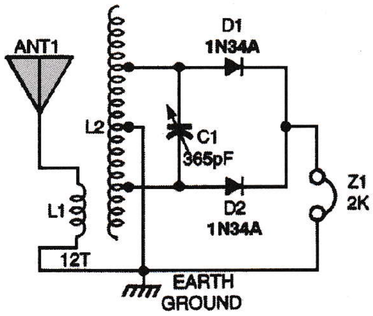
25

Crystal Radio Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Full-Wave Detector Crystal Set
Tunable Dual-Coil Crystal Radio
Three-Coil Crystal Receiver
Antenna-Matched Crystal Radio
Crystal Radio Coils
Single-Coil Crystal Radio

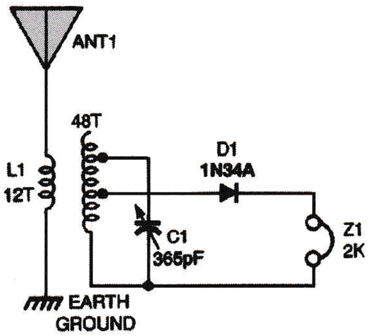
FULL-WAVE DETECTOR CRYSTAL SET



POPULAR ELECTRONICS *Fig. 25-1*

The 12-turn coil of L1 couples the RF signal to the large coil, L2. Connect the center tap of L2 to ground, the fourth tap up from the center to diode D1, and the fourth tap down from the center to diode D2. The combined audio output drives the headphones (Z1). If you change tap positions, keep the same number of turns on each side of center. That will balance the RF that feeds each detector diode. The circuit's sensitivity and audio output can be increased by placing L1 inside of L2 (the forms specified for the coils should make that possible). For maximum selectivity, L1 should be loose-coupled to L2.

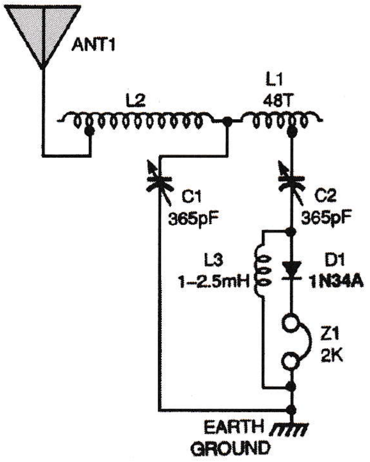
TUNABLE DUAL-COIL CRYSTAL RADIO



POPULAR ELECTRONICS *Fig. 25-2*

The 12-turn primary winding couples the RF signal from the antenna/ground system to the 48-turn secondary winding. Here C1, a 365-pF variable capacitor, tunes the L/C circuit to the desired radio-frequency signal. A 1N34A germanium diode, D1, detects the audio and feeds it to the headphones (Z1). The various taps on L1's secondary allow impedance matching of the antenna/ground system and the detector diode, as well as the inductance value needed to tune to the desired RF signal.

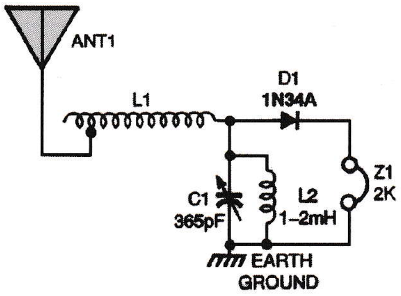
THREE-COIL CRYSTAL RECEIVER



POPULAR ELECTRONICS *Fig. 25-3*

This circuit uses three inductors to increase the receiver's selectivity and sensitivity. Components L2 and C1 are used in an antenna impedance-matching circuit, while L1 and C2 operate in a series-tuned low-output impedance circuit that matches the impedance of the diode detector. A 1- to 2-mH inductor (L3), as in the previous circuit, offers dc continuity to the detector circuit.

ANTENNA-MATCHED CRYSTAL RADIO



POPULAR ELECTRONICS *Fig. 25-4*

This receiver uses a tuning circuit that is, in some ways, similar to an antenna-matching device used by amateur-radio operators to impedance-match their receiver/transmitter input/output circuitry to the impedance of the antenna for maximum signal transfer. Inductor L2 provides a dc-signal return path for D1's output. The inductance of L2 is too large to affect the circuit's tuning function.

CRYSTAL RADIO COILS

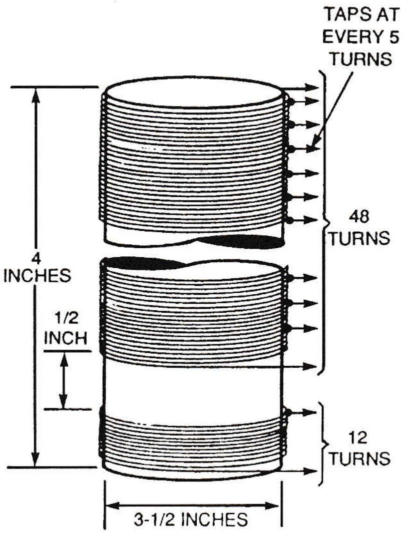


Fig. 1. This small coil is made up of two windings. Note that the 48-turn winding has taps at every five turns. The 12-turn coil will be used for RF coupling.

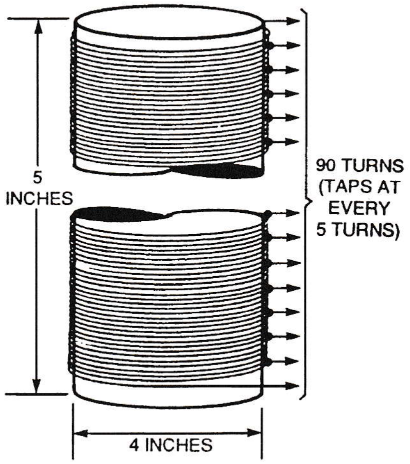
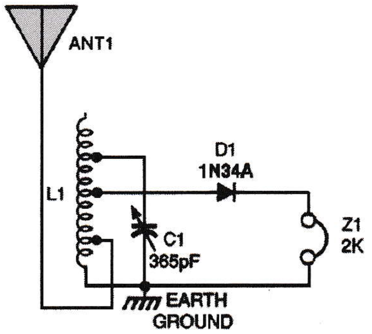


Fig. 2. The large coil has one 90-turn winding with taps at every five turns.

POPULAR ELECTRONICS **Fig. 25-5**

These coils are suitable for crystal sets and broadcast receiver experiments. They are wound with 19- or 20-gauge wire and should be wound on a material having low loss at AM broadcast frequencies. PVC or polystyrene tubing would be suitable, but cardboard or fiberglass will do as well.

SINGLE-COIL CRYSTAL RADIO



POPULAR ELECTRONICS **Fig. 25-6**

A starting setup for this circuit is as follows: Connect the antenna to the second tap up from the bottom of the coil (that's the end of the coil that's connected to ground). The diode should connect to about the fourth tap up from the bottom, and C1 should be attached to the seventh tap or so up from the bottom. Those tap positions might not be the best starting point for your antenna/ground arrangement. That doesn't matter, however, because to obtain the best results with the receiver at your location, you should experiment with all variables anyway.

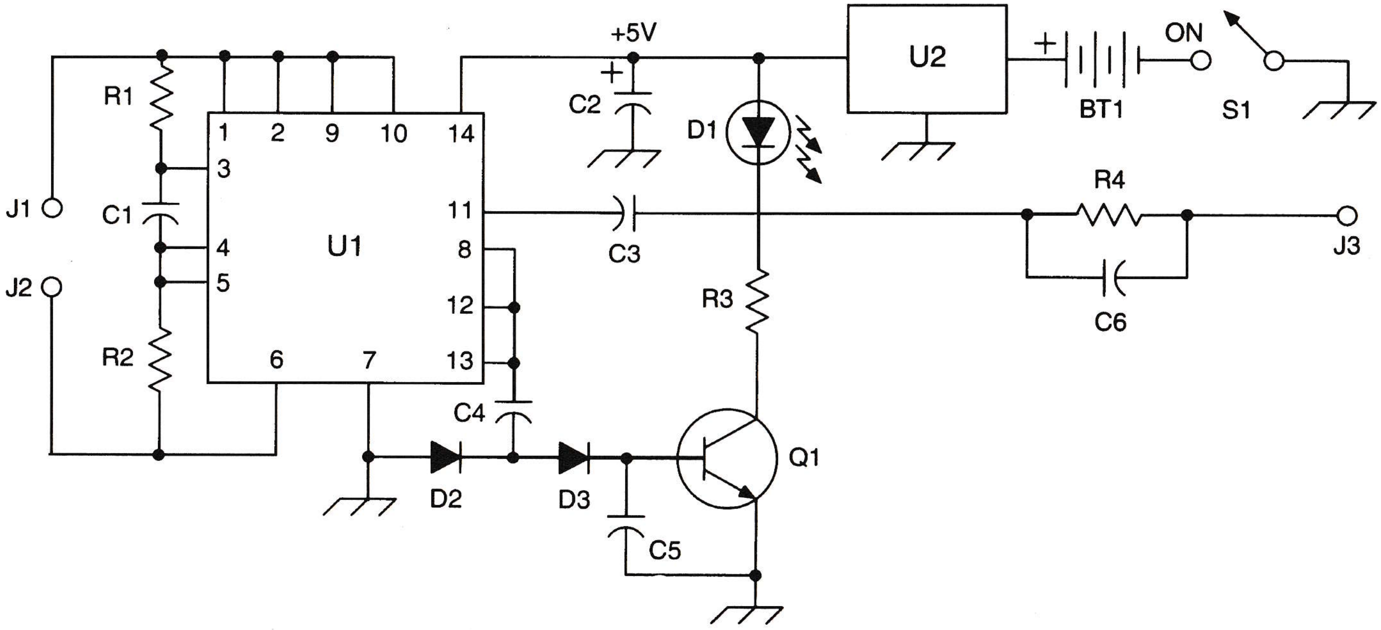
26

Crystal Test Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Crystal Activity Tester
Quartz Crystal Specifications
Meter Indicator for Crystal Activity Tester

CRYSTAL ACTIVITY TESTER

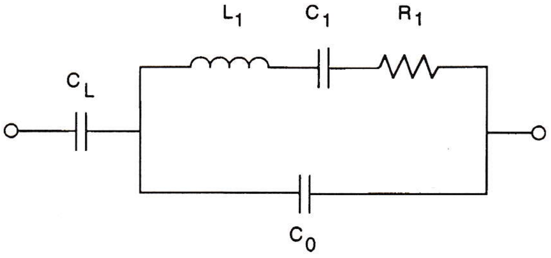


73 AMATEUR RADIO TODAY

Fig. 26-1

U1 is a 74LS00 quad two-input NAND-gate logic chip. The LS version was selected because of its low current requirement. Two of its internal gates are connected as inverters and, in conjunction with R1, R2, and C1, form a crystal oscillator when a crystal is connected between J1 and J2. The third gate, also connected as an inverter, is used as a buffer to provide RF at the crystal frequency from pin 11, through isolation capacitor C3 and high-pass filter R4 and C6, to J3 so that the crystal frequency can be monitored by an external-frequency counter. The fourth gate, also connected as an inverter-buffer, provides RF at the crystal frequency from pins 8, 12, and 13 connected in parallel. The RF is fed through isolation capacitor C4 to voltage-doubling rectifiers D2 and D3, and the resulting dc voltage is filtered by C5 and provides a positive bias to the base of Q1, an NPN transistor, which is normally cut off. Q1 goes into conduction, and its collector current flows through LED D1 and R3 in series, both forming the collector load circuit. The greater the activity of the crystal, the higher the positive bias on the base of Q1 will be, and the higher its collector current will be. This current illuminates D1, and its relative brightness is indicative of the level of crystal activity.

QUARTZ CRYSTAL SPECIFICATIONS



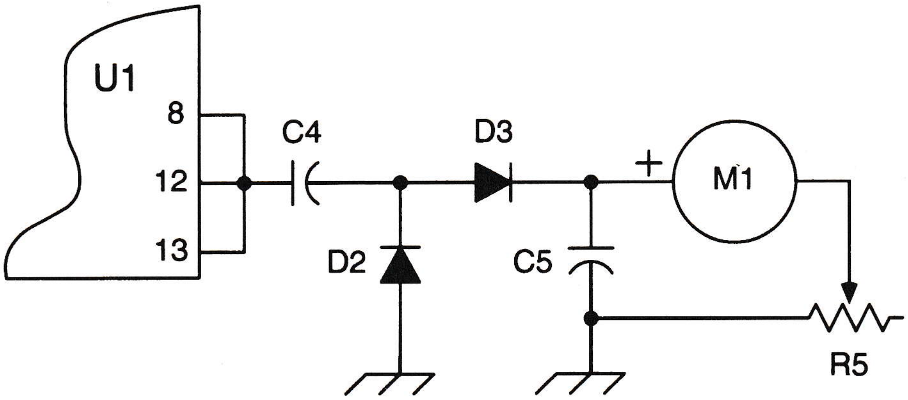
RF DESIGN ***Fig. 26-2***

Five main parameters control the characteristics of a crystal, as noted in the equivalent circuit for the figure. These parameters are:

- C_1, the motional capacitance
- L_1, the motional inductance
- R_1, the equivalent series resistance (ESR)
- C_0, the parallel capacitance resulting from the electrodes and crystal packaging
- C_L, external load capacitance of the circuit

C_1 and L_1 are interdependent because they determine the resonant frequency of the crystal. If we know one of the parameters, we can readily compute the other if we know the series resonant frequency. R_1 is the resistance determined by the motional (piezoelectric) behavior of the crystal. If it is too high, the crystal might not start oscillation. C_0 is a physical capacitor, created by the electrodes plated onto the crystal surface, along with some additional capacitance from the package. Generally, larger C_0 contributes to better pullability. C_L is the load capacitance of the user's circuit. The crystal must operate at the right frequency in the intended circuit, so this value needs to be included in the crystal purchase specification.

METER INDICATOR FOR CRYSTAL ACTIVITY TESTER



73 AMATEUR RADIO TODAY *Fig. 26-3*

A meter can be added as shown, replacing the LED in the original circuit. The meter movement should be a 0- to 1-mA type.

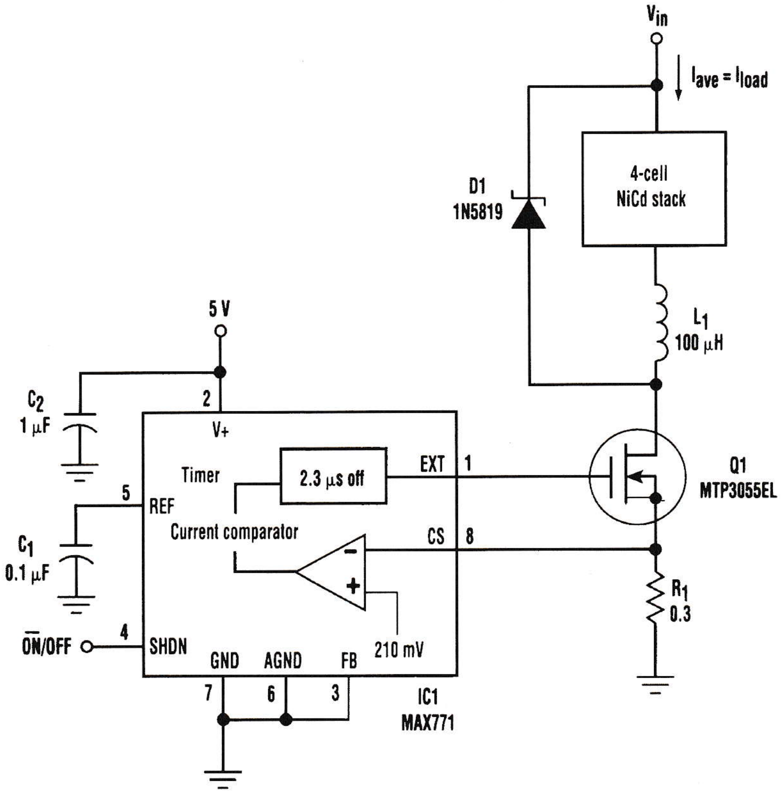
27

Current Source Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Constant-Current Source Converter
Programmable Current Source

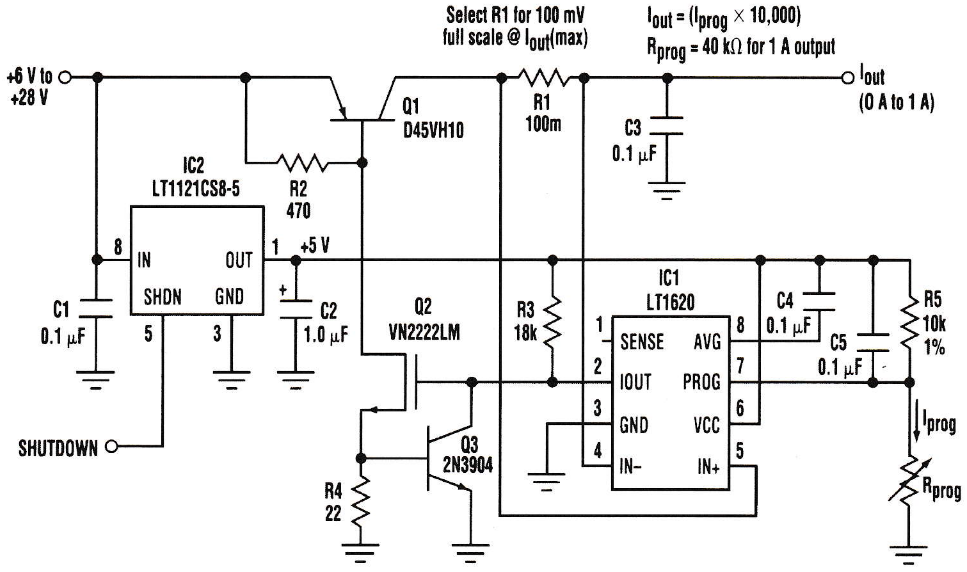
CONSTANT-CURRENT SOURCE CONVERTER



ELECTRONIC DESIGN *Fig. 27-1*

To maintain regulation, the switching voltage regulator shown includes independent loops of current and voltage feedback. If the voltage loop is disabled, the current loop can be used to implement a general-purpose current source. The first step in obtaining a current source is to apply 5 V to V^+. Because the chip expects 12 V of feedback at that terminal, it assumes a loss of regulation and shifts control to the current loop. This mode of operation allows an increasing ramp of current through Q1, causing the voltage at pin 8 to increase until it reaches the internal comparator threshold (210 mV). Timing circuitry then turns off Q1 for a fixed 2.3 μs, and the cycle repeats. The result is a relatively constant inductor current, which also happens to be the load current. With a proper choice of component values, the circuit generates constant current over a wide range of input voltages. The circuit (with component values shown) is a fast charger for NiCd batteries that provides 60-mA charging currents.

PROGRAMMABLE CURRENT SOURCE



ELECTRONIC DESIGN

Fig. 27-2

Constant-current sources are required in many applications, particularly when it comes to battery charging. In such applications, it is desirable that the output current be accurate, temperature-stable, and adjustable. The controller also can be successfully employed as the control element in a low-cost linear current source. Output current is sensed by resistor R1, with the value selected so that 100 mV is full-scale. The voltage across R1 is amplified by a factor of 10 and averaged across capacitor C4. An internal transconductance error amplifier compares the voltage on pin 8 against the programming voltage at pin 7. The error-amplifier output is present on pin 2 (I_{out}), and is level-shifted by Q2 to control the PNP pass transistor. Output current is programmed by adjusting the voltage across R5 (1 V full-scale). The LT1121 LDO regulator provides a 5-V, ±1.5 percent reference voltage so that current can be accurately programmed by simply connecting different values for R_{prog}. The input voltage can range from +6 to +28 V, with output current changing less than 0.3 percent. Proper heat sinking must be provided for Q1, especially when operating with large input-to-output voltage differentials. Transistor Q3 and R4 limit the magnitude of Q1's base drive during dropout, preventing excessive dissipation in driver transistor Q2. Using voltage regulator IC2, the constant-current source operates directly from the unregulated input voltage. Pulling IC2's shutdown pin low turns off V_{CC} to the entire circuit, and limits the reverse current drawn from the output to less than 25 μA.

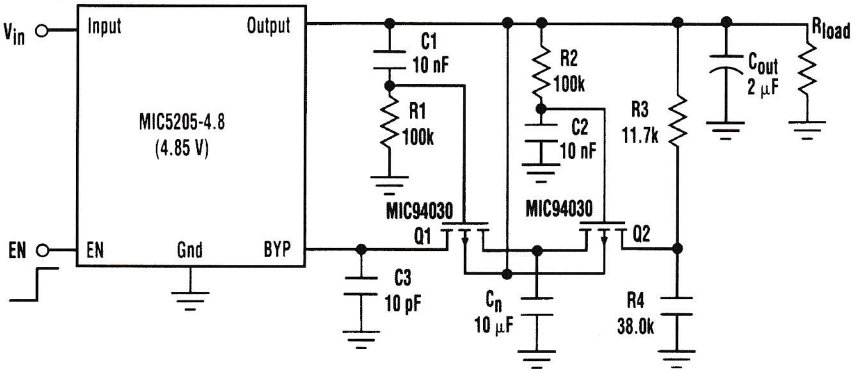
28

Dc-to-Dc Converter Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Quick-Switching PNP Regulator
±20-V Charge Pump Boost Converter
500-kHz 3.3-V–to–12-V Dc Converter
Basic Boost Converter Circuit
Micropower Step-Up Converter
Micropower Positive-to-Negative Converter
Inductorless –5-V Converter
Two-Cell 5-V 500-mA Converter
9-V Dc-to-Dc Converter
3- to 7-V Dc-to-Dc Converter
Dual-Output 500-kHz ±15-V Dc-to-Dc Converter
500-kHz 5-V–to–12-V 400-mA Dc-to-Dc Converter
High-Current 5-V–to–12-V 2.5-A Dc-to-Dc Converter
5-V–to–12-V 1-A Dc-to-Dc Converter
70-V-Input 5-V 700-mA Telecom Converter
40-V-Input 5-V 10-A Dc-to-Dc Converter
9-V-Input ±5-V Output Dc-to-Dc Converter
6- to 25-V-Input 5-V 1.25-A Dc-to-Dc Converter
Efficient 5-V–to–3.3-V Converter
95-Percent-Efficient 5-V-Input 3.3-V-Output Dc-to-Dc Converter
Two-Cell–to–5-V Boost Converter
Simple 5-V–to–3.3-V Converter
Four-Cell–to–5-Vdc Converter
5-V–to–4-V Converter
Low-Noise Dc-to-Dc Converter
1.2-V Regulator for GTL Termination
Current-Limiting A-Series Regulator
Transformerless Dc-to-Dc Converter

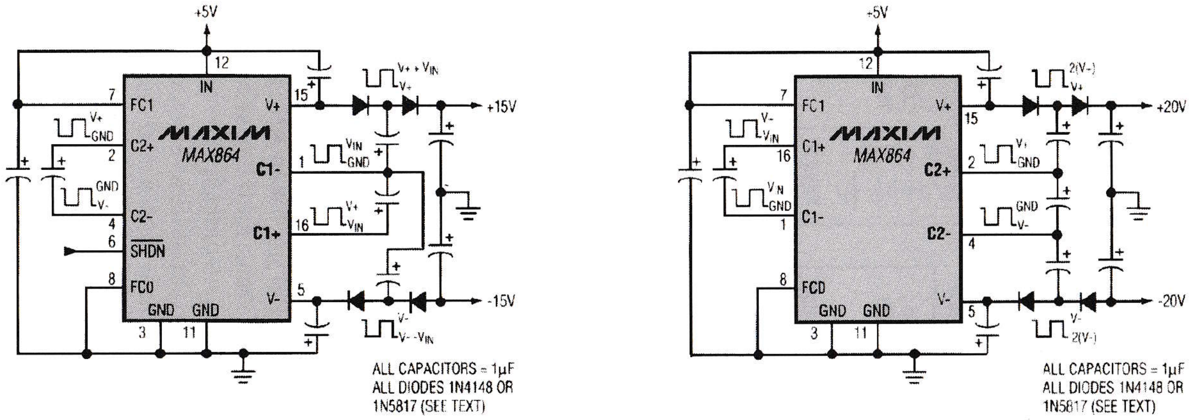
QUICK-SWITCHING PNP REGULATOR



ELECTRONIC DESIGN *Fig. 28-1*

The MIC5205 is a low-dropout PNP regulator that incorporates a noise bypass pin for additional noise reduction. A single 10-nF capacitor, connected from the bypass pin to ground, reduces output noise by $V_{out}/1.24$ V (12 dB for the 5-V part) and creates a noise pole below 100 Hz. Switch-on time is increased from 80 µs to 15 ms. With the addition of a few components, the following circuit preserves a low switch-on time. A low-to-high signal on EN switches the output on quickly. This allows R1 and C1 to hold Q1 off while R2 and C2 hold Q2 on. C_n is also quickly charged to the bypass pin voltage through Q2 by the voltage divider R3, R4. C1 and C2 then charge to the output voltage, turning Q1 on and Q2 off. C_n is now switched from the voltage divider to the bypass pin. The regulator is now in the low-noise configuration, which takes about 100 µs. When EN goes low, C1 and C2 discharge through R1, R2, R3, R4, and R_{load}. This resets the circuit for the next turn-on cycle. C3 helps prevent overshoot on the output. Ratio R_3/R_4 can be found empirically: First, set the ratio close to the ratio $1.24\ \text{V}/(V_{out} - 1.24\ \text{V})$, then adjust the value so the output turns on quickly without overshoot. The final tolerance needs to be 1 percent. Switch-off time is determined only by output capacitor size and the load.

±20-V CHARGE PUMP BOOST CONVERTER



ALL CAPACITORS = 1µF
ALL DIODES 1N4148 OR
1N5817 (SEE TEXT)

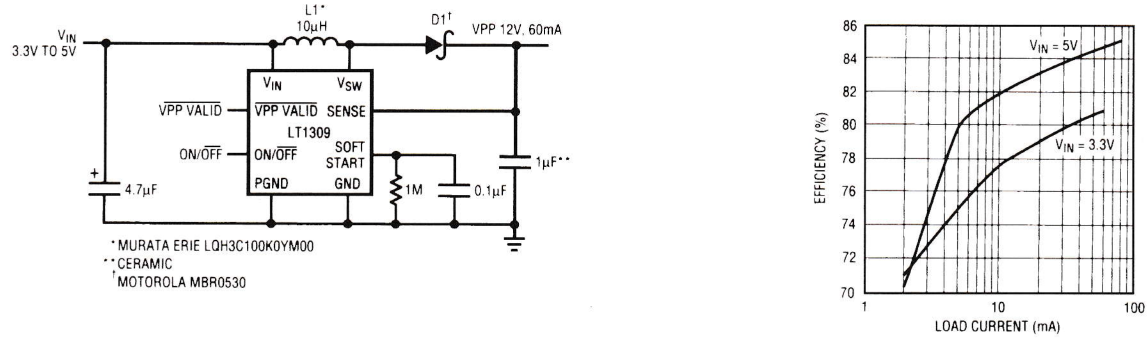
ALL CAPACITORS = 1µF
ALL DIODES 1N4148 OR
1N5817 (SEE TEXT)

MAXIM ENGINEERING JOURNAL

Fig. 28-2

A low-power converter of 5 to ±20 V can be made surprisingly small by enhancing a dual-output charge-pump IC with an extra boost stage composed of discrete diodes. Such supplies are useful for CCD power supplies, LCD bias, and varactor tuners. The MAX864 on its own can generate ±10 V (minus load-proportional losses) from a 5-V input, or ±6.6 V from a 3.3-V input. Using additional diode-capacitor stages, these outputs can be doubled again to approximately $\pm 4V_{in}$, or multiplied by 1.5 to approximately $\pm 3V_{in}$. Note that the external diode/capacitor network connects to C1 for ±15-V outputs or to C2 for ±20-V outputs.

500-kHz 3.3-V–TO–12-V DC CONVERTER

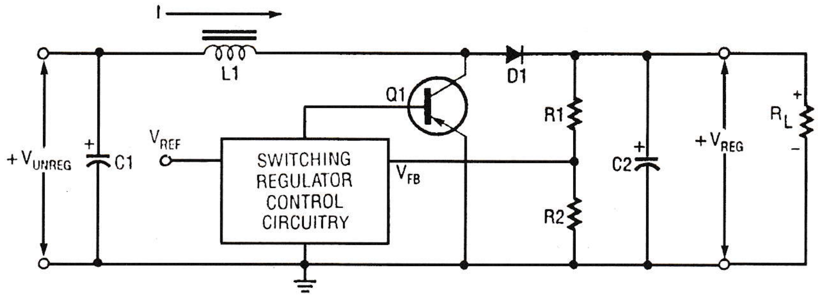


*MURATA ERIE LQH3C100K0YM00
**CERAMIC
†MOTOROLA MBR0530

LINEAR TECHNOLOGY POWER SOLUTIONS ***Fig. 28-3***

The LT1309 500-kHz micropower dc-to-dc converter circuit shown provides a compact 12-V supply. High-frequency operation permits the use of low-inductance and low-capacitance values for surface-mount parts. The LT1309 provides 60 mA of output current at 12 V, required for 8-bit-wide flash memory chips. In addition, when the flash memory card is removed, the LT1309 can be shut down by the system, reducing current draw to 6 μA. A soft-start feature allows the output voltage to ramp up to 12 V over a period of time, minimizing inrush current needed from the 3.3-V supply to charge the PCMCIA input capacitance. An active-low VPP VALID output signals the system that the 12-V supply is within regulation after being switched on.

BASIC BOOST CONVERTER CIRCUIT



ELECTRONICS NOW ***Fig. 28-4***

This boost converter with a single switching transistor depends on the transformer for energy storage.

MICROPOWER STEP-UP CONVERTER

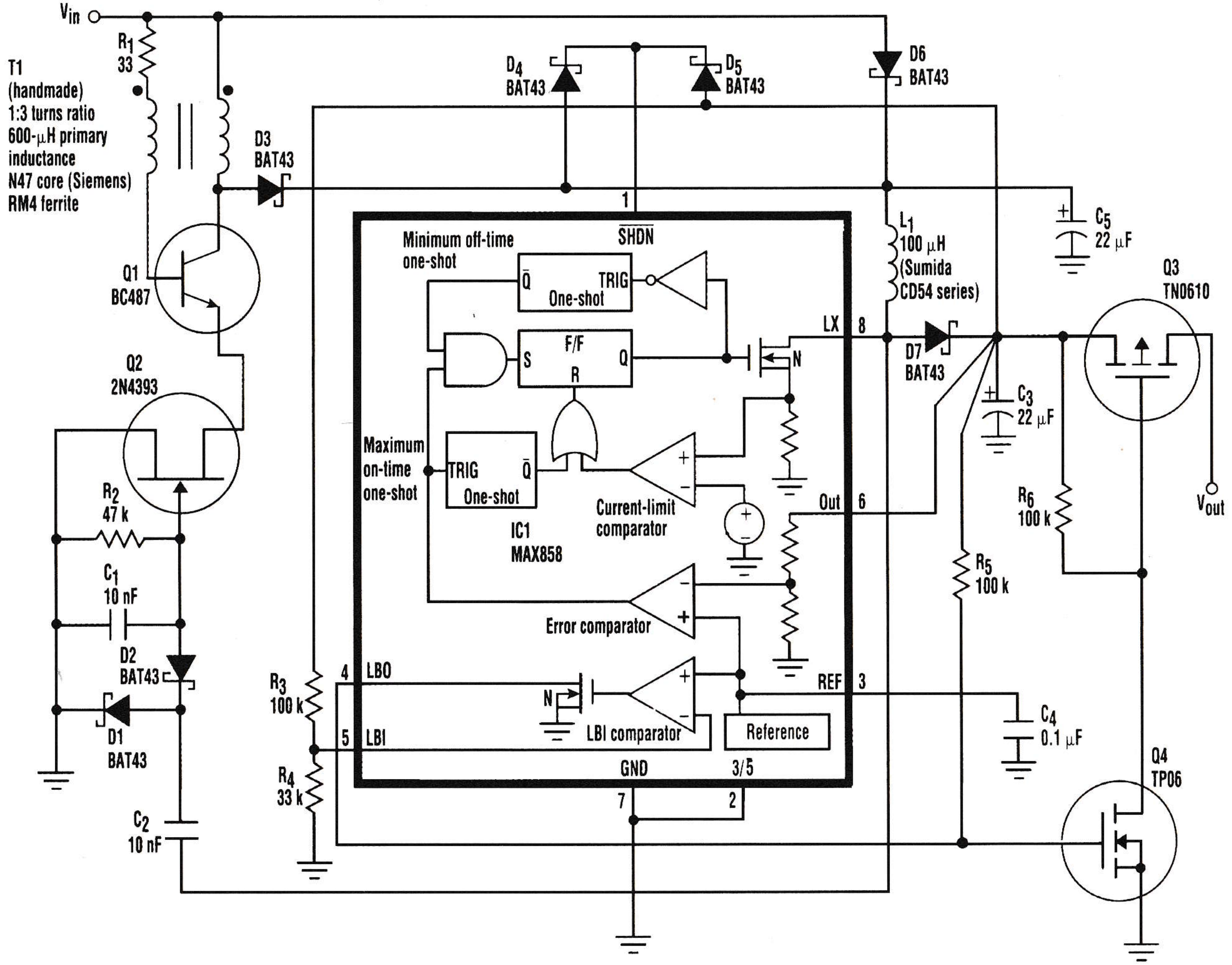
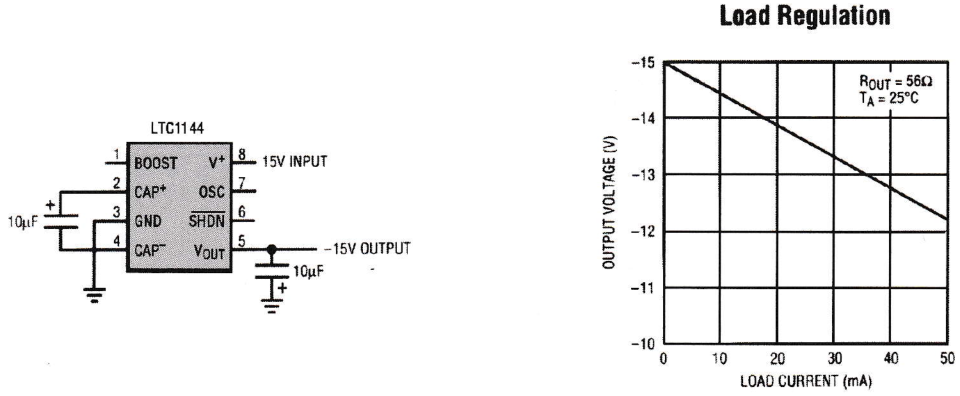


Fig. 28-5

MICROPOWER STEP-UP CONVERTER *(Cont.)*

This circuit can start with inputs as low as a diode drop, i.e., 0.6 V. It provides a 5-V output with 15-mA current capability, but for this application, the load current must be limited. The circuit powers a meter from the drop across a single diode in a 4- to 20-mA current loop, and provides 77 percent efficiency at a current of 0.5 mA (with diode D6 shorted). Load current available to the meter (I_{load}) is limited by the 4-mA minimum loop current. Transistor Q1 and transformer T1 form a resonant tank circuit that self-oscillates at a frequency of approximately $1/L_1R_1$. R1 is a current-limiting resistor. At 50 kHz, with an input of 0.6 V, the value shown for resistor R1 (33 Ω) limits the maximum current into the base of transistor Q1 to 20 mA. The primary inductance of transformer T1, although not a crucial parameter, should be 660 μH for this value resistor of R1.

MICROPOWER POSITIVE-TO-NEGATIVE CONVERTER

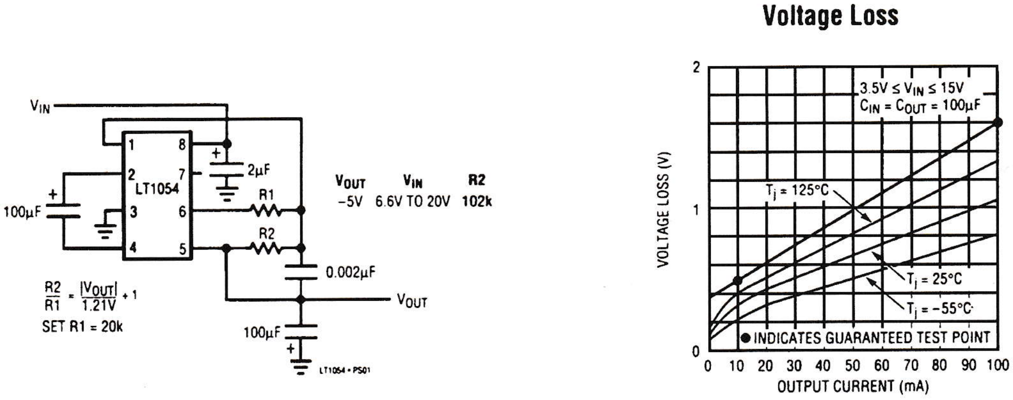


LINEAR TECHNOLOGY POWER SOLUTIONS

Fig. 28-6

Switched capacitor voltage converters are a convenient way to generate a local negative supply for biasing special circuitry, but have been limited by CMOS processes to 10 V of supply or less. The LTC1144 voltage converter overcomes this limitation, extending the maximum input voltage to 20 V. Still, the part retains the low power of CMOS operation. The LTC1144 circuit shown here generates a negative supply voltage of −13.8 V typ. (−12.6 V min.) from a 15-V input at a maximum load current of 20 mA. Higher load currents are possible at slightly lower output voltages. The low-cost circuit includes two surface-mount capacitors, minimizing board space. A supply current of 1.2 mA (max.) results in high conversion efficiency, while just 8 μA of supply current is consumed in shutdown, making the LTC1144 excellent for use in battery-powered systems.

INDUCTORLESS −5-V CONVERTER

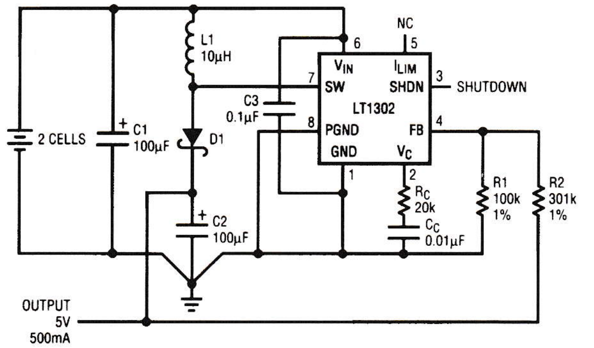


LINEAR TECHNOLOGY POWER SOLUTIONS

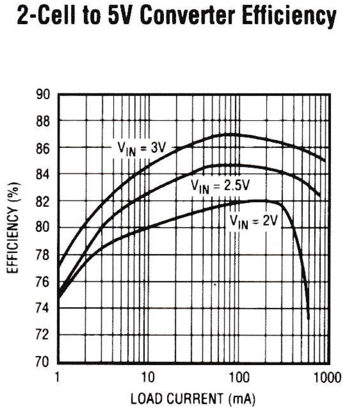
Fig. 28-7

Switched capacitor voltage converters are great for supplying an unregulated negative voltage from a positive supply. To provide a regulated negative voltage, a linear regulator is normally required. The LT1054 eliminates the extra voltage regulator by adding a pair of feedback resistors, as shown here. An internal feedback circuit allows full regulation of the output voltage with changes in input voltage and load current. With a minimum input of 6.5 V, the LT1054 can produce a regulated −5-V output at loads of up to 100 mA max. External components required include four capacitors and two resistors.

TWO-CELL 5-V 500-mA CONVERTER



C1 = C2 = SANYO OS-CON
L1 = COILTRONICS CTX10-3
COILCRAFT DO3316-103
D1 = MOTOROLA MBRS130LT3

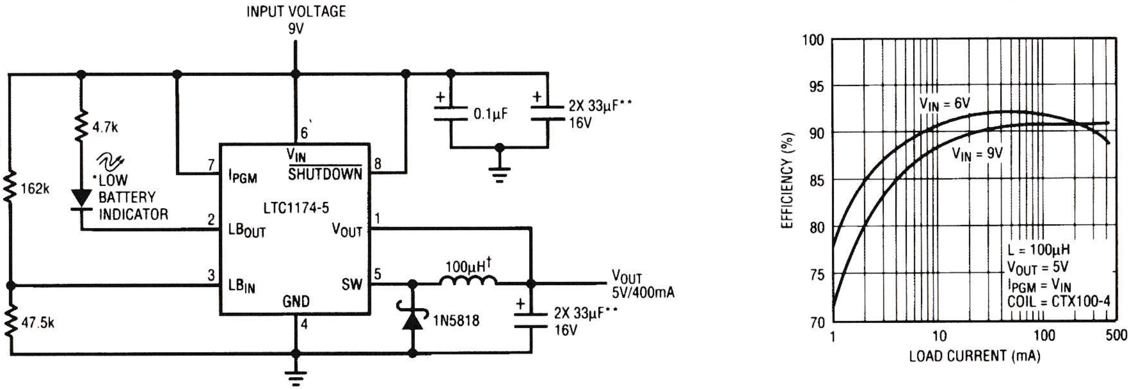

2-Cell to 5V Converter Efficiency

LINEAR TECHNOLOGY POWER SOLUTIONS

Fig. 28-8

Hand-held instruments, PCMCIA cards, and portable communications gear often require high current for their operation, although only for short periods at a time. Current of 500 mA at 5 V can be obtained from a two-cell battery using a switching regulator controller IC, an external switch transistor, and some discrete components, but the solution is inefficient, space-intensive, and cumbersome. The LT1302 was designed to provide higher output currents by using an integrated 2-A low-loss switch. An output current of 500 mA at 5 V with 85 percent efficiency is possible from two AA cells. Component size is minimized by using a fixed-frequency 220-kHz PWM architecture. The circuit maintains high efficiencies at low load currents by automatically switching to Burst mode operation at lower switch currents.

9-V DC-TO-DC CONVERTER



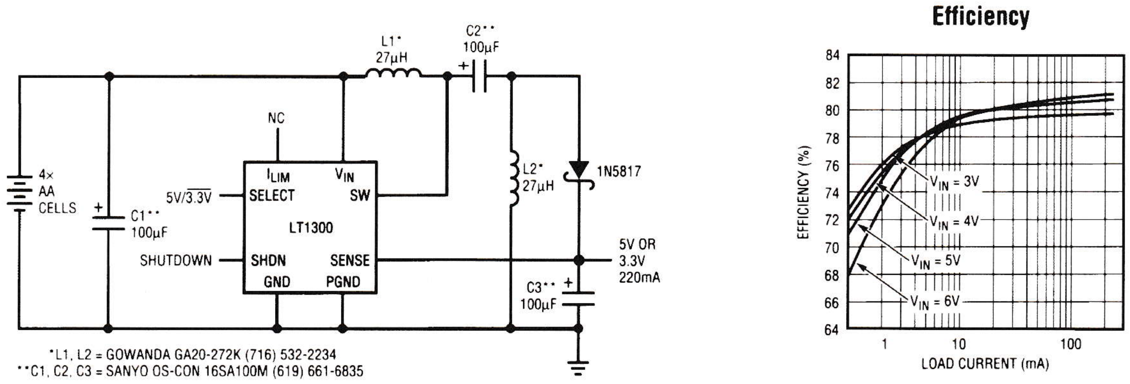
Efficiency

*LOW-BATTERY INDICATOR IS SET TO TRIP AT V_{IN} = 5.5V
**AXV TPSD336K016
†COILTRONICS CTX100-4

LINEAR TECHNOLOGY POWER SOLUTIONS ***Fig. 28-9***

In portable applications, 9-V batteries are frequently used. For low-power dc-to-dc step-down conversion, the LTC1174 is a simple integrated solution. With its internal MOSFET power switch, the LTC1174-5 requires only four external parts to achieve 90-percent efficiency. All surface-mount assembly is standard, with high-frequency operation at up to a 200 kHz switching frequency. Extremely low dropout operation is possible because the LTC1174 operates at 100-percent duty cycle with low input voltages. A single logic-level input selects an output voltage of 3.3 V or 5 V.

3- TO 7-V DC-TO-DC CONVERTER

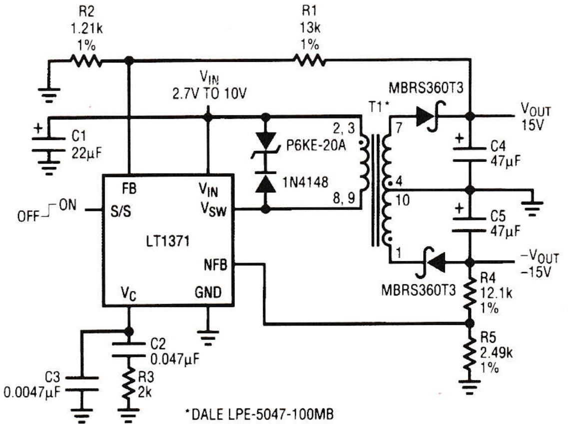


*L1, L2 = GOWANDA GA20-272K (716) 532-2234
**C1, C2, C3 = SANYO OS-CON 16SA100M (619) 661-6835

LINEAR TECHNOLOGY POWER SOLUTIONS ***Fig. 28-10***

Converting the voltage from a four-cell battery pack to 5 V while using the full capacity of the batteries requires two modes of operation: step-down from an input voltage of 6 V and step-up from an input of 4 V (or less). A flyback topology can accomplish this, but uses a costly custom transformer. The LT1300 circuit shown utilizes the simple SEPIC topology, and is capable of 220 mA of output current at 5 V from a minimum 3-V input. The two inductors specified are available off the shelf. The circuit uses a boost section and a buck, or step-down, section, with the two inductors (L1 and L2) and two capacitors (C2 and C3) all acting as energy-storage elements. Efficiency is slightly less than that of a direct step up (see graph), but is better than that of an equivalent flyback configuration. Other features of the circuit include shutdown (10 μA max. supply current) with full input-to-output isolation, which allows the output to go to zero volts, yet present no load to the batteries. Also, either a 3.3-V or 5-V output can be selected by using the logic-select pin of the LT1300.

DUAL-OUTPUT 500-kHz ±15-V DC-TO-DC CONVERTER

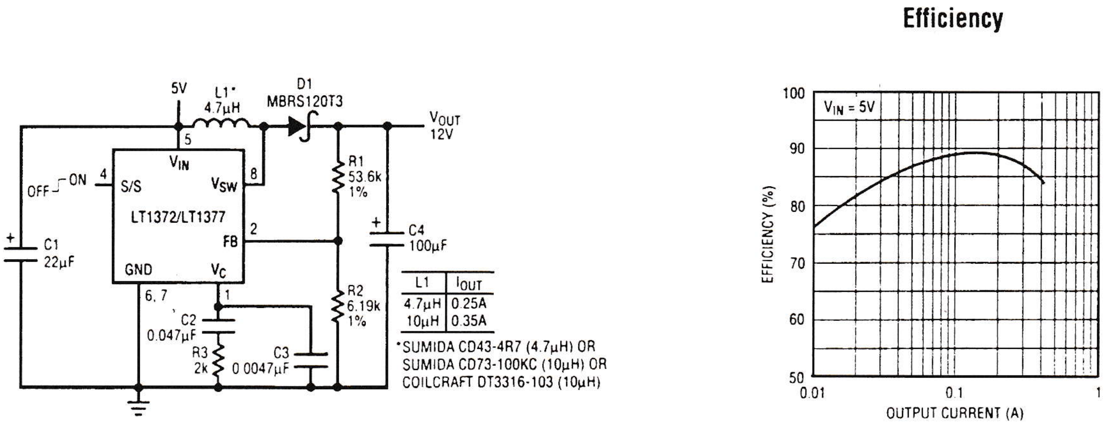


*DALE LPE-5047-100MB

LINEAR TECHNOLOGY POWER SOLUTIONS ***Fig. 28-11***

The LT1371 dual-output flyback converter circuit shown generates ±15 V at 200 mA each from a 5-V supply. The LT1371 is a 500-kHz high-efficiency switching regulator with 3-A power switch, yet it uses only 4 mA typical quiescent current. The high operating frequency allows a small surface-mount, dual-output winding flyback transformer to be used. Each output is monitored by separate positive and negative feedback inputs on the LT1371 to be sure that neither output rises above its set point. This removes a common problem in dual-output designs using a single controller: the tendency of the voltage of the least loaded output to fly high. Output voltage regulation is best when both outputs are evenly loaded.

500-kHz 5-V–TO–12-V 400-mA DC-TO-DC CONVERTER



L1	IOUT
4.7μH	0.25A
10μH	0.35A

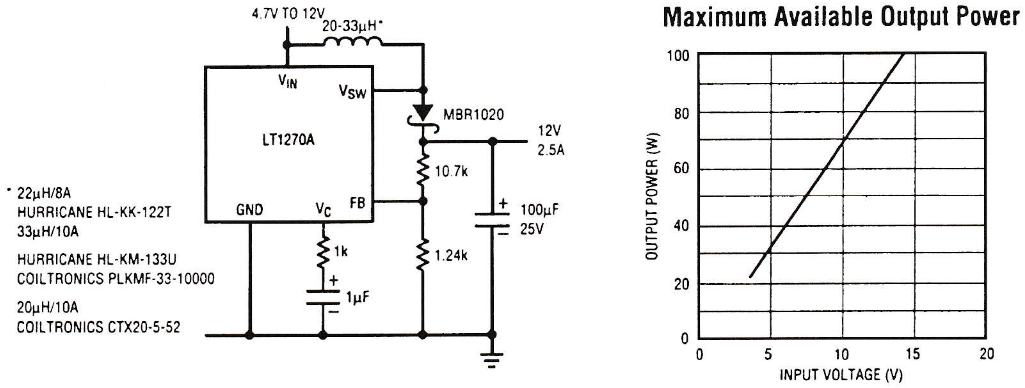
*SUMIDA CD43-4R7 (4.7μH) OR
SUMIDA CD73-100KC (10μH) OR
COILCRAFT DT3316-103 (10μH)

LINEAR TECHNOLOGY POWER SOLUTIONS

Fig. 28-12

In some 5-V-only systems, it is necessary to generate a local 12-V supply to power op amps, data-acquisition circuitry, or devices, such as small motors. The LT1372 is a 500-kHz high-efficiency switching power regulator that provides this capability, as shown in this circuit. The 500-kHz switching frequency reduces the size of the magnetics significantly over that in lower-frequency designs; they consume just 0.5 in^2 of total board space. The internal switches are current-limited to 1.5 A. In addition, the quiescent current of LT1372 is just 4 mA, which, along with very low switch losses, provides up to 89 percent efficiency in this application. Other features of the LT1372 include synchronization of the switching action to a system clock source and shutdown capability, reducing supply currents to just 12 μA. Also, the LT1372 has two feedback inputs that allow regulation of either positive or negative output voltages.

HIGH-CURRENT 5-V–TO–12-V 2.5-A DC-TO-DC CONVERTER

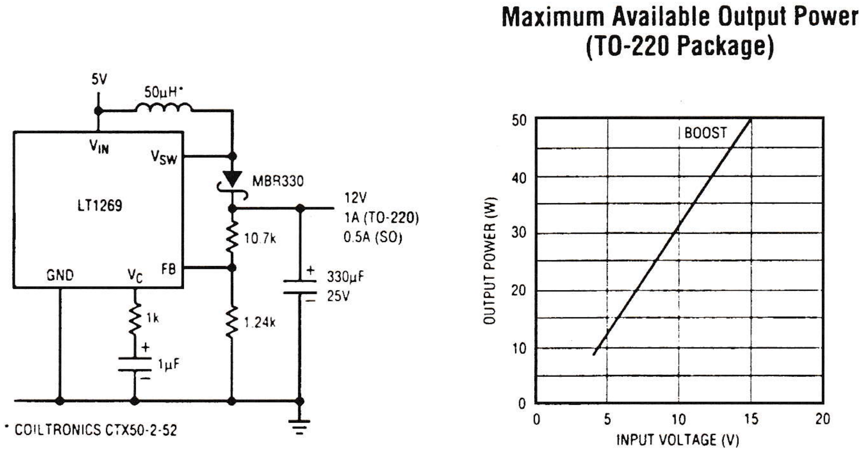


LINEAR TECHNOLOGY POWER SOLUTIONS

Fig. 28-13

Many applications require a 12-V supply for control, data storage, interface, or driver functions. These designs often require high peak currents, and a 12-V supply might not be available with high enough current. The LT1270A circuit shown here will provide a minimum of 2.5 A at 12 V from a 5-V ±5 percent supply. The LT1270A has a 10-A high-efficiency switch and a low 10-mA (maximum) supply current, which provides excellent efficiency in high-current-output dc-to-dc conversion circuits. The 60-kHz switching frequency has been optimized for best efficiency.

5-V–TO–12-V 1-A DC-TO-DC CONVERTER

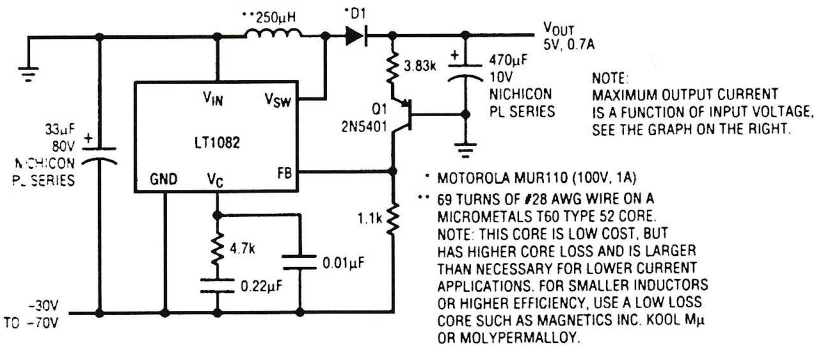


Maximum Available Output Power (TO-220 Package)

LINEAR TECHNOLOGY POWER SOLUTIONS *Fig. 28-14*

Local on-board conversion from 5 V to 12 V for use in amplifier, signal conditioning, or bus driver circuitry normally entails the use of a module or complex dc-to-dc converter design. The LT1269 100-kHz PWM switching regulator can provide a minimum of 1 A at a regulated 12 V in a surface-mountable DD package (500 mA in 20-lead, small-outline SMT). Included on the chip is a low-ON-resistance switch (0.33 Ω) with a 4-A current limit for high-efficiency conversion in the boost converter shown here. The high switching frequency permits the use of small inductors and capacitors in this converter. The device can be placed in a micropower shutdown mode (100 µA typical supply current) by activating a clamp on the V_C pin.

70-V-INPUT 5-V 700-mA TELECOM CONVERTER

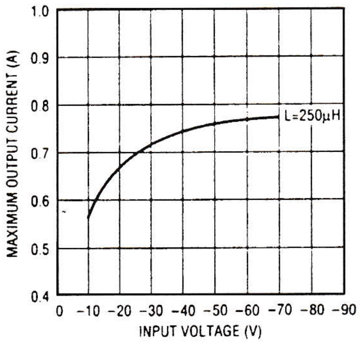


NOTE:
MAXIMUM OUTPUT CURRENT
IS A FUNCTION OF INPUT VOLTAGE.
SEE THE GRAPH ON THE RIGHT.

* MOTOROLA MUR110 (100V, 1A)

** 69 TURNS OF #28 AWG WIRE ON A MICROMETALS T60 TYPE 52 CORE. NOTE: THIS CORE IS LOW COST, BUT HAS HIGHER CORE LOSS AND IS LARGER THAN NECESSARY FOR LOWER CURRENT APPLICATIONS. FOR SMALLER INDUCTORS OR HIGHER EFFICIENCY, USE A LOW LOSS CORE SUCH AS MAGNETICS INC. KOOL Mμ OR MOLYPERMALLOY.

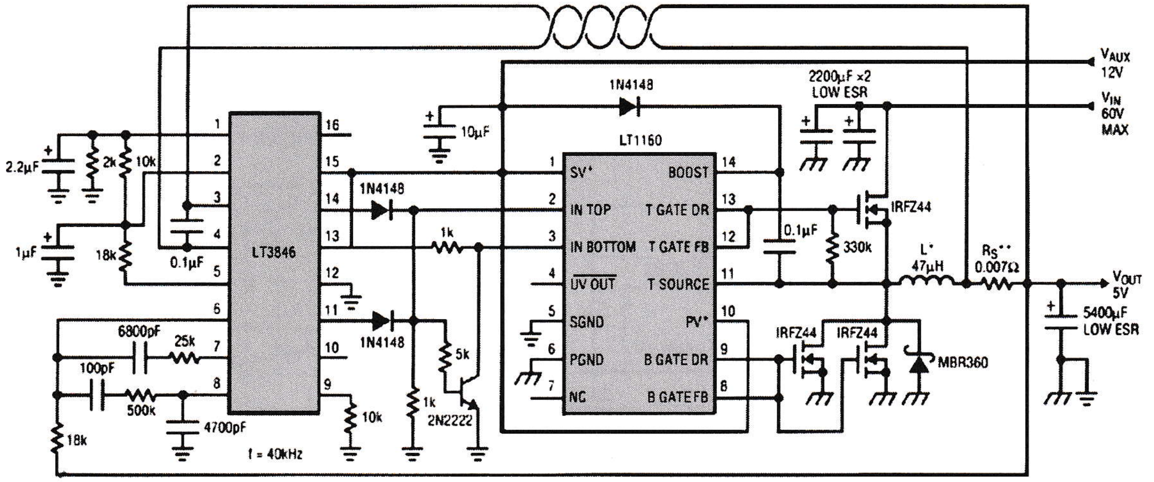
Maximum Available Output Current



LINEAR TECHNOLOGY POWER SOLUTIONS *Fig. 28-15*

Telecom dc-to-dc conversion applications are usually complex because of the wide input voltage range of −30 to −70 V. Either big, expensive converter modules or space- and component-intensive discrete solutions are normally required to handle these higher voltages. The LT1082 contains a 1-A switch that can handle 100 V, enabling a −48-V–to–5-V converter to be designed with minimal size and cost. Features include foldback of the 60-kHz switching frequency under short-circuit conditions, protecting the LT1082 and power components from excessive power dissipation. The LT1082 dc-to-dc converter circuit provides up to 750 mA of output current, and the solution costs less than a modular supply of similar capabilities.

40-V-INPUT 5-V 10-A DC-TO-DC CONVERTER



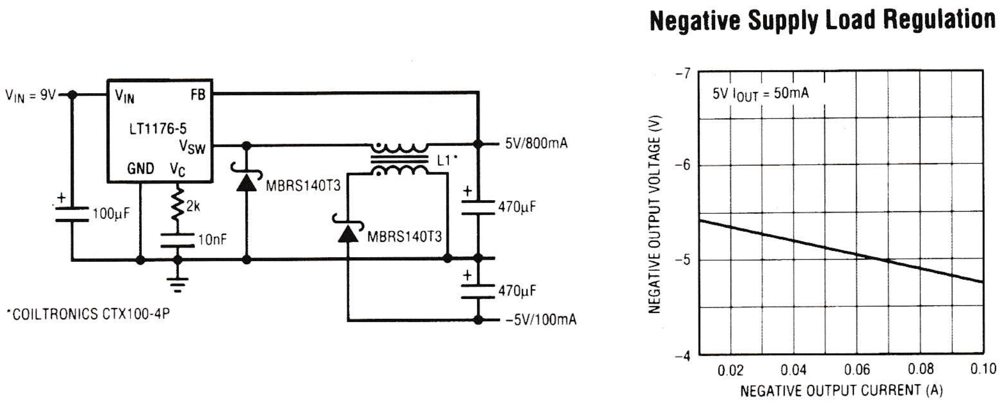
* HURRICANE LAB HL-KM147U

** DALE TYPE LVR-3 ULTRONIX RCS01

LINEAR TECHNOLOGY POWER SOLUTIONS ***Fig. 28-16***

Generating 5 V at 10 A from a 40-V supply with up to 90 percent efficiency is possible using a synchronous switching regulator. The synchronous switching regulator circuit shown achieves this high efficiency by using external MOSFETs with low R_{DS}(ON) and by shunting the Schottky diode after the topside MOSFET has completely turned off to minimize the Schottky diode's conduction losses. The LT1160 half-bridge driver alternately drives the high side and low side MOSFETs ON and OFF during switching. The loop is controlled by the LT3846 current-mode PWM controller and operates at 40 kHz. A key feature of this circuit is the ability to drive the external high-current MOSFETs safely. Internal logic in the LT1160 prevents both MOSFETs from being on at the same time, and its unique adaptive protection against shoot-through currents eliminates all matching requirements for the external MOSFETs. These protection features, in combination with the LT1160's ability to drive up to 10,000 pF of gate capacitance, make paralleling power MOSFETs for high-current applications an easy task. The high-side gate voltage is provided by a floating supply, which is boosted above the HV rail by bootstrap capacitance C_{boost}. An undervoltage detector in the LT1160 can sense an undervoltage condition at either the input supply or the floating supply and turn off both MOSFETs to prevent excessive power dissipation.

9-V-INPUT ±5-V OUTPUT DC-TO-DC CONVERTER



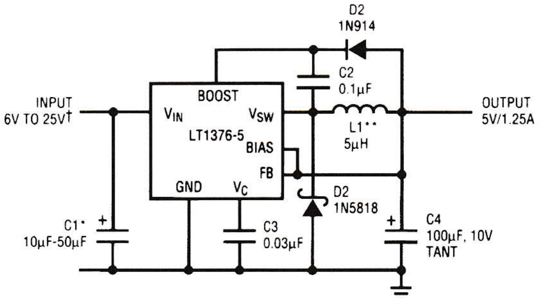
Negative Supply Load Regulation

LINEAR TECHNOLOGY POWER SOLUTIONS

Fig. 28-17

Many dc-to-dc converter applications require regulated complementary output voltages from a single loosely regulated source. A common use for this is supplying 5 V and −5 V to a video op amp for amplification or cable driving. Accomplishing this task in a space-effective manner with a minimum of components is a challenge for a designer. The LT1176-5 circuit shown here uses a single integrated switching regulator and an off-the-shelf inductor with an extra winding to generate ±5 V from an 8- to 12-V input. The circuit is designed to supply 5 V as the main output with up to 800 mA of load current, and −5 V as a secondary output with up to 100 mA load current. Regulation is adequate for most op-amp circuits: 5-V regulation will be ±3 percent and −5-V regulation is about ±10 percent for loads between −10 and −100 mA. The LT1176-5 provides a complete 100-kHz switching regulator with a 1.2-A on-chip switch in a thin 20-lead SO package. The enhanced thermal characteristics of the fused-lead SO package allow higher power outputs than were previously possible with SOs.

6- TO 25-V-INPUT 5-V 1.25-A DC-TO-DC CONVERTER

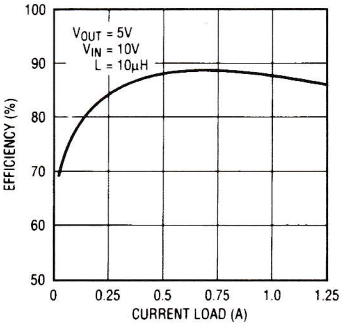


* VOLTAGE RATING FOR SOLID TANTALUM SHOULD BE TWICE MAXIMUM INPUT VOLTAGE. RIPPLE CURRENT RATING = ONE HALF LOAD CURRENT

** INCREASE TO 10μH FOR LOAD CURRENT ABOVE 0.6A AND TO 20μH ABOVE 1A

† FOR INPUT VOLTAGE BELOW 7.5V, SOME RESTRICTIONS MAY APPLY. SEE DATA SHEET

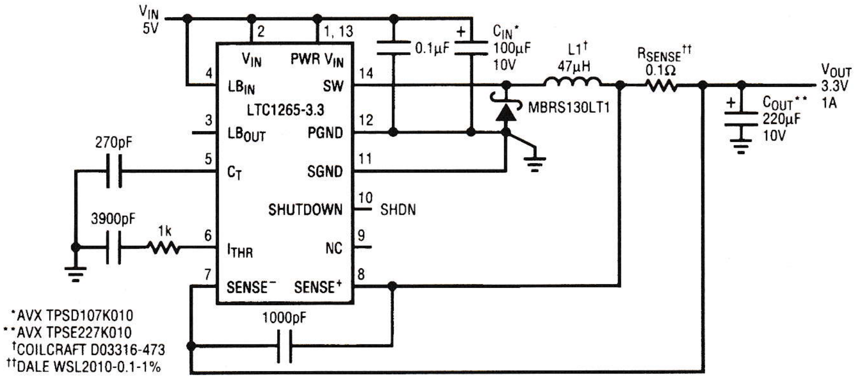
Efficiency

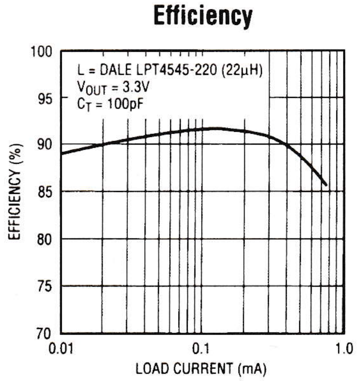


LINEAR TECHNOLOGY POWER SOLUTIONS ***Fig. 28-18***

One of the keys to success for many portable devices is small size. In many cases, the requirement for a wide battery supply voltage range and high-current, regulated 5-V output seems incompatible with the size requirement. The 500-kHz LT1376, shown in this circuit, provides a powerful, compact power supply. Operating at such a high frequency permits the use of a very small 5-μH surface-mount inductor and a surface-mount output capacitor. In addition, the internal switch has just 0.4 Ω of ON resistance, which reduces power loss and boosts efficiency to 88 percent. A special boost pin and circuitry reduces the minimum operating supply voltage in step-down applications. The maximum current rating of the switch is 1.5 A. The input voltage range extends from 6 to 25 V and is well matched for many battery-pack assemblies. The typical supply current is 4 mA, whereas the shutdown current is just 20 μA.

EFFICIENT 5-V–TO–3.3-V CONVERTER

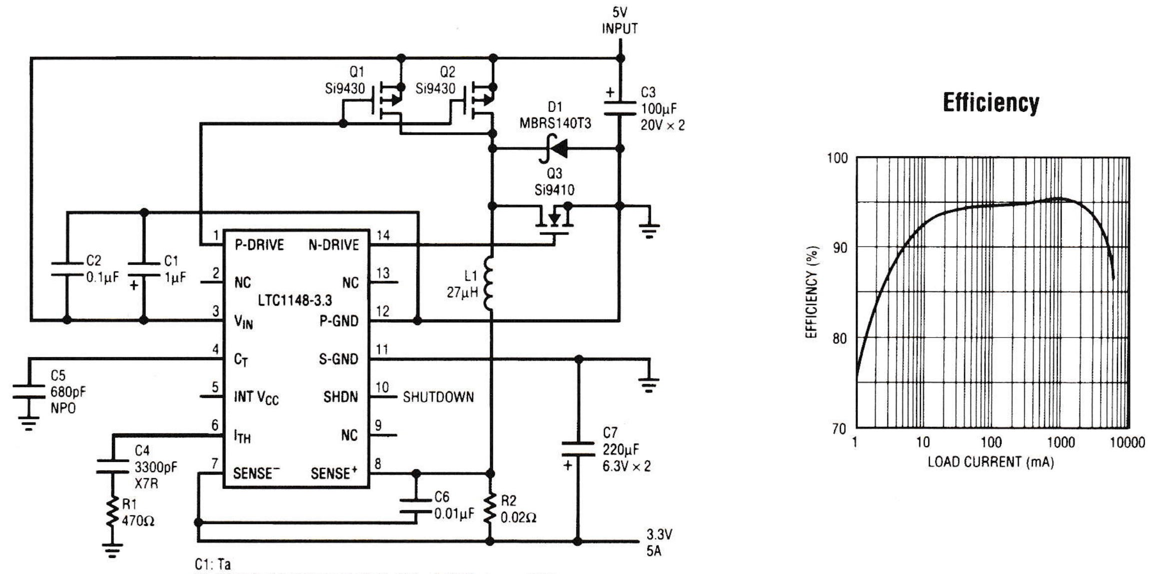




LINEAR TECHNOLOGY POWER SOLUTIONS ***Fig. 28-19***

An increasing number of portable devices need 5-V–to–3.3-V converters. High efficiency at up to 1 A is needed to power 3.3-V ICs, such as power-hungry high-speed microprocessors. The LTC1265-3.3 high-efficiency switching regulator circuit shown generates up to 1 A at 3.3 V. The LTC1265-3.3 utilizes a constant OFF-time current-mode architecture for excellent line and load regulation and contains an internal P-channel power MOSFET with 0.3 Ω ON resistance, as well as a low-battery detector. The output current is user-programmable by selection of the current sense resistor R_{sense} according to the formula $I_{\text{out}} = 100\text{ mV} / R_{\text{sense}}$. Short-circuit protection is inherent in the current-mode architecture and limits the maximum current. The LTC1265 draws only 160 μA quiescent current under no load and just 5 μA when placed in shutdown.

95-PERCENT-EFFICIENT 5-V-INPUT 3.3-V-OUTPUT DC-TO-DC CONVERTER

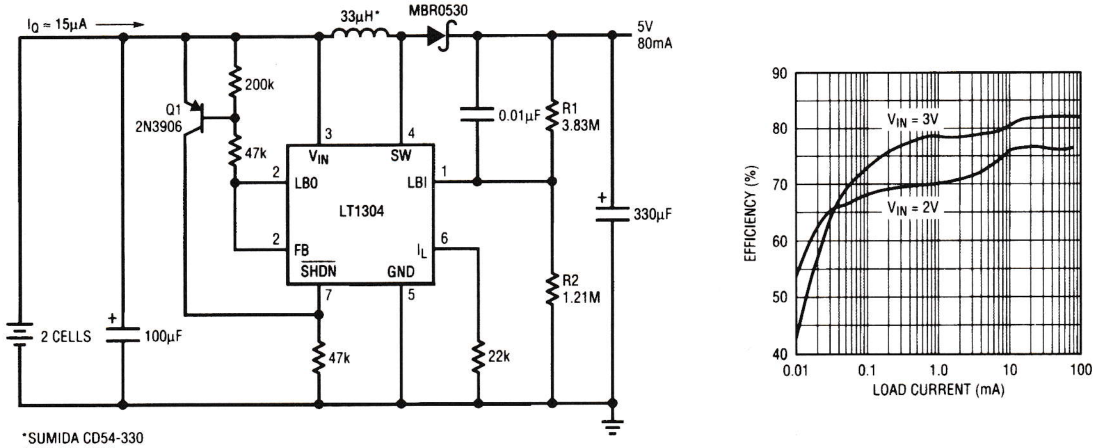


C1: Ta
C3: SANYO (OS-CON) 20SA100M, ESR = 0.037Ω, I_{RMS} = 2.25A
C7: SANYO (OS-CON) 10SA220M, ESR = 0.035Ω, I_{RMS} = 2.36A
Q1, Q2: SILICONIX PMOS BV_{DSS} = 20V, DCR_{ON} = 0.100Ω, Qg = 50nC
Q3: SILICONIX NMOS BV_{DSS} = 30V, DCR_{ON} = 0.050Ω, Qg = 30nC
D1: MOTOROLA SCHOTTKY VBR = 30V
R2: KRL NP-2A-C1-0R020J, P_D = 3W
L1: 17 TURNS #16 ON MAGNETICS 77120-A7

LINEAR TECHNOLOGY POWER SOLUTIONS ***Fig. 28-20***

Computing equipment increasingly requires both 3.3-V and 5-V logic supplies, with only the 5-V being readily available. As 3.3-V current demands increase to include microprocessors, coprocessors, DSP processors, and memory, the total power demands on the 3.3-V supply rule out the relatively low efficiency and high dissipation of a linear regulator. The circuit shown here supplies 5 A at 3.3 V with over 94-percent efficiency by using the LTC1148-3.3 synchronous switching regulator. This surface-mount solution (L1 is through-hole) requires no heatsinks and very little board space. High efficiency is also maintained at low output currents by implementing Burst mode operation, making the LTC1148-3.3 solution ideal for supplies using normal/sleep modes, such as those in "Green PCs." The LTC1148-3.3 can be placed in a shutdown mode, reducing supply current to a mere 22 µA.

TWO-CELL–TO–5-V BOOST CONVERTER

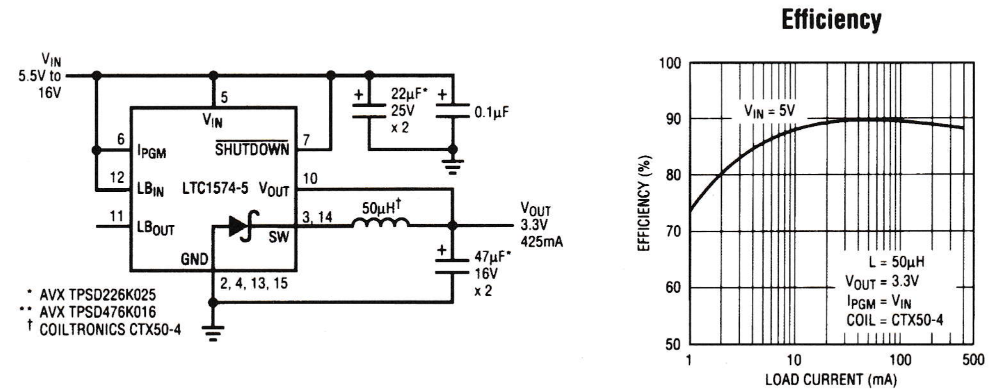


*SUMIDA CD54-330
(708) 956-0666

LINEAR TECHNOLOGY POWER SOLUTIONS ***FIg. 28-21***

Extending the battery life of a portable device that spends most of its life time in standby mode is critical in two-cell applications. The standard LT1304 boost circuit requires two capacitors, one diode, and one inductor and provides 5 V at 200 mA from a two-cell battery with 80 percent typical efficiency. For improved efficiency at very light loads, the LT1304 switching regulator circuit shown achieves an efficiency of 50 percent at just 10 μA of load current. As indicated in the graph, high efficiency over a very wide range of load current is obtained by using the extra circuitry to control Burst Mode operation. The LT1304 is a micropower step-up dc-to-dc converter with an internal comparator that is operational in shutdown. The peak switch current limit can be set up to 1 A by the resistor at the I_{LIM} input. In this circuit, it is set to 500 mA. The input voltage range extends down to 1.65 V, ensuring operation—even as the two-cell battery voltage drops during discharge. The on-board comparator shuts down the LT1304 micropower regulator when the output voltage is higher than the target 5-V output. In shutdown, the LT1304 consumes 10 μA of current, which is less than one-tenth of its active quiescent current of 120 μA. When the output voltage begins to droop below the target 5-V output, the comparator switches the LT1304 on again to recharge the output capacitor.

SIMPLE 5-V–TO–3.3-V CONVERTER

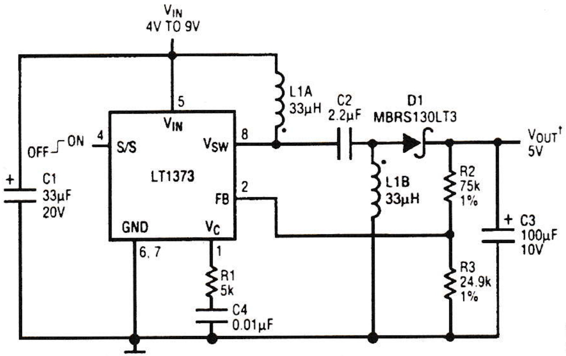


* AVX TPSD226K025
** AVX TPSD476K016
† COILTRONICS CTX50-4

LINEAR TECHNOLOGY POWER SOLUTIONS ***Fig. 28-22***

In portable logic systems requiring mixed 5-V and 3.3-V supplies, space and efficiency are paramount. Enter the LTC1574-3.3, a small and simple solution that provides over 90 percent efficiency. The LTC1574-3.3 features an internal Schottky diode, reducing the external component count to just three parts. This high-efficiency circuit uses all surface-mount components, and employs Burst Mode operation to extend high efficiency to low current levels (see graph). A low-loss internal power MOSFET ($R_{DS} = 1.2\ \Omega$ is typical for this circuit) switch and constant off-time architecture are key in achieving this high efficiency. The LTC1574 can be shut down, limiting the supply current to 25 µA (max).

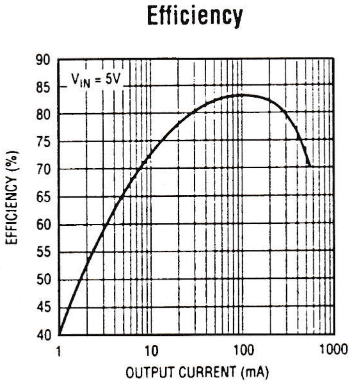
FOUR-CELL–TO–5-VDC CONVERTER



C1 = AVX TPSD 336M020R0200
C2 = TOKIN 1E225ZY5U-C203-F
C3 = AVX TPSD 107M010R0100
L1 = COILTRONICS CTX33-2, SINGLE
INDUCTOR WITH TWO WINDINGS

†MAX I_{OUT}

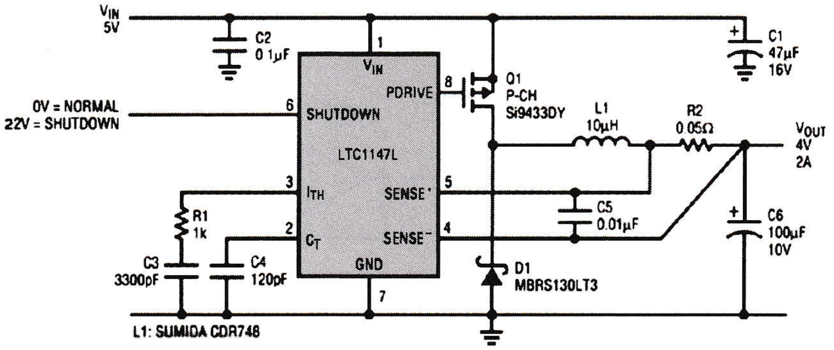
I_{OUT}	V_{IN}
0.45A	4V
0.55A	5V
0.65A	7V
0.72A	9V



LINEAR TECHNOLOGY POWER SOLUTIONS ***Fig. 28-23***

Generating a regulated 5-V output from a four-cell NiCd battery pack requires step-down operation when the battery voltage is above 5 V (fully charged pack at 6 V) and step-up operation when the battery voltage drops from 5 V to 3.6 V during discharge. The LT1373 converter circuit shown achieves up to 83 percent efficiency at high current (100- to 200-mA range), better than a flyback approach. The 250-kHz switching frequency minimizes inductor values, and both 33-µH inductors are wound on the same core, requiring less board area. With a quiescent current of 1 mA typically, the LT1373 offers high efficiency at high frequency, extending the battery lifetime in applications.

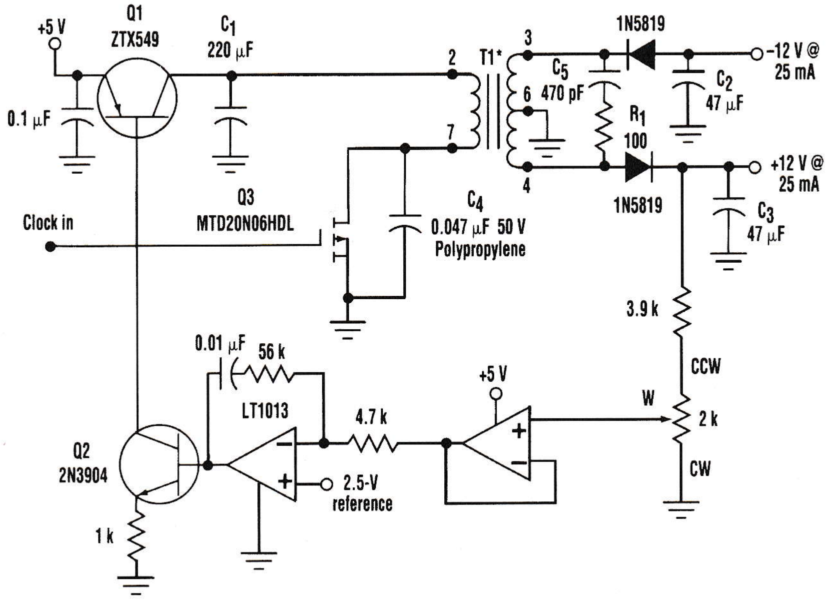
5-V–TO–4-V CONVERTER



LINEAR TECHNOLOGY POWER SOLUTIONS ***Fig. 28-24***

Generating a 4-V supply voltage for some of the new microprocessors from a 5-V main requires a low-voltage-loss capability in an efficient switching power supply. The LTC1147L circuit shown provides this capability in only 0.6 in^2 of board space. The LTC1147L is a high-efficiency step-down switching regulator controller that provides gate drive control for an external P-channel MOSFET switch. Up to 100 percent duty cycle is possible with the LTC1147L, allowing the output voltage to be close to the input voltage. This device uses a constant off-time architecture and can operate at switching frequencies exceeding 400 kHz. The LTC1147L is an adjustable device, with the output voltage set by an external resistor divider network. Maximum load current is set by the value of the current sense resistor R2.

LOW-NOISE DC-TO-DC CONVERTER



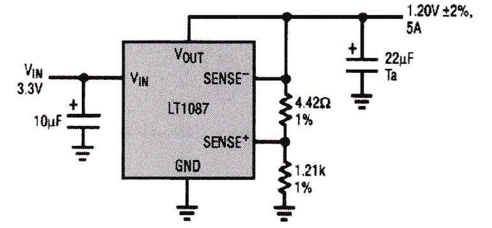
*Notes on T1:
Core: Philips 813E187-3C85
Bobbin: Philips E187PBB1-8 (Core and bobbin samples available from Elna Ferrite Labs, (800) 553-2870).
Winding: 7 turns of 20 AWG. Begin pin 2, wind clockwise, end pin 7. One layer Mylar tape. Then
12 turns, 24 AWG. Begin pin 3, wind clockwise 6 turns, pause at pin 6, continue clockwise 6 turns, end pin 4.
Gap outer legs of core at 0.002 in. Primary inductance should be about 5µH

ELECTRONIC DESIGN

Fig. 28-25

Low noise is achieved by this inexpensive and versatile 5-V–to–±12-V dc-to-dc converter. Wideband output noise appears to be well under 500 µV p-p. The converter accepts external clocks from 80 to 120 kHz. The converter operates much like a TV horizontal deflection circuit. Q3 is a logic-level power MOSFET driven by an external clock. When Q3 is switched on, current ramps up through T1's primary. When Q3 is switched off, Q3's drain flies back to 25 V as C4 resonates with T1's primary, transferring energy to the secondary. As the flyback voltage falls and attempts to go below ground, the intrinsic diode of the power MOSFET clamps it. In addition, the excess resonant energyflows backward through T1's primary, recharging C1. When this point is reached, Q3 is again switched on and the cycle repeats. Q3's gate (trace 2) is switched on and off when Q3's drain is near ground. Q3's gate driver power requirements are modest enough to be handled by any 74HC logic gate. Regulation is achieved by the error amplifier (LT1013). Despite the fact that Q1 acts as a linear pass transistor, converter efficiency can exceed 75 percent if the voltage drop across Q1 is minimized. This can be accomplished by either adjusting the clock frequency or tuning C4 to adjust the flyback voltage.

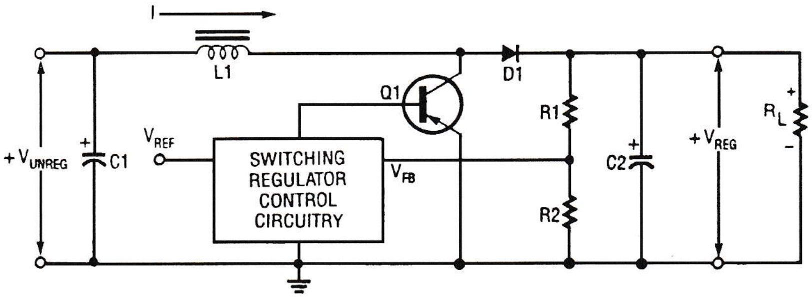
1.2-V REGULATOR FOR GTL TERMINATION



LINEAR TECHNOLOGY POWER SOLUTIONS ***Fig. 28-26***

A recent development in high-speed digital design has resulted in a new family of logic chips called *gunning transition logic (GTL)*. These chips use high-speed logic and require active termination for best interconnection performance. The termination voltage required is 1.2 V, and the input voltage can be as low as 3.3 V from a logic supply. The LT1087 5-A low-dropout regulator shown here addresses these requirements by providing a regulated 1.2-V ±2 percent output voltage from a minimum 2.7-V input. Note that the LT1087 has a 1.25-V reference, but provides Kelvin sensing inputs for the feedback amplifier. The 4.42-Ω resistor is inserted as a simple way to adjust the internal reference downward without sacrificing regulation. This GTL termination circuit supplies 5 A maximum load current and can handle 3.3-, 5-V, or higher supplies, although 3.3 V is recommended for minimum device dissipation.

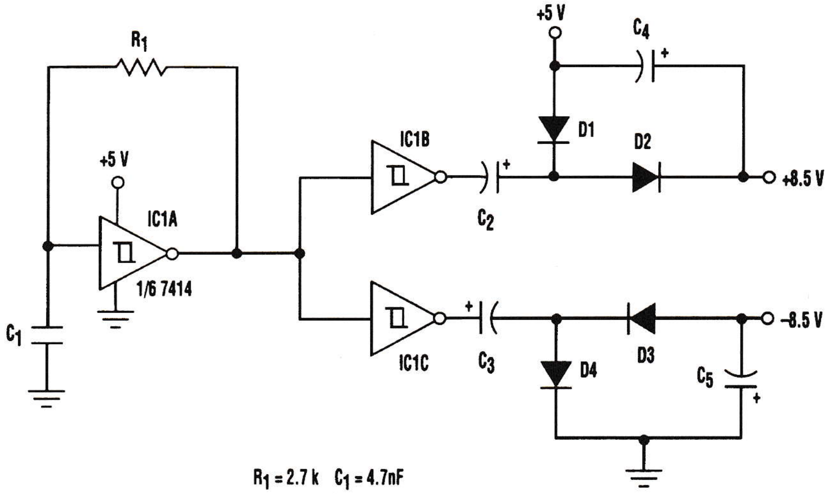
CURRENT-LIMITING A-SERIES REGULATOR



ELECTRONICS NOW *Fig. 28-27*

If the current limitation of the series-pass transistor is exceeded, transistor Q1 could be damaged or destroyed. This can be prevented with the addition of a current-limiting transistor, as shown in the figure. When the current through Q1 becomes high enough, the voltage drop across R2 becomes high enough to forward-bias transistor Q2. When Q2 starts to conduct, its internal resistance decreases. When this occurs, the forward bias of Q1 is fixed, and its output is a constant current. The current-limiting transistor and resistor in the figure protect the pass transistor and rectifier diodes if the load terminals are accidentally short-circuited. However, the addition of transistor Q2 increases the already high power dissipation in pass transistor Q1 when the load demand is high.

TRANSFORMERLESS DC-TO-DC CONVERTER



$R_1 = 2.7$ k $C_1 = 4.7$nF
D1-D4 = 1N 914
C_2, C_3 = 10 µF, 16 V
C_4, C_5 = 47 µF, 16 V

ELECTRONIC DESIGN ***Fig. 28-28***

This configuration should prove handy in situations in which dual-polarity supplies are needed for a few devices on a board that has only one +5-V supply. The circuit doesn't need any dc-to-dc converter ICs, nor does it require any transformers or inductors. Three Schmitt-trigger inverters, such as the 7414, form the heart of the circuit (see the figure). One inverter is configured as a high-frequency astable multivibrator employing a single resistor and a capacitor. For the RC values shown, the frequency of the astable output is around 100 kHz. The frequency of the oscillation is given by $f = 1/T$, where $T = R_1C_1 \ln [(1 - V_{CC}/V_{LT})/(1 - V_{CC}/V_{UT})]$ and R_1 and C_1 are the timing components of the astable multivibrator, V_{CC} is the supply voltage, and V_{LT} and V_{UT} are the lower trip point and upper trip point of the Schmitt trigger. The astable multivibrator's output drives a pair of inverters that, in turn, drive a pair of diode-capacitor voltage-doubler circuits. The outputs of the diode-capacitor circuits are around 8.5 V with the polarities shown. Diodes D1 to D4 should be fast-switching types, like the 1N914 or 1N4148. As a result, the circuit can generate ±8.5 V from a single +5-V supply making it useful in many applications.

29

Decoder Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

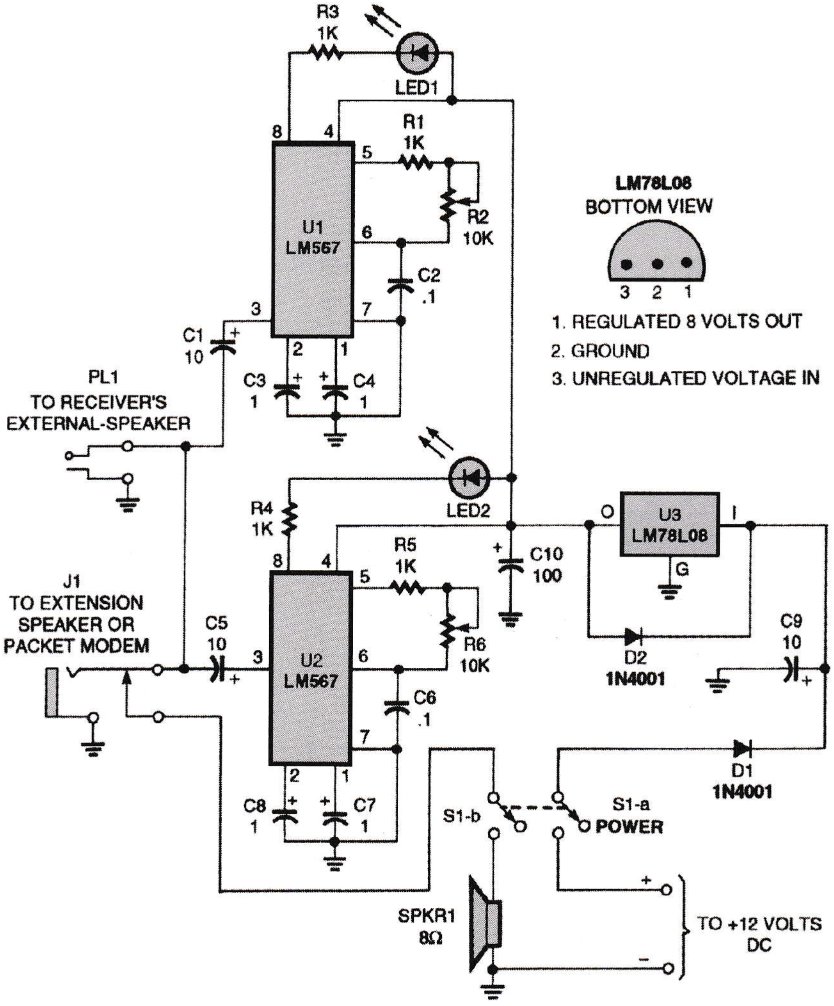
29

Decoder Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Packet Radio Tuning Indicator
Alphanumeric Pager Decoder
TV Line Decoder I
TV Line Decoder II
DTMF Decoder I
DTMF Decoder II
DTMF Receiver Decoder
RTTY Tone Decoder
BCD Decoder-Driver Circuit
One-IC Tone Decoder

PACKET RADIO TUNING INDICATOR

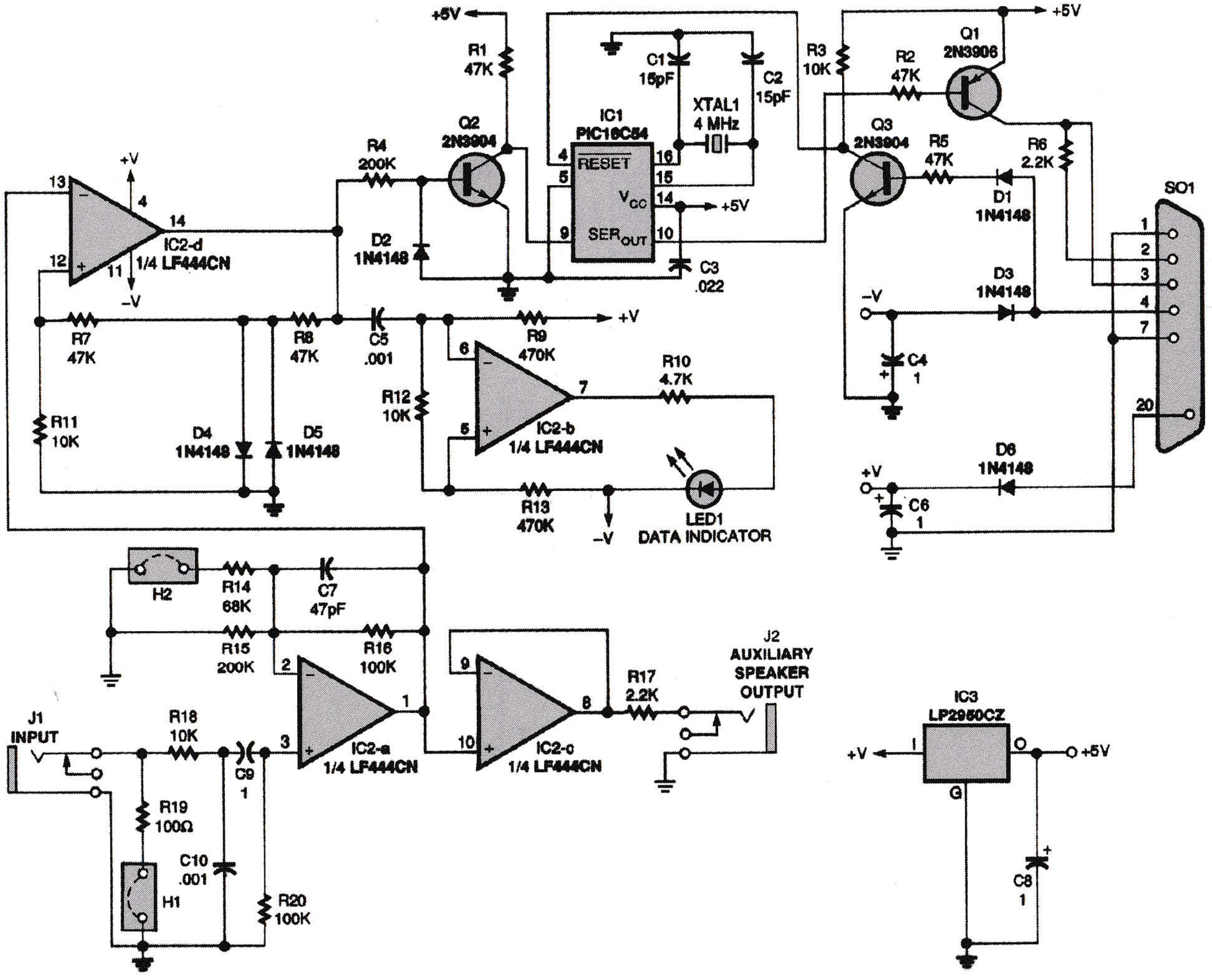


POPULAR ELECTRONICS

Fig. 29-1

The tuning indicator is simply two identical tone decoders adjusted to different frequencies that share a power supply. When a decoder receives a signal of the right frequency, it lights its LED. Simply tune the circuit so that both LEDs illuminate.

ALPHANUMERIC PAGER DECODER



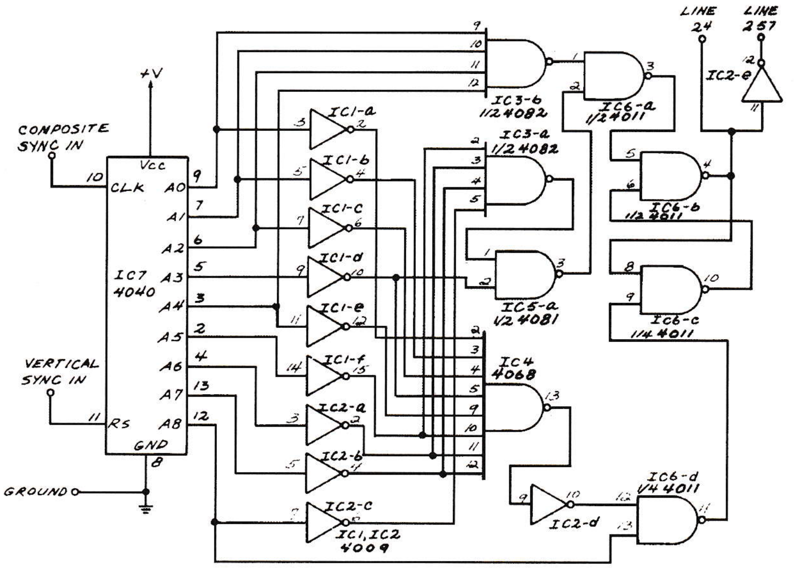
POPULAR ELECTRONICS

Fig. 29-2

ALPHANUMERIC PAGER DECODER *(Cont.)*

This pager decoder interfaces a scanner plugged into J1 with a personal computer's serial port via the DB25 connector. Software is necessary and can be obtained from the Internet at http://cylex-inc.com/download.htm.

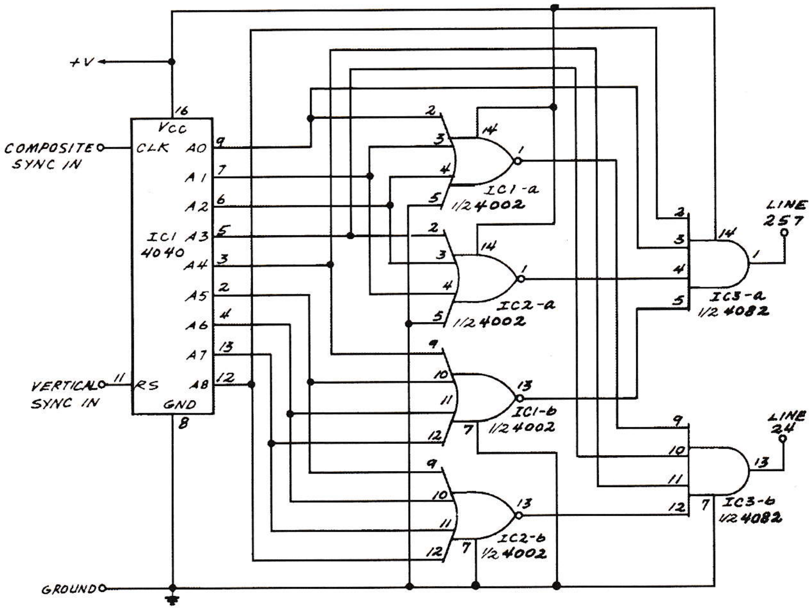
TV LINE DECODER I



ELECTRONICS NOW *Fig. 29-3*

This circuit will produce outputs on TV lines 24 and 257. It was used for a decoder circuit. It uses a CMOS counter and gate logic. Only one pin is used for the output line indicator.

TV LINE DECODER II

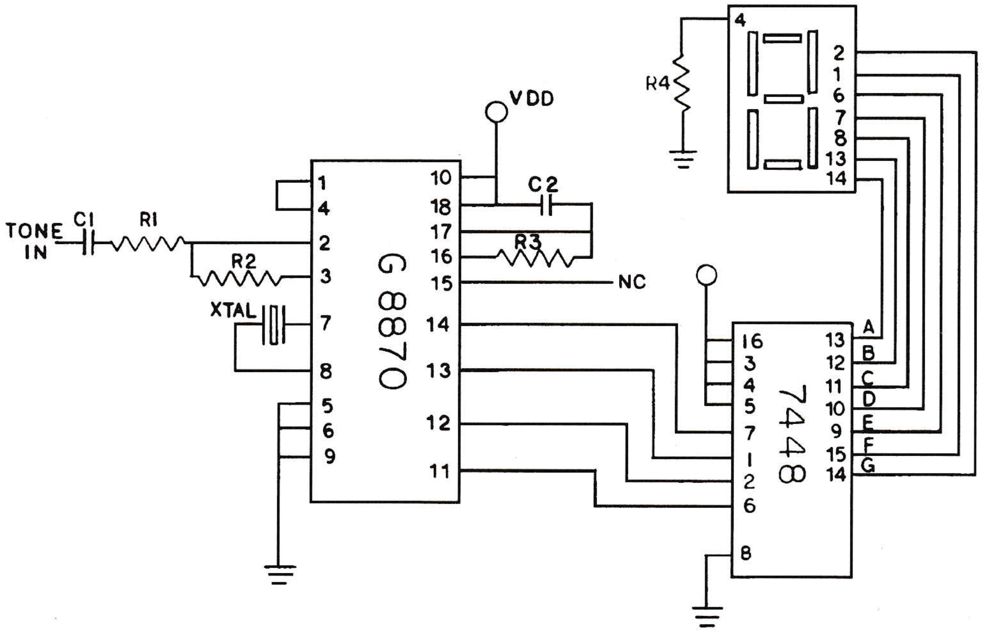


ELECTRONICS NOW

Fig. 29-4

This circuit will produce outputs on TV channels 24 and 25. It was used in a decoder circuit. It uses a CMOS counter and gate logic.

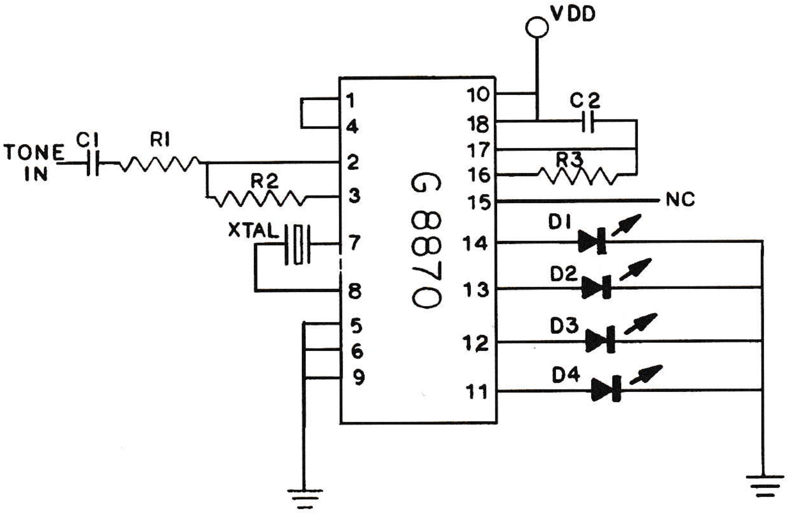
DTMF DECODER I



NUTS AND VOLTS *Fig. 29-5*

This decoder uses a G8870 DTMF receiver decoder chip to decode DTMF signals and display them via an LED display driven by a 7448 decoder driver chip. Xtal is a 3.579-MHz TV burst crystal. $C_1=C_2=0.1$ μF, $R_1=R_2=100$ kΩ, and $R_3=300$ kΩ. D1 through D4 are small red LEDs.

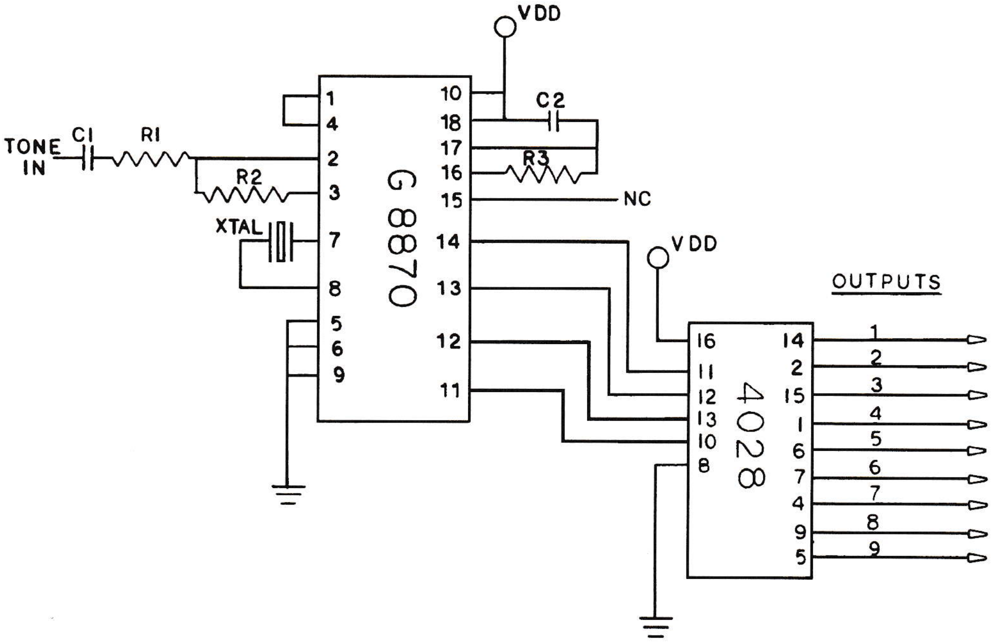
DTMF DECODER II



NUTS AND VOLTS *Fig. 29-6*

This decoder uses a G8870 DTMF receiver decoder chip to decode DTMF signals and display them in binary via LEDs. Xtal is a 3.579-MHz TV burst crystal. $C_1=C_2=0.1$ µF, $R_1=R_2=100$ kΩ, and $R_3=300$ kΩ. D1 through D4 are small red LEDs.

DTMF RECEIVER DECODER

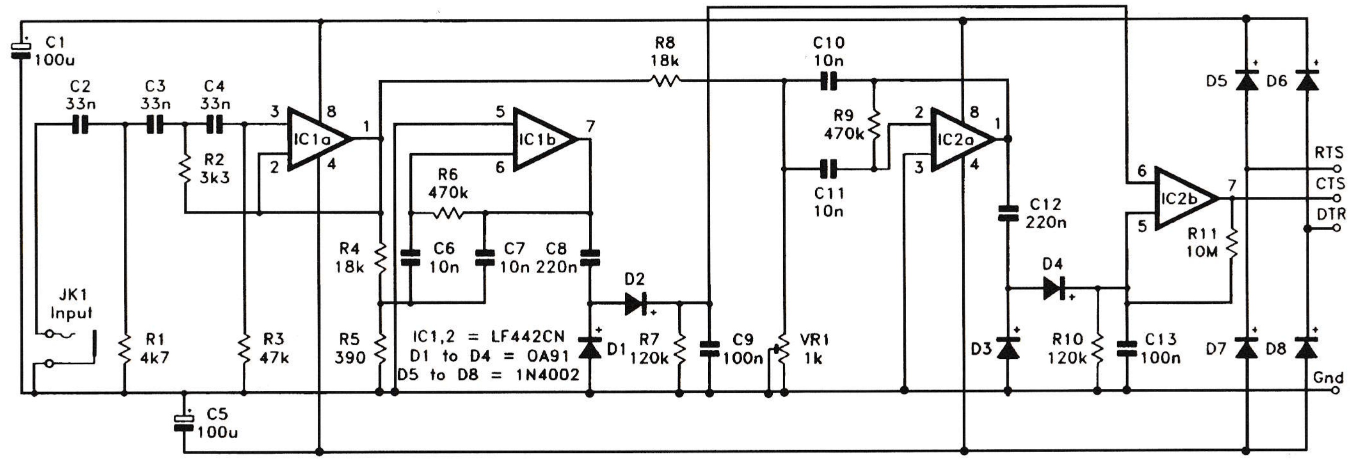


NUTS AND VOLTS

Fig. 29-7

This decoder uses a G8870 DTMF receiver decoder chip to decode DTMF signals and drive individual outputs via a 4028 binary-decimal decoder. Xtal is a 3.579-MHz TV burst crystal. $C_1=C_2=0.1$ µF, $R_1=R_2=100$ kΩ and $R_3=300$ kΩ. D1 through D4 are small red LEDs.

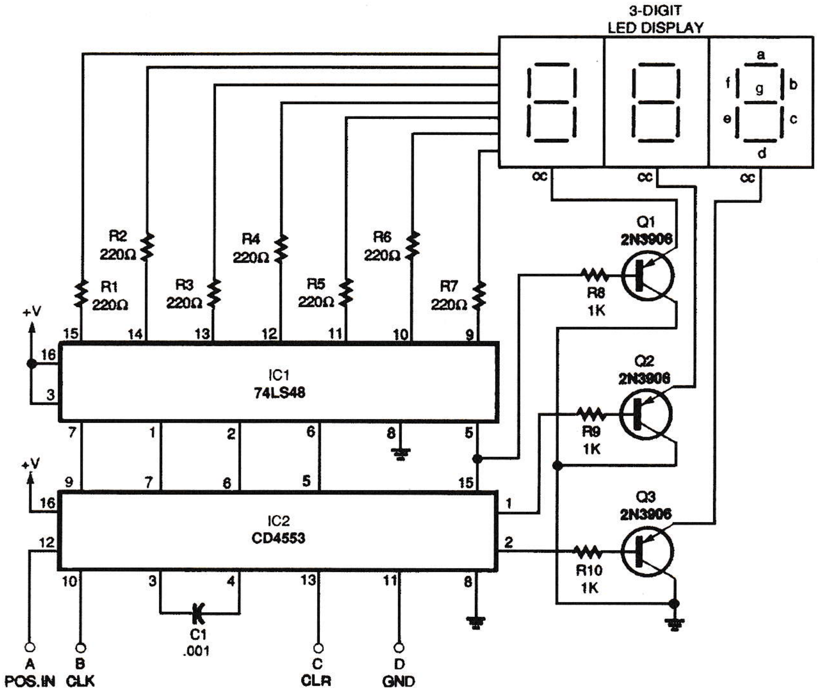
RTTY TONE DECODER



EVERYDAY PRACTICAL ELECTRONICS *Fig. 29-8*

The full circuit diagram for the RTTY tone decoder is shown. The input filter is based on IC1a, and it is a third-order (18 dB per octave) high-pass type with a cutoff frequency at approximately 750 Hz. IC1b is used in the higher-frequency bandpass filter. Capacitor C8 couples the output of this filter to a conventional half-wave rectifier and smoothing network based on diodes D1 and D2. The time constant of R7 and C9 is long enough to give a well-smoothed output signal, but short enough to permit the unit to respond rapidly as the input signal alternates between one tone and the other. The second bandpass filter is based on IC2a and is essentially the same as the first, but it has a preset resistor (VR1) as one section of the input attenuator. This enables the center frequency of the filter to be adjusted, but (in operation) it is set 170 Hz lower than the center frequency of the other filter. If preferred, preset potentiometer VR1 can be set to give a center frequency 170 Hz higher than the other filter. It can also be set for shifts of other than 170 Hz. The output of IC2a (pin 1) feeds into a rectifier and smoothing circuit that is identical to the one used at the output of the other filter. The outputs of both the smoothing circuits drive the inputs of IC2b, which acts as the voltage comparator. A small amount of dc positive feedback is provided by resistor R11, and this helps to avoid problems with jitter at the output when only background noise is present at the input. Power is obtained from two of the otherwise unused handshake outputs of the PC's serial port. Diodes D5 to D8 form a bridge rectifier that ensures that the circuit is always provided with a supply of the correct polarity. Only a milliampere or two can be drawn from the handshake outputs. Accordingly, IC1 and IC2 must be low-supply-current operational amplifiers.

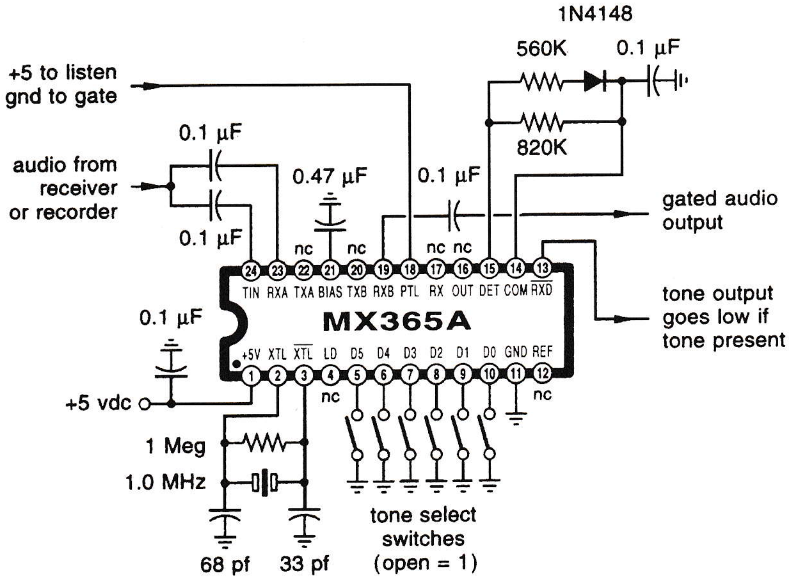
BCD DECODER-DRIVER CIRCUIT



ELECTRONIC EXPERIMENTERS HANDBOOK ***Fig. 29-9***

The BCD decoder-driver circuit will interface with any standard BCD output to produce a digital display.

ONE-IC TONE DECODER



ELECTRONICS NOW

Fig. 29-10

This circuit can be used in a receiver or a repeater to require that a tone be present on a received signal so as to unsquelch the receiver.

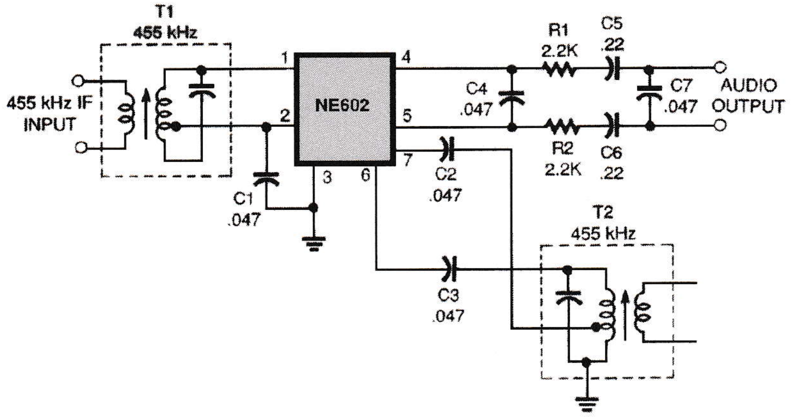
30

Detector Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

NE602 Product-Detector Circuit
Missing-Pulse Detector
HV Static Detector
PLL Lock Detector
Quadrature Detector Design
Basic Vacuum Tube Regenerative Detector
Vibration Detector
Peak Detector
Null Detector
Draught Detector
Carbon Monoxide Detector

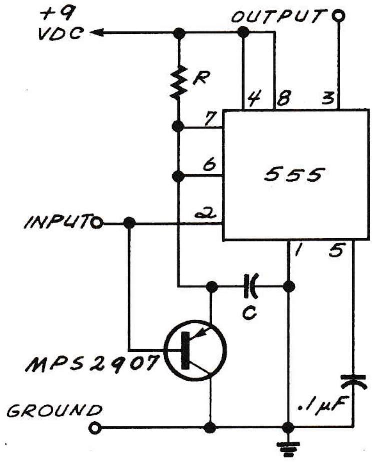
NE602 PRODUCT-DETECTOR CIRCUIT



ELECTRONICS NOW *Fig. 30-1*

This circuit uses an NE602 as a product detector. The component values depend on operating frequency and are typical for 455-kHz operation. Note that a passive RC filter is shown in the audio output circuit. T2 acts as an oscillator coil for the 455-kHz local oscillator (or, in this case, beat frequency oscillator).

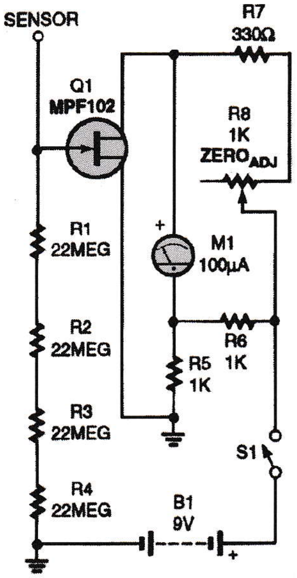
MISSING-PULSE DETECTOR



ELECTRONICS NOW *Fig. 30-2*

A missing-pulse detector is a circuit whose output is triggered only when there is a loss of signal at its input. In the circuit shown, the 555 timer IC is configured as a one-shot multivibrator that produces a pulse whose width is determined by the value of resistance R and capacitance C, shown in the schematic. The values for those parts can be calculated by using the formula $T=1.1RC$. Select values that make the output pulses about twice as wide as the input trigger pulses from the control line. As long as there is a steady stream of input trigger pulses, the 555 will output a logic high. If there is only one input pulse period, the 555 will time out and its output will go logic low until the next trigger pulse arrives. The logic low at the 555 output can trigger an alarm, a time recorder, a counter, or any other device.

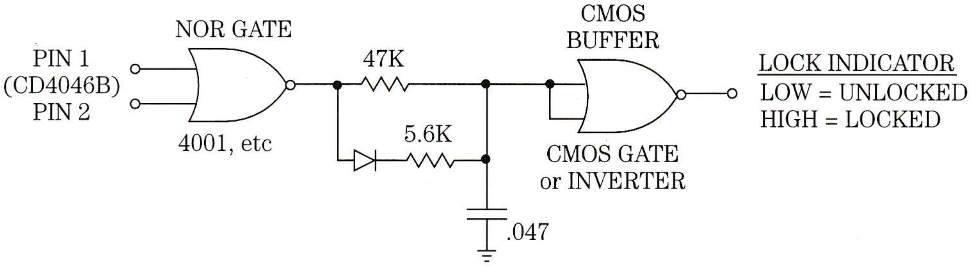
HV STATIC DETECTOR



One leg of a Wheatstone bridge is replaced by an MPF102 N-channel JFET. The JFET's high gate input impedance turns the simple bridge circuit into a very sensitive high-voltage static detector. The JFET's gate is tied to ground through four 22-MΩ resistors. A 1- to 2-in piece of solid-copper wire is connected directly to the JFET's gate and serves as the input sensor. With the sensor clear, adjust R8 for a zero meter reading. Run a comb through your hair and move it toward the sensor. The meter should go off the scale. Place the static-sensor next to your computer or any static sensitive equipment and take special notice when the meter moves.

POPULAR ELECTRONICS *Fig. 30-3*

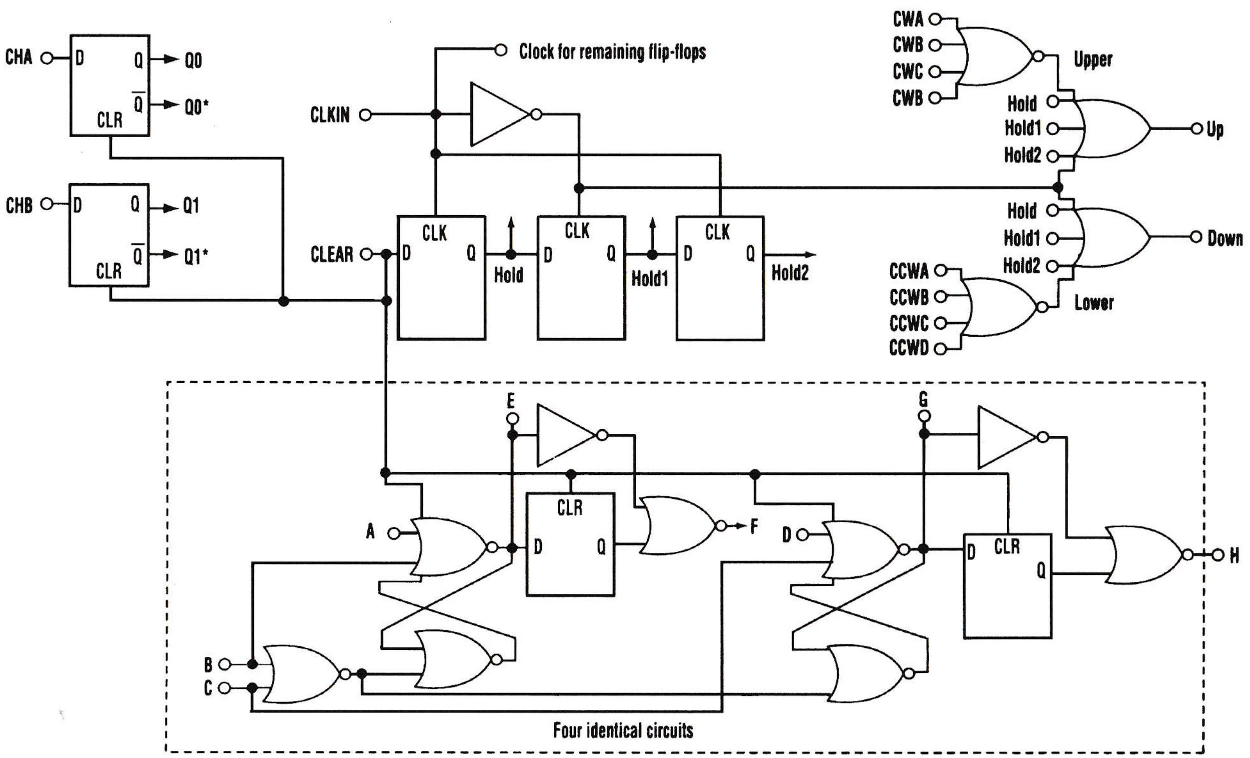
PLL LOCK DETECTOR



WILLIAM SHEETS *Fig. 30-4*

When the loop is locked, the waveforms at pins 1 and 2 of CD4046B are almost identical, differing only in polarity. This holds the output of the NOR gate low. When the loop is not locked, the output of the NOR gate is a series of pulses. This charges the 0.047-μF capacitor, and causes a low output from the CMOS buffer.

QUADRATURE DETECTOR DESIGN

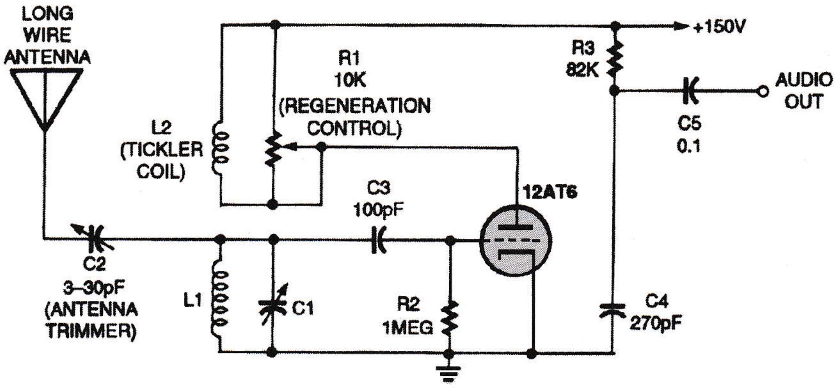


ELECTRONIC DESIGN

Fig. 30-5

One common electrical requirement when dealing with motion control is to monitor the angular position of a rotating object. Quite often, an optical encoder is attached to a rotating shaft, and the encoder's quadrature outputs provide angular displacement information. The key is to turn those quadrature signals into clock pulses, and then into a displacement count that's useful for your application. This circuit requires a reset as well as a clock for sampling the input data. The clock frequency needs to be adjusted to guarantee at least one rising clock edge for each input state change. The circuit takes a set of quadrature signals (CHA, CHB), samples them with CLKIN, and generates output clock pulses (UP or DN) for each input state change. The up/down output clock pulses then can be fed directly into 74XX193 counters as the up and down clocks. If CLKIN is synchronized to external timing, the 193 ripple counter's output can be latched out of phase with the updates to ensure stable counter values. The timing diagram shows the internal functionality of the design. Intervals 1 to 5 illustrate the reset function, which blanks startup instability conditions. Intervals 5 through 12 show timing for a jitter pulse that's been sampled. Interval 13 depicts a jitter pulse that missed being sampled and, therefore, caused no change in the output. The remaining intervals illustrate complete cycles for each direction of motion.

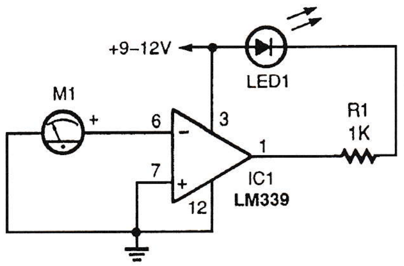
BASIC VACUUM TUBE REGENERATIVE DETECTOR



POPULAR ELECTRONICS *Fig. 30-6*

The traditional tube-based regenerative receiver is essentially an Armstrong RF oscillator with variable feedback that is connected to an antenna and a resonant circuit. C1 is usually a 140-pF variable capacitor, and L1 and L2 are wound on a plug-in coil form, with L2 typically having 10 to 20 percent of the turns on L1 and wound next to the cold side of L1. The inductance depends on the desired frequency range, but 150 kHz to about 18 MHz is typical for this circuit.

VIBRATION DETECTOR



A D'Arsonval meter movement is used as a vibration detector in this novel application. The meter acts as a generator, producing a voltage when the needle moves. An inexpensive panel meter can be used, but a high-sensitivity movement (50 μA) works best.

POPULAR ELECTRONICS

Fig. 30-7

PEAK DETECTOR

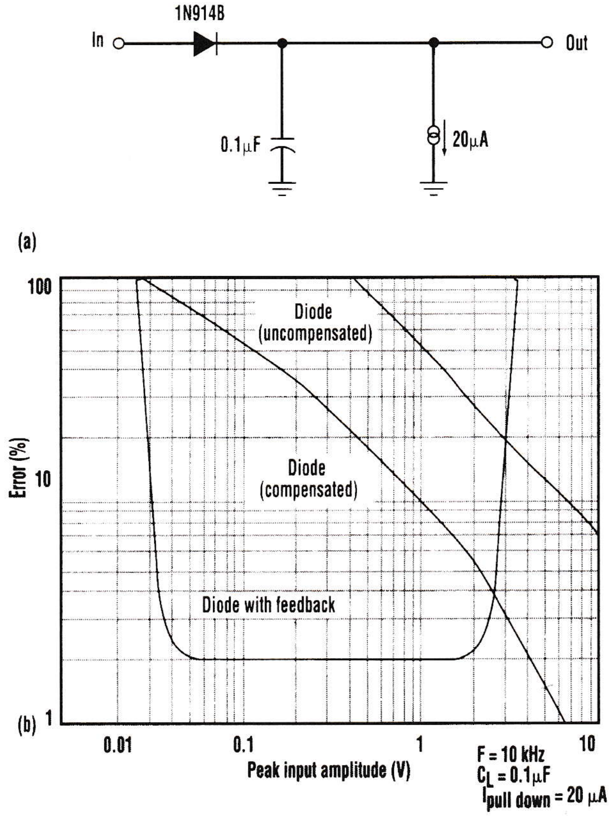


FIG 1

PEAK DETECTOR *(Cont.)*

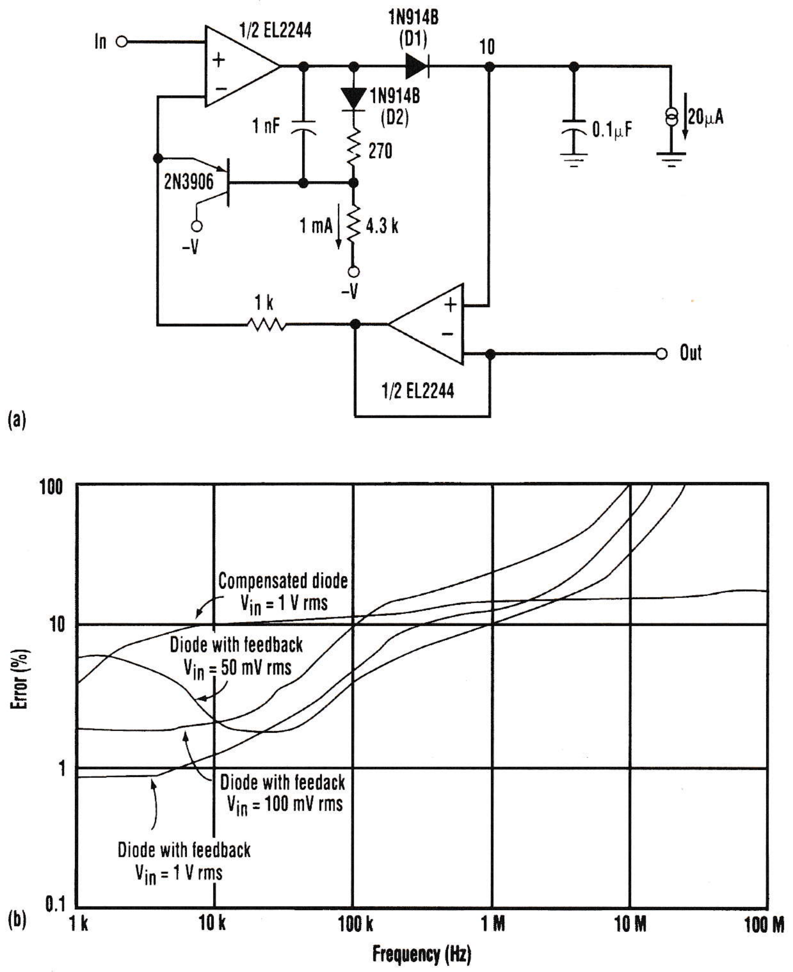


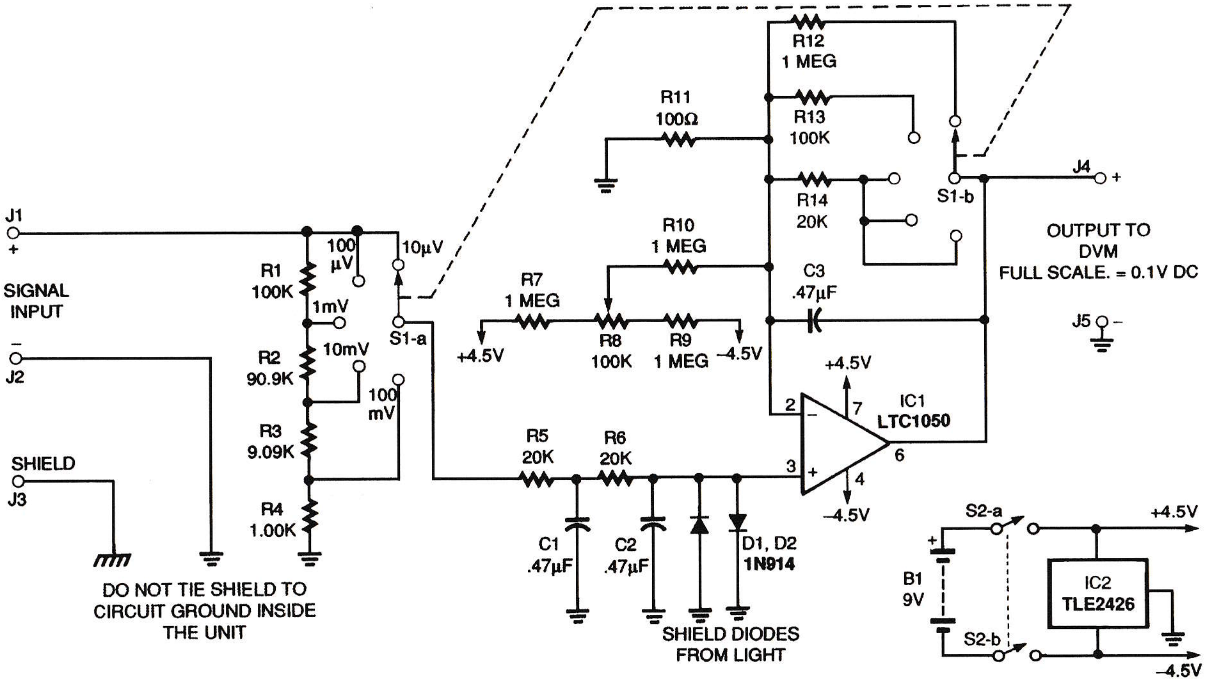
FIG 2

ELECTRONIC DESIGN ***Fig. 30-8***

A simple peak detector, in its most common configuration, provides a mediocre 10 percent error for very large input voltages (a). If the diode is linearized, the necessary input voltage is only reduced to 1 V peak for the same 10 percent error (b).

Feedback circuitry can provide better accuracy and more sensitivity at the input. Feedback makes possible peak detection at input voltages as small as 50 mV rms (a). If 5 percent errors can be tolerated, the circuit has a bandwidth of 100 kHz (b).

NULL DETECTOR

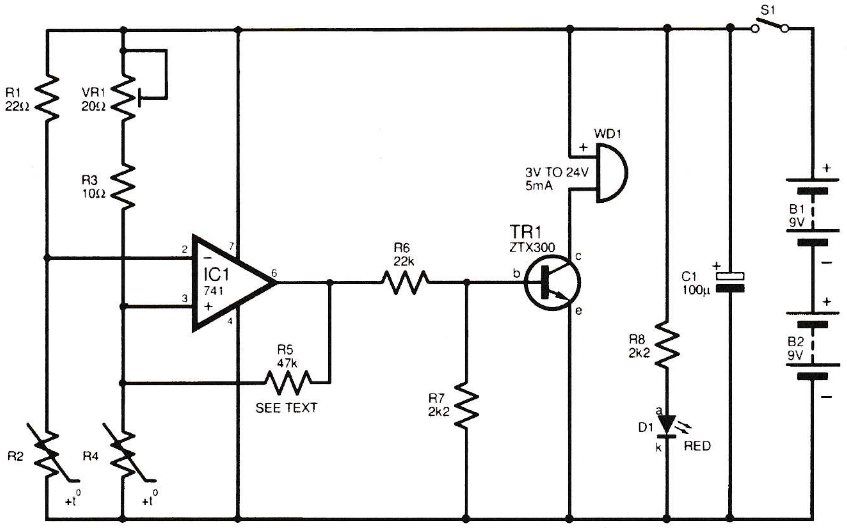


ELECTRONICS NOW

Fig. 30-9

This null detector is based on the Linear Technology LTC1050 amplifier. Chopper stabilized, it provides performance that is almost drift-free. The low-frequency gain is guaranteed to be over 130 dB, so only one amplifier stage is needed. Input bias and offset currents are in the picoampere region, and, finally, the sample-and-hold capacitors have been incorporated within the amplifier, further simplifying the null detector's design. The circuit must be battery-powered, but no cells give reasonable positive and negative supply values. The answer lies in the TLE2426 "rail splitter" ground IC. Using this special divider/buffer, a standard 9-V battery will provide 4.5-V supplies—perfect for the CMOS chopper amplifier. The input of this detector is limited to a maximum of 100 mV. The most sensitive range is 10 µV, full scale. This allows the detector to resolve 1-μV differences with no difficulty. The input impedance will be 200 kΩ for normal "in-range" signals, falling to a minimm of 40 kΩ under overload conditions. The limiting factor is the voltage rating of the first input-filter capacitor, which runs at about one half of the input voltage under overload conditions.

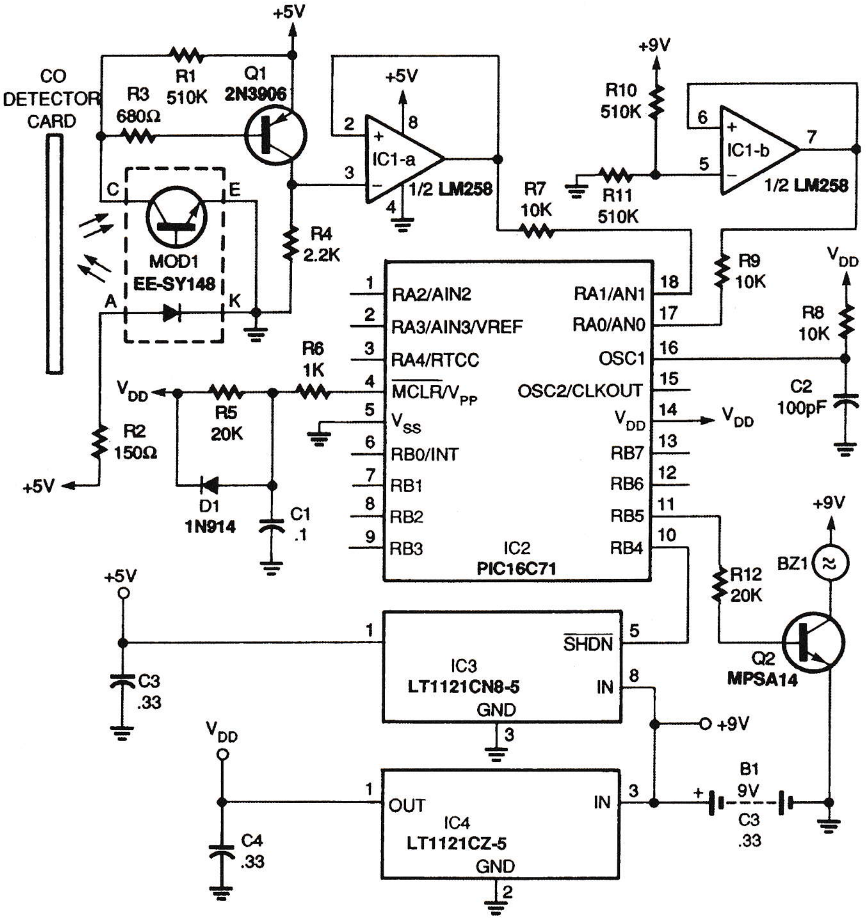
DRAUGHT DETECTOR



EVERYDAY PRACTICAL ELECTRONICS ***Fig. 30-10***

The complete circuit diagram for the draught detector is shown. The key components are R2 and R4; these form a pair of identical positive-temperature-coefficient (p.t.c.) thermistors. It is essential to use this particular type of thermistor. With switch S1 on, current flows from the nominal 18-V supply to the rest of the circuit. Thermistors R2 and R4 are included in a pair of potential dividers. The first comprises fixed resistor R1 in the upper arm and thermistor R2 in the lower one. The second consists of potentiometer VR1, connected in series with fixed resistor R3, in the upper arm and thermistor R4 in the lower one. With room temperature below 60°C, the current in the thermistors will be 150 mA approximately, sufficient for them to self-heat. They will then approach the threshold temperature within a few seconds. The thermistors will stabilize when the temperature reaches about 75°C, corresponding to a resistance of some 500 Ω. In the absence of a draught, each thermistor will be surrounded by a blanket of warm air. However, thermistor R4 is arranged so that it does not receive any draught impinging on detector R2. When a draught is detected, the warm air around R2 is disturbed, and this thermistor is cooled slightly. This results in a lower resistance and hence a falling voltage being developed across it. This sounds the alarm. R5 supplies a little hysteresis to the alarm circuit.

CARBON MONOXIDE DETECTOR



ELECTRONICS NOW

Fig. 30-11

This circuit has a focused optical sensor to transmit light to the CO reagent, and then sense the amount of light reflected. The reagent for CO detection darkens from a light yellow color when exposed to CO. According to the card's manufacturer, a concentration as low as 100 parts per million (ppm) will darken the detector after 15 to 45 min. A concentration of 600 ppm will darken it in 1 to 2 min. The reagent will return to its original color when the air freshens, usually after about 10 min. The time it takes for the reagent to return to its original color depends on the concentration of CO to which it was exposed. The "brain" of the CO detector circuit is a PIC16C71 microcontroller (IC2) that contains a built-in four-channel analog-to-digital converter. Other than the microcontroller, the main component of this circuit is MOD1, an Omron EE-SY148 optical reflector module. The module directs infrared light to the CO reagent and then receives the light reflected back to it. When CO is present, the reagent will darken, thus reducing the reflectivity. The reduction is sensed by the microcontroller, which then turns on buzzer BZ1.

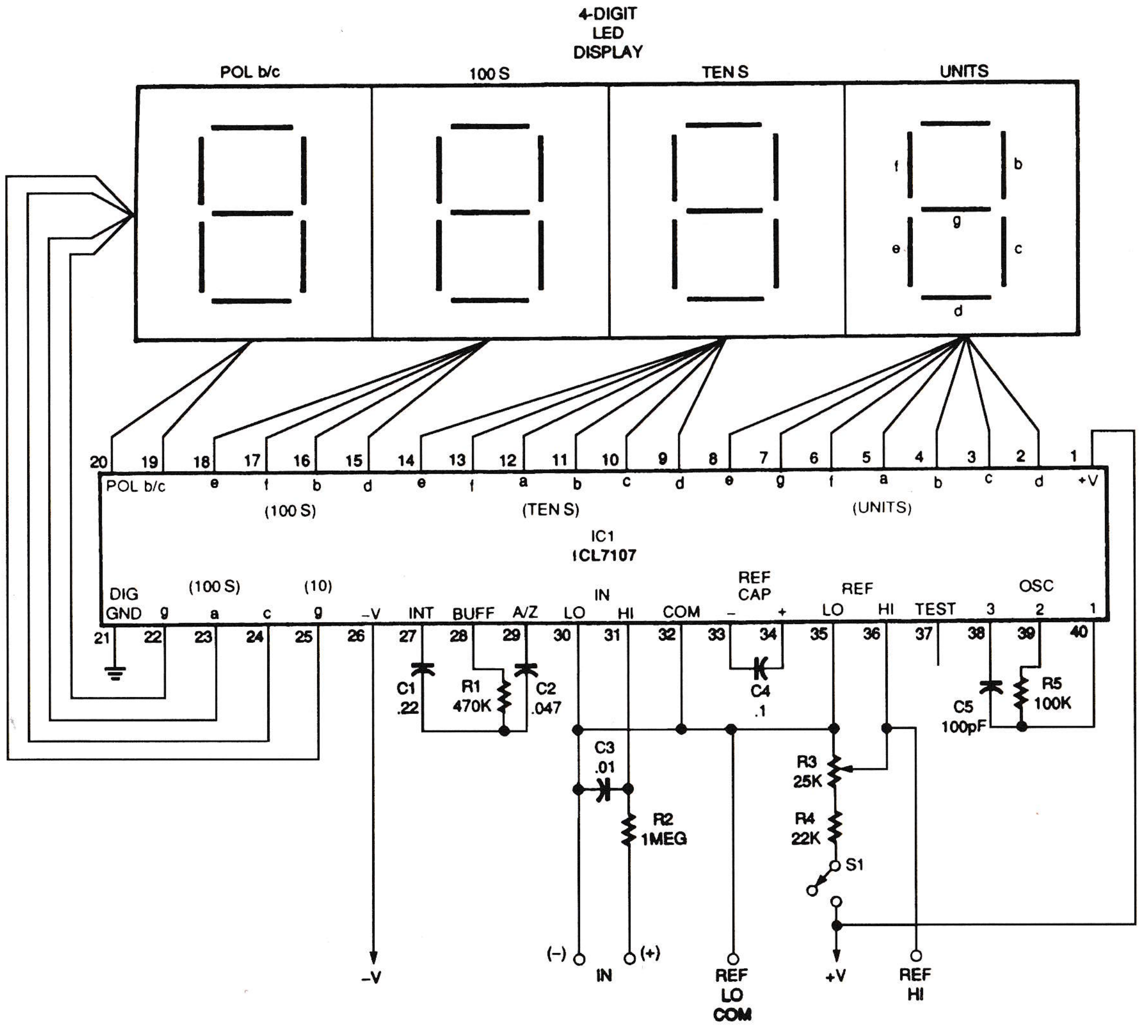
31

Display Circuits

The sources of the following circuits are contained in the Sources section, which begins on page 1043. The figure number in the box of each circuit correlates to the entry in the Sources section.

Simple Four-Digit DVM Basic Circuit
High-Intensity LED Circuit
Volume Unit Display and Alarm
Ac-Dc Supply LED Circuit
EEPROM Display Driver
Multicolor LED Driver
Flashing LED HV Supply Circuit
Economical LED Bar Display
Surround Sound Indicator
LED Ac Pilot Lamp Circuit
Three Cascaded Bar-Graph Display Drivers
Bridge Rectifier LED Light String
Two Cascaded Bar-Graph Display Drivers
External Voltage Reference with Bar-Graph Display Driver
Bar-Graph Display Driver Scale Setting
Bar-Graph Display Circuit
Constant-Brightness LED Circuit
Volume Unit Display and Alarm
10-LED Bar-Graph Indicator Circuit
Bicolor-LED SPST Switch
Tricolor LED Peak Indicator Circuit
Dual LED Light String
Dual-Color LED Light String
Electroluminescent Panel
LED Light String
LED Dc-Level Indicator
LED Bar-Graph Circuit
Alternating-Color LED Light String
Tricolor LED Sign Display
Bar-Graph Display
Electroluminescent Panel Driver
Varying LCD Bias Circuit
Basic Bar-Graph Display Circuit

SIMPLE FOUR-DIGIT DVM BASIC CIRCUIT



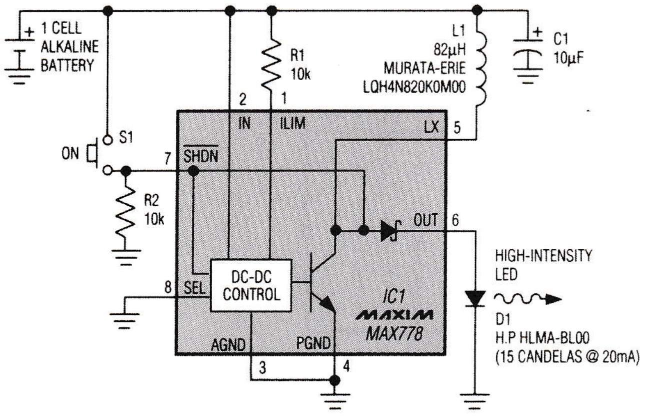
ELECTRONICS NOW

Fig. 31-1

SIMPLE FOUR-DIGIT DVM BASIC CIRCUIT *(Cont.)*

This circuit is designed around a Harris Semiconductor AD converter/LED display driver IC. The power supply is ±5 V.

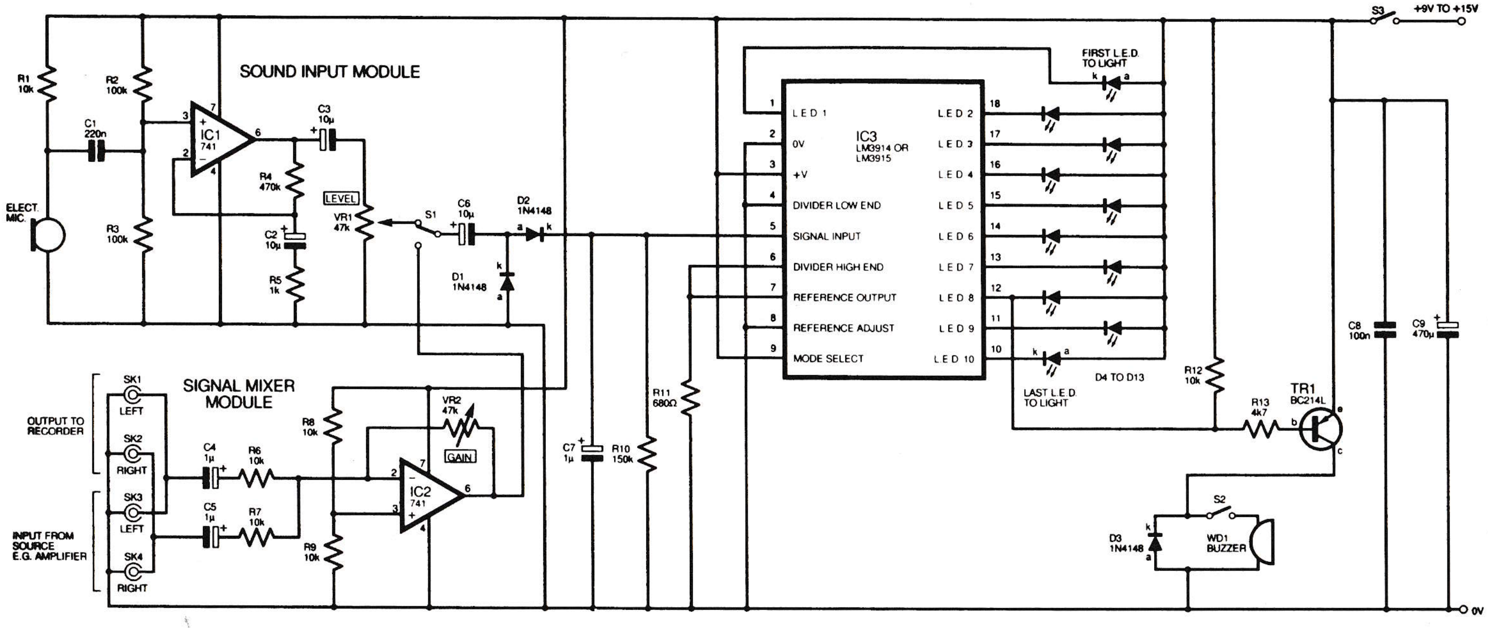
HIGH-INTENSITY LED CIRCUIT



MAXIM ENGINEERING JOURNAL ***Fig. 31-2***

The forward voltage for high-intensity LEDs (1.5 to 2.5 V) is too large for operation with one-cell batteries. The circuit shown overcomes this limitation with a boost-regulator technique—it drives controlled current pulses through the LED, regardless of the LED's forward voltage, and operates on input voltages from 6.2 V to below 1 V. The circuit is useful for bicycle lights, beacons, alarms, flashlights, and low-power indicators. IC1 is normally part of a regulated boost converter, but, in this case, it simply transfers energy without regulating the output. Omission of the usual rectifier and output filter capacitor makes the circuit compact, as does the high switching frequency (about 175 kHz). Programming resistor R1 sets the LED intensity by setting a peak current for the inductor and LED. A 10-kΩ value for R1 sets the approximate peak at 75 mA, and the average LED current at about 26 mA. A shutdown command turns off the OUT terminal completely, even if cell voltage exceeds the LED's forward voltage, by turning off the diode internal to IC1. (During shutdown, most step-up converters exhibit a troublesome dc path from the battery through the coil and diode to the load.) This circuit draws about 8 μA during shutdown and about 60 mA during normal operation. It operates for 35 hours continuously on one AA (or R4 size) alkaline cell.

VOLUME UNIT DISPLAY AND ALARM

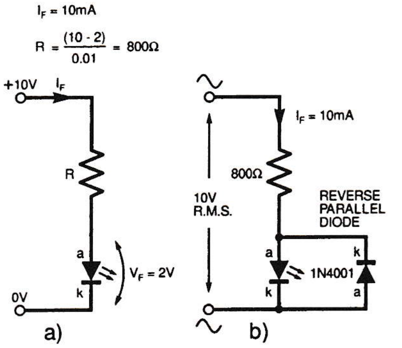


EVERYDAY PRACTICAL ELECTRONICS

Fig. 31-3

This circuit uses two audio amplifiers, one for a microphone and one for a stereo input, to drive an LED bar-graph display, rather than a meter. When the input exceeds a certain level, an LED (#8 in this circuit) will light and also cause an alarm buzzer or some other signal to actuate. A switch is provided for source selection.

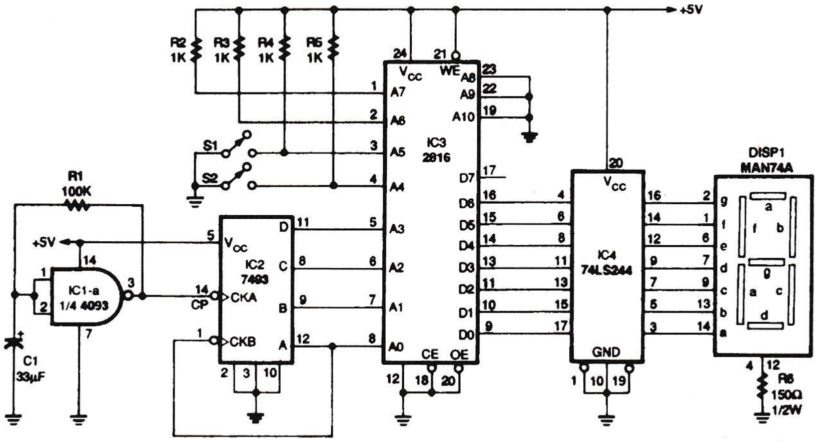
AC-DC SUPPLY LED CIRCUIT



EVERYDAY PRACTICAL ELECTRONICS ***Fig. 31-4***

(*a*) Series resistor calculation; (*b*) using an LED on an ac supply.

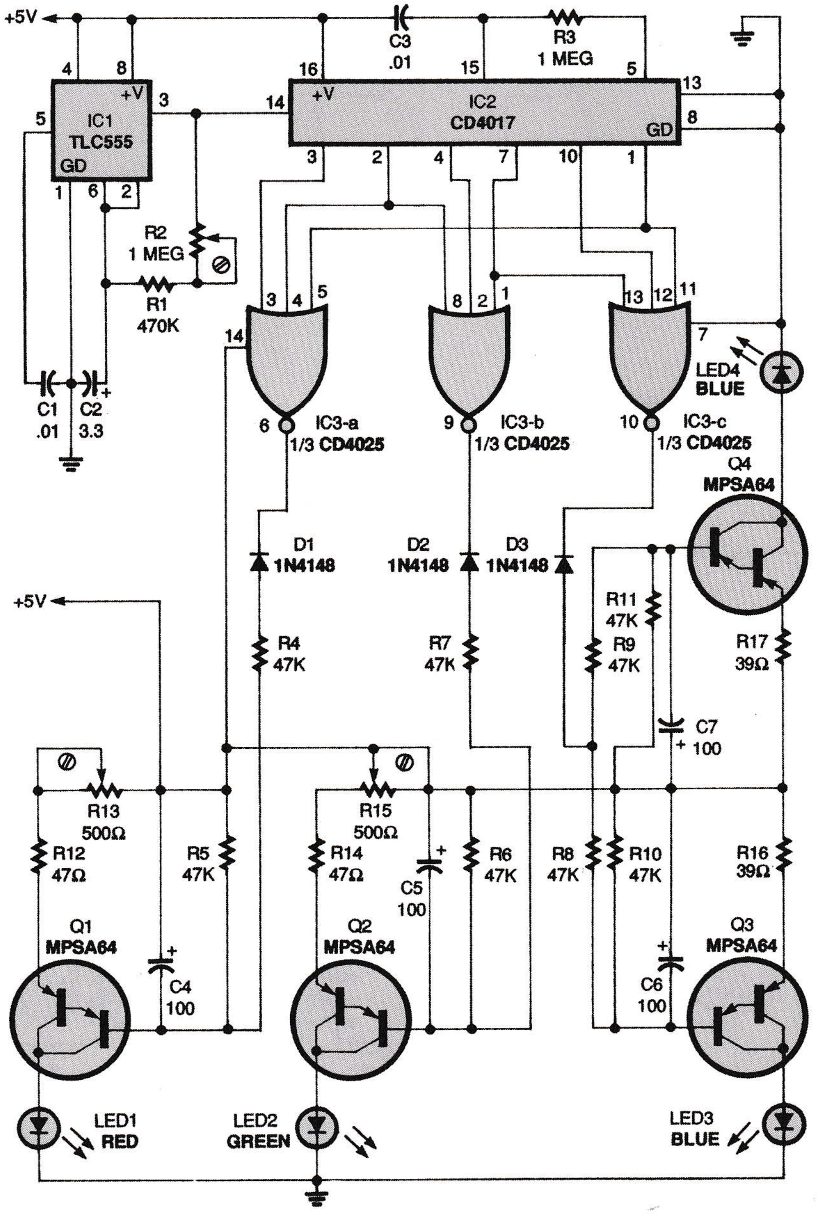
EEPROM DISPLAY DRIVER



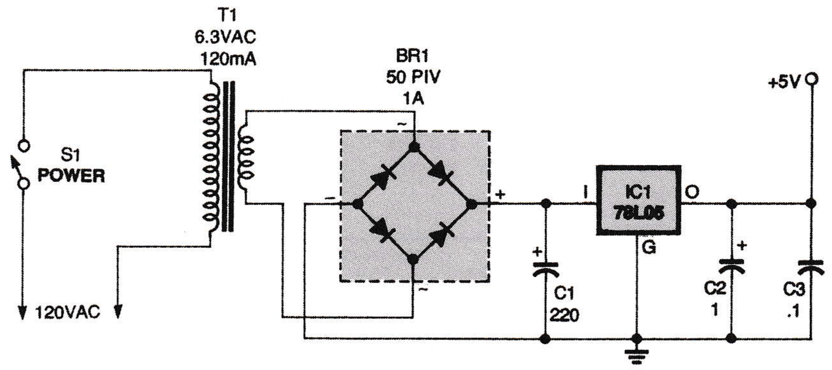
ELECTRONICS NOW ***Fig. 31-5***

This circuit illustrates use of an EEPROM as a decoder and display driver. IC1 and IC2 generate a binary sequence of addresses in the EEPROM, and the data out of the EEPROM drive (IC4) and the display.

MULTICOLOR LED DRIVER



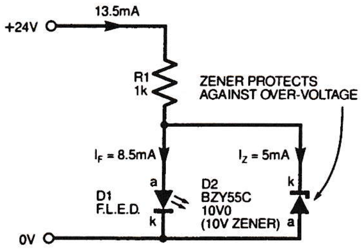
MULTICOLOR LED DRIVER *(Cont.)*



POPULAR ELECTRONICS *Fig. 31-6*

A TLC555 CMOS timer, IC1, is configured as a square-wave generator that has an adjustable time period of about 2 to 7 s. That output drives IC2, a CD4017 CMOS Johnson counter, which provides the six decoded output steps necessary to trigger the three additive and three subtractive primary color combinations. A CD4025 CMOS triple three-input NOR gate, IC3, gates the six outputs to the proper LED current sources, thereby maintaining the correct color-mixing sequence. Four MPSA64 PNP Darlington transistors (Q1 to Q4) are configured as gated current sources, with capacitors C4 to C7 providing long time constants that allow LED1 to LED4 to ramp up and down in intensity. This allows the color changes to be continuous, rather than in six abrupt steps. Power for the circuit is provided by a 5-V supply. Transformer T1 steps down the voltage from a wall outlet to 6.3 Vac, rectified by BR1 and regulated by IC1, a 78L05.

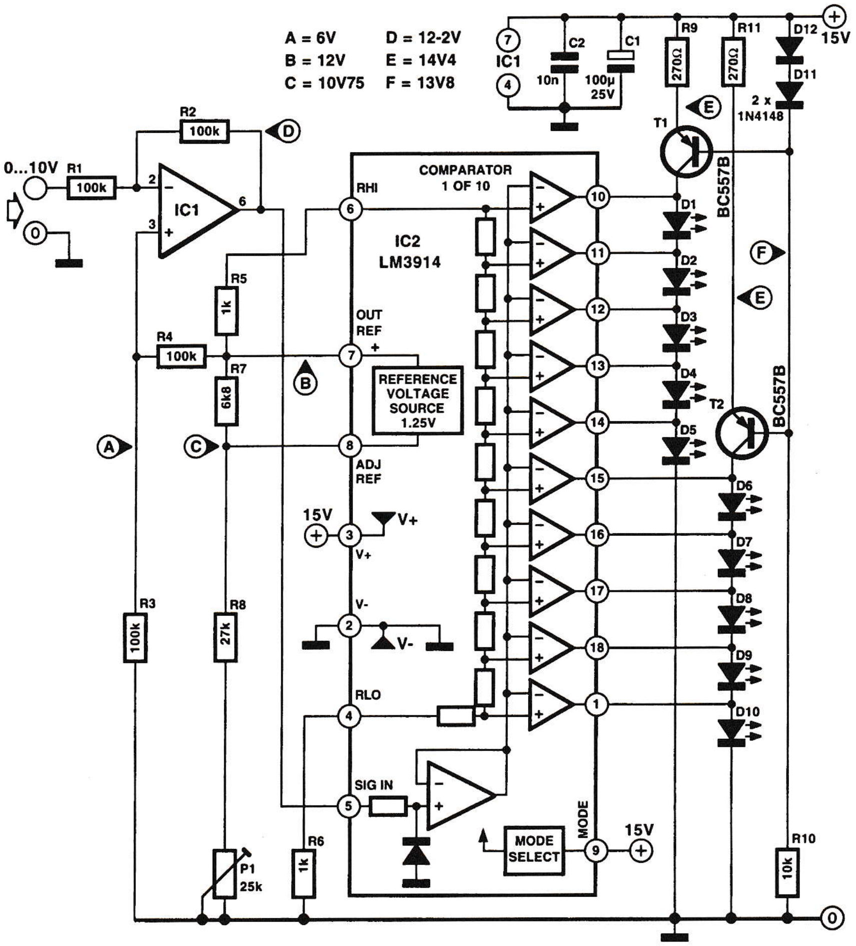
FLASHING LED HV SUPPLY CIRCUIT



EVERYDAY PRACTICAL ELECTRONICS *Fig. 31-7*

When using FLEDs on a supply voltage higher than the rating of the FLED, precautions should be taken to ensure that the device never “sees” a voltage above its maximum rating.

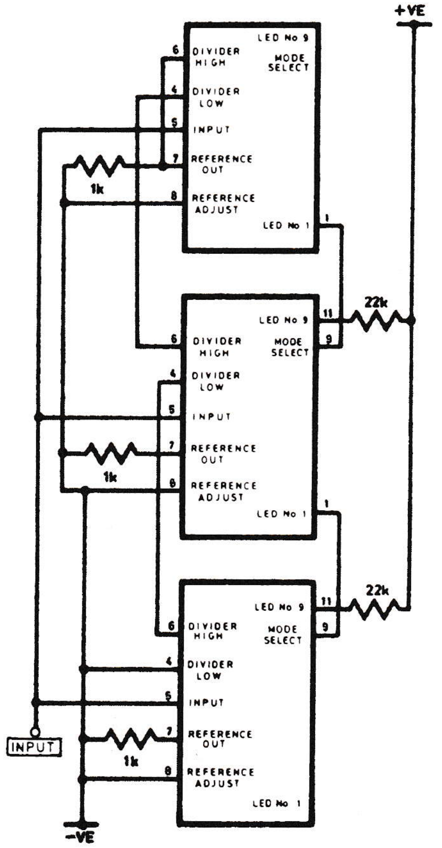
ECONOMICAL LED BAR DISPLAY



ELEKTOR ELECTRONICS *Fig. 31-8*

A particular difficulty with LED bar displays is the high current drain. In the diagram, LED driver LM3914 controls a chain of LEDs instead of, as is usual, a number of parallel-connected LEDs. This means that in principle only a single diode current is needed to make several LEDs light. The cost of this, of course, is a higher supply voltage because account must be taken of a number of diode forward voltages. The economizing effect is strengthened if high-efficiency LEDs are used. In the diagram, the current drain of about 15 mA is less than half that of the standard application (32 mA).

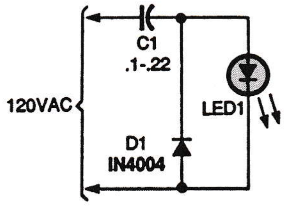
SURROUND SOUND INDICATOR



The circuit indicates, with the aid of two LEDs, whether or not the input signal contains surround data. The criterion for this is the phase difference between the two channels: If this is zero, there is no surround data. In the circuit diagram, if there is a phase difference between the two channels, the output levels of comparators IC1b and IC1c will differ. These outputs are constantly compared by XOR gate IC2c; if there is a difference, the output of the gate will go high. Depending on the output state, the red or green half of D1 will be actuated via gate IC2d, which is here connected as an inverter. If there is a pure surround signal, the red half will light brightly; if there is a mono signal, the green half will light. If the input is a standard stereo signal, the rapid changes in the output of IC2c will cause the diode to appear yellow-orange.

ELEKTOR ELECTRONICS *Fig. 31-9*

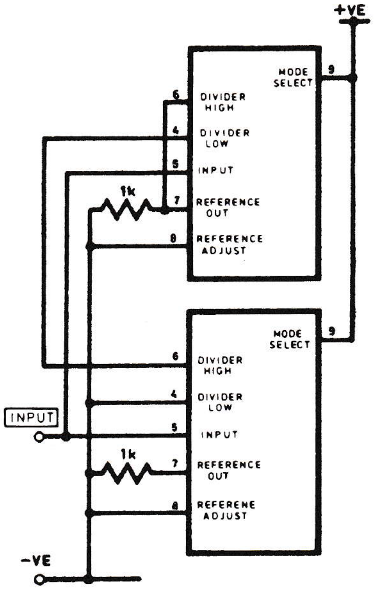
LED AC PILOT LAMP CIRCUIT



This circuit places an LED in an ac circuit, where it operates as a pilot lamp. The capacitance value sets the LED's current. For 120-Vac operation, a 0.1-μF, 400-V capacitor will result in a 5- to 10-mA current, and a 0.22-μF unit will produce approximately 20 mA of current.

POPULAR ELECTRONICS *Fig. 31-10*

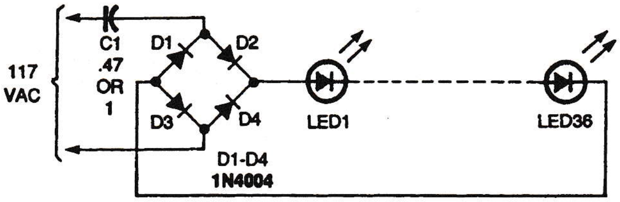
THREE CASCADED BAR-GRAPH DISPLAY DRIVERS



This shows how to cascade three bar-graph display drivers. The basic scheme can be extended to four or more drivers, if desired.

EVERYDAY PRACTICAL ELECTRONICS *Fig. 31-11*

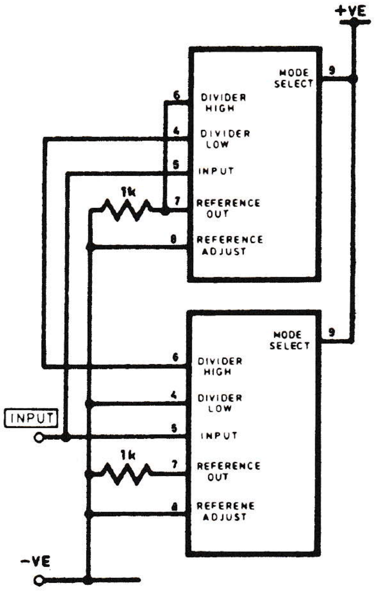
BRIDGE RECTIFIER LED LIGHT STRING



POPULAR ELECTRONICS *Fig. 31-12*

This circuit has a full-wave bridge rectifier feeding the LED string. With a 0.47-µF capacitor, as shown, the string's current was about 12 mA. If you substitute a 1-µF unit, the current will go up to about 20 mA, allowing you to add additional LEDs without suffering too severe a loss in brightness.

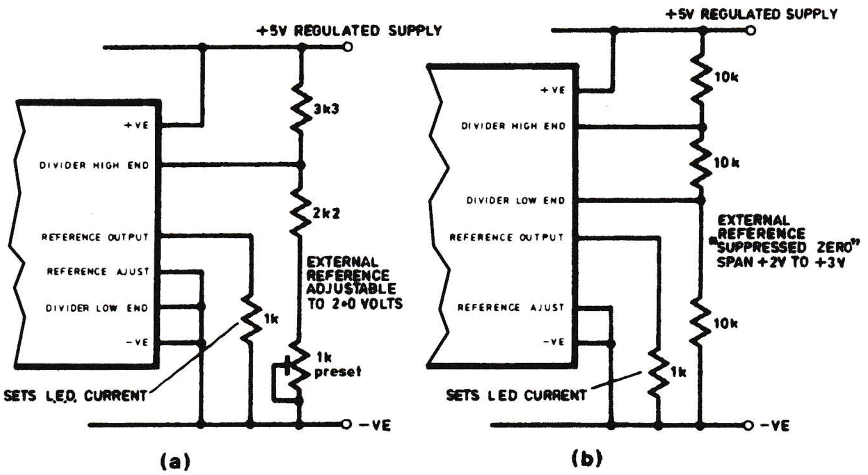
TWO CASCADED BAR-GRAPH DISPLAY DRIVERS



This shows how to cascade two bar-graph display drivers.

EVERYDAY PRACTICAL ELECTRONICS ***Fig. 31-13***

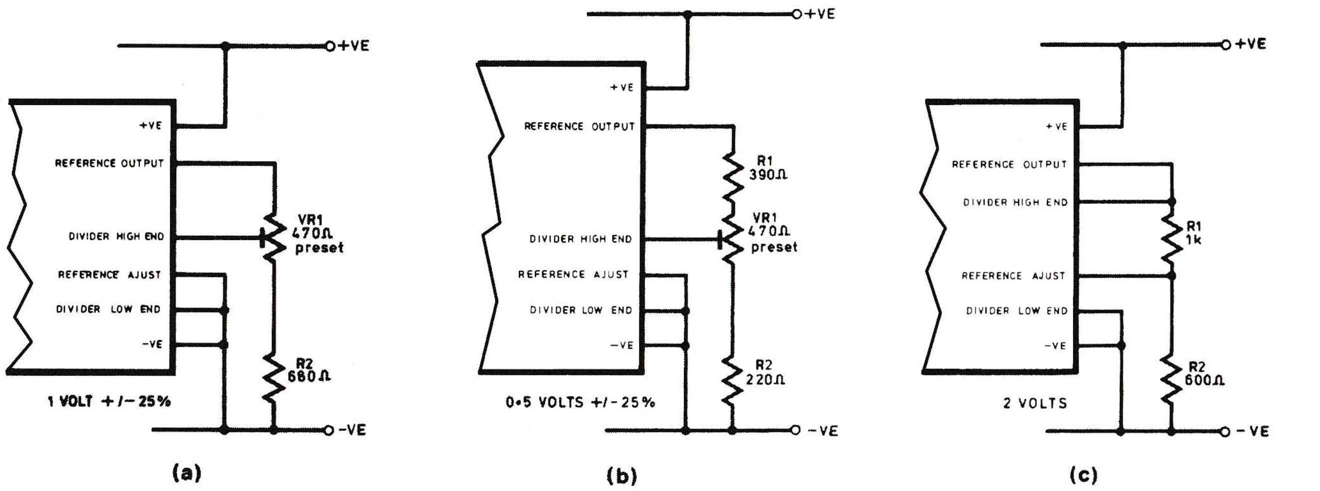
EXTERNAL VOLTAGE REFERENCE WITH BAR-GRAPH DISPLAY DRIVER



EVERYDAY PRACTICAL ELECTRONICS ***Fig. 31-14***

Using external reference sources to produce (*a*) an adjustable 2 V and (*b*) up to +3 V starting from +2 V.

BAR-GRAPH DISPLAY DRIVER SCALE SETTING

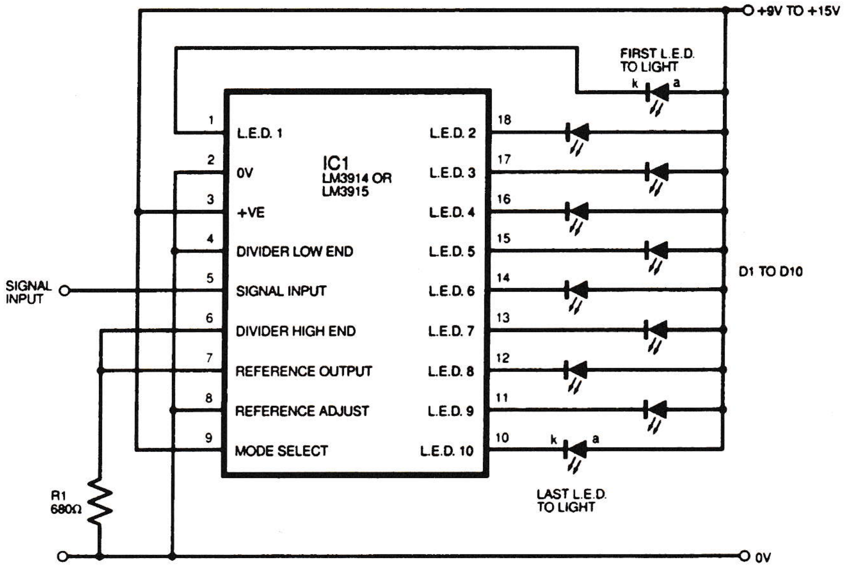


EVERYDAY PRACTICAL ELECTRONICS

Fig. 31-15

The figure shows ways of varying the reference with the internal generator of the bar-graph driver chip. (*a*) and (*b*) show two ways of using the “internal reference” to obtain full scales of 1 V and 0.5 V, respectively. In (*c*), the “reference adjust” and internal reference are used to produce 2 V.

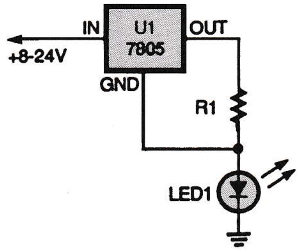
BAR-GRAPH DISPLAY CIRCUIT



EVERYDAY PRACTICAL ELECTRONICS *Fig. 31-16*

This shows how an LM3914 or LM3915 is connected for 9- to 15-V operation. D1 to D10 can be separate LEDs or part of an integral display module.

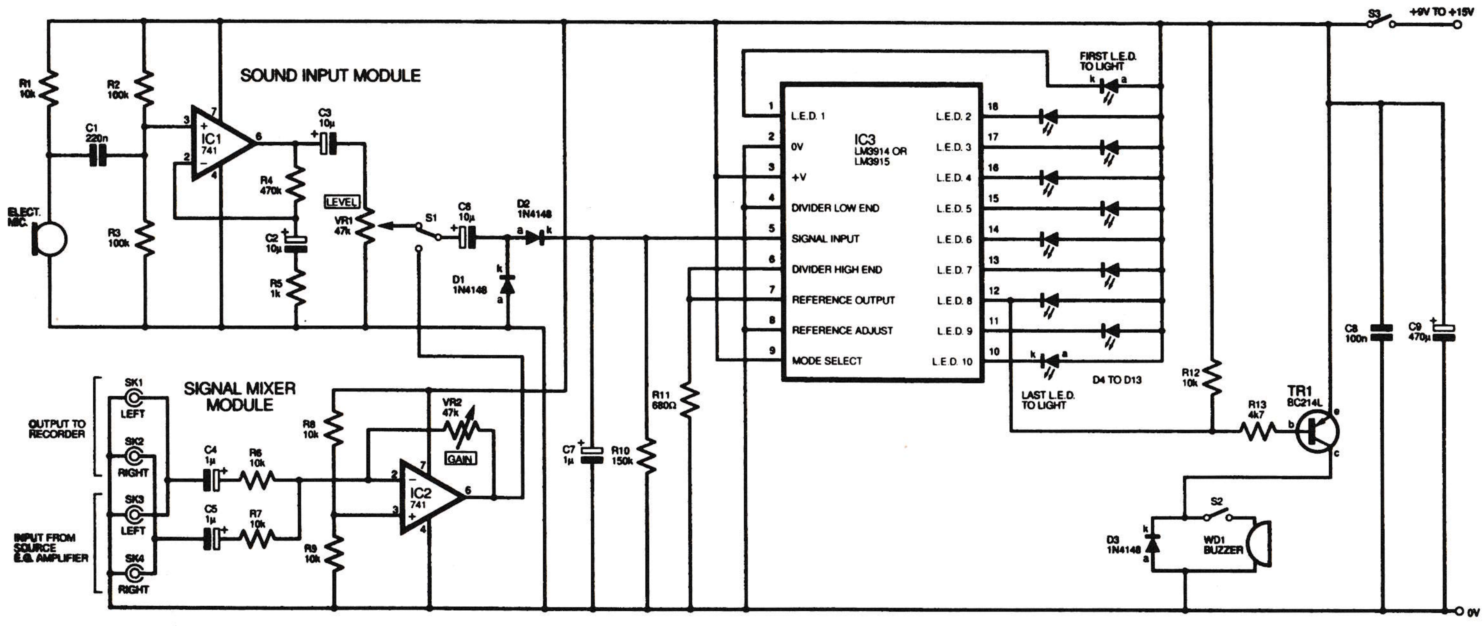
CONSTANT-BRIGHTNESS LED CIRCUIT



This setup ensures that the LED will glow with equal brightness as long as the input voltage remains between 8 and 24 V. $R=5/I$, where I=desired LED current.

POPULAR ELECTRONICS *Fig. 31-17*

VOLUME UNIT DISPLAY AND ALARM

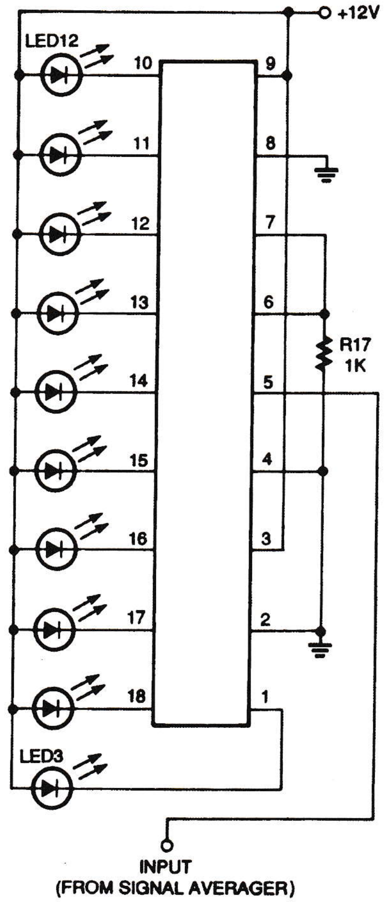


EVERYDAY PRACTICAL ELECTRONICS

Fig. 31-18

The concept is achieved by using two input modules, namely the sound input circuit and the signal mixer circuit, and selecting between them by means of a switch. The signal is then processed by an integrated circuit (IC3) and associated components, which convert a rising and falling voltage into a rising and falling LED display. The buzzer output module is connected so that when the appropriate LED lights, the buzzer sounds, indicating the excess level warning.

10-LED BAR-GRAPH INDICATOR CIRCUIT

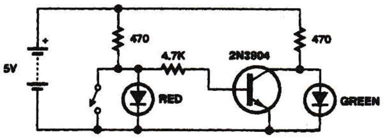


The solid-state level indicator consists of a string of 10 LEDs in one package. With a low-level signal input, all LEDs are off. As the signal increases, more LEDs light up, until finally all 10 are turned on to indicate the maximum level. The heart of the circuit shown in this figure is the National Semiconductor LM3915. The LM3915 contains a precision voltage reference, resistor divider chain, and 10 comparators to drive the LEDs. This IC also contains current-limiting circuitry that limits the brightness of the LEDs without the need for separate resistors, and logic to select either a bar graph or a moving-dot display.

ELECTRONICS NOW

Fig. 31-19

BICOLOR-LED SPST SWITCH

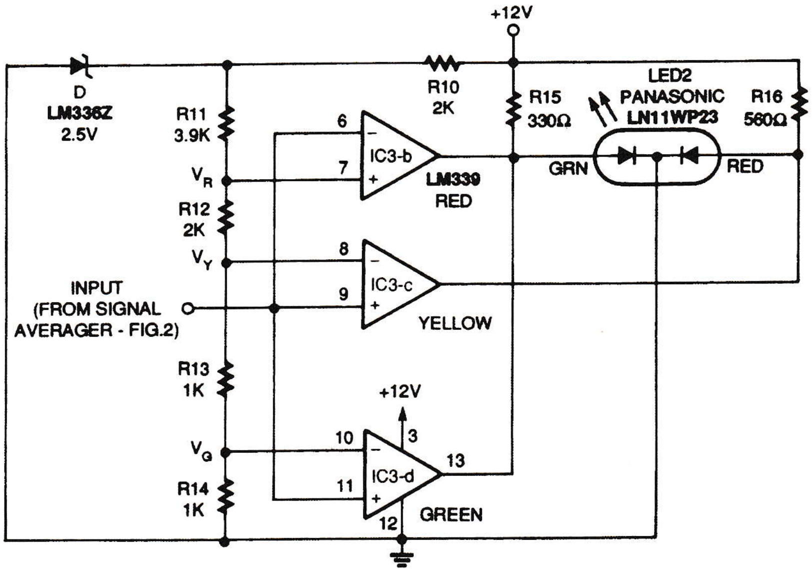


A transistor and a few resistors control two LEDs where the cathodes have a common lead.

ELECTRONICS NOW

Fig. 31-20

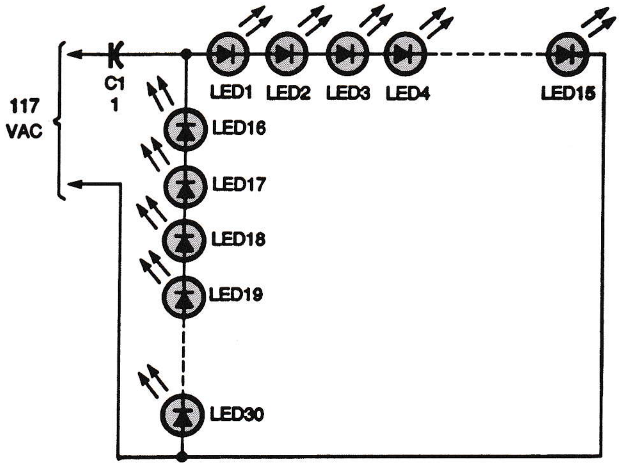
TRICOLOR LED PEAK INDICATOR CIRCUIT



ELECTRONICS NOW *Fig. 31-21*

This is a tricolor LED circuit. With a low input level, LED2 is off. As the input voltage increases, LED2 turns on and glows first green, then yellow, and finally red. Resistor R10 and 2.5-V precision voltage reference IC4 provide a precision voltage reference that is further subdivided by resistors R11, R12, R13, and R14. This chain of resistors creates three different reference voltages that set the voltage thresholds for the three LEDs, which are fed to the three comparators along with the input signal. The output of these comparators is then connected to LED2. If the output of all of the comparators is floating, the red and green dies in the tricolor LED are biased ON by R15 and R16, causing LED2 to glow yellow. However, if the output of a comparator is internally grounded, the connected color element will be pulled below 2 V, and the element will turn off. To set the gain level of the amplifier, apply a maximum-level signal to the input of the averager and reduce the level to allow for headroom.

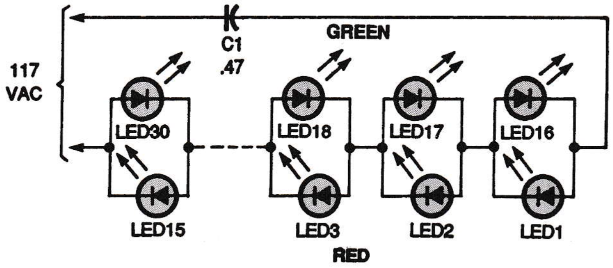
DUAL LED LIGHT STRING



POPULAR ELECTRONICS *Fig. 31-22*

This circuit lets you light up two separate 15-light strings from a single power source. On the positive half cycle of the 60-Hz ac waveform, LEDs 1 through 15 light, and on the negative half cycle, LEDs 16 through 30 light. Because the eye's response is much slower than 60 Hz, both strings appear to be on at the same time.

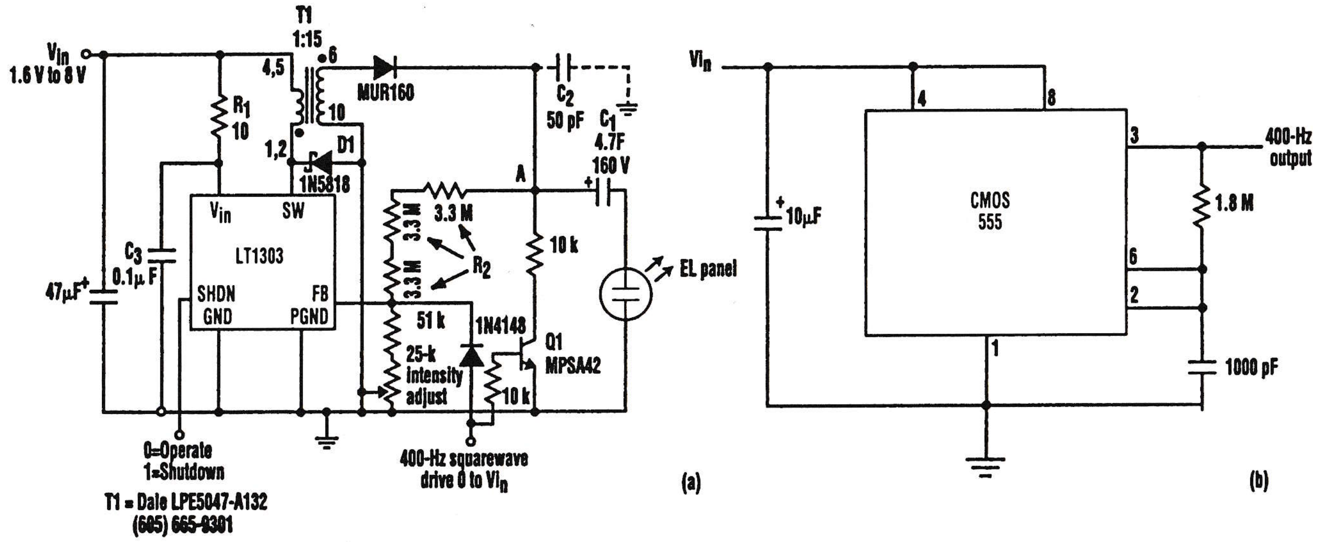
DUAL-COLOR LED LIGHT STRING



POPULAR ELECTRONICS *Fig. 31-23*

The red LEDs are lit during the positive transition of the ac waveform, and the green ones are lit during the negative transition.

ELECTROLUMINESCENT PANEL

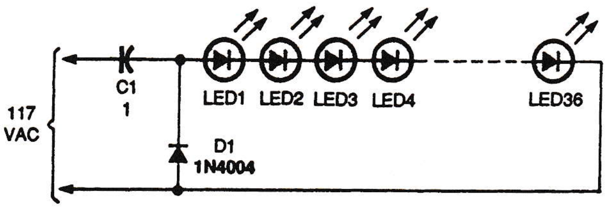


ELECTRONIC DESIGN

Fig. 31-24

Electroluminescent (EL) panels offer a viable alternative to LED, incandescent, or CCFL backlighting systems in many portable devices. EL panels are thin, rugged, lightweight, and low power; require no diffuser, and emit aesthetically pleasing blue-green light. Capacitive in nature, they typically exhibit about 3000 pF/in^2 of panel area and require a low-frequency (50 Hz to 1 kHz) 120-V rms ac drive. These problems can be solved by using a setup that includes an LT1303 micropower switching-regulator IC along with a small surface-mount transformer in a flyback topology. The 400-Hz drive signal can be supplied externally or derived from a simple CMOS 555 circuit. When the drive signal is low, flyback transformer T1 charges the panel until the voltage at point A reaches 240 Vdc. C1 removes the dc component from the panel drive, resulting in +120 Vdc at the panel. When the input drive signal goes high, the LT1303's feedback (FB) pin is pulled high as well, idling the IC and turning on Q1. Q1's collector pulls point A to ground and the panel to −120 Vdc. C2 can be added to limit voltage if the panel is disconnected or open. R1 provides intensity control by varying the output voltage. Intensity also can be modulated by varying the drive-signal frequency.

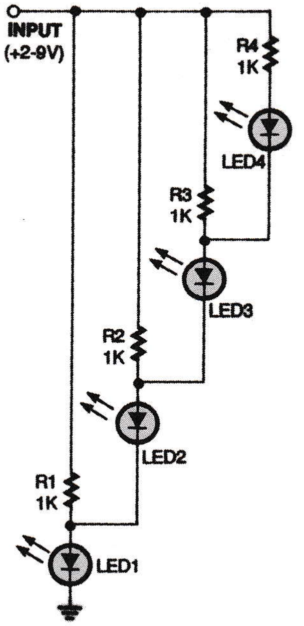
LED LIGHT STRING



POPULAR ELECTRONICS *Fig. 31-25*

Capacitor C1, a 1-μF, 400-V Mylar or similar unit, operates in the circuit as a no-loss, ac-limiting component connected in series with the LED string. The capacitor's reactance acts like a transistor to the ac without the losses found with a standard power resistor. The 1N4004 silicon diode protects the LEDs from reverse-voltage damage. The circuit was tested with 36 red and green LEDs with an operating current of about 15 mA. Additional LEDs might be added in series if you wish, but that will reduce the brilliance of the LED string somewhat.

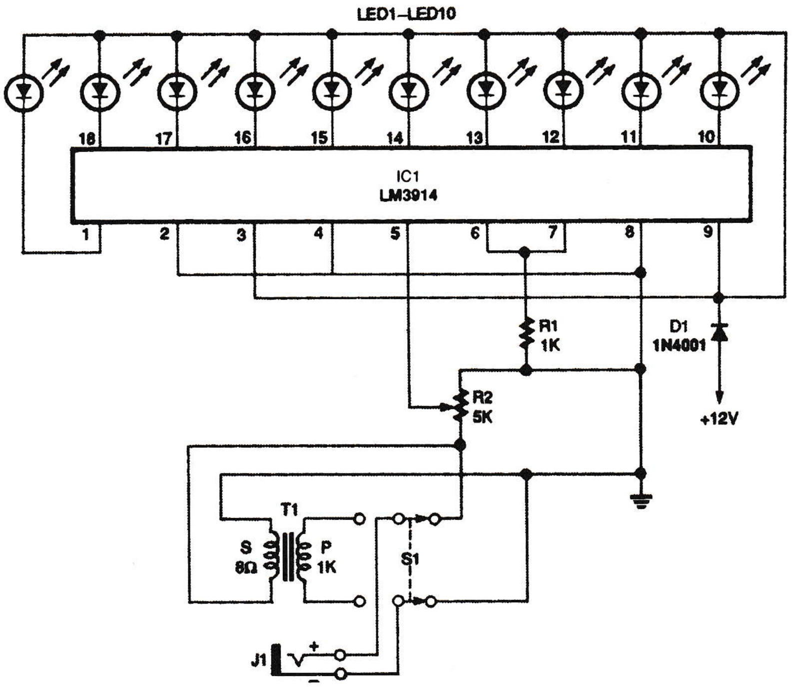
LED DC-LEVEL INDICATOR



Here's a simple dc-level indicator.

POPULAR ELECTRONICS *Fig. 31-26*

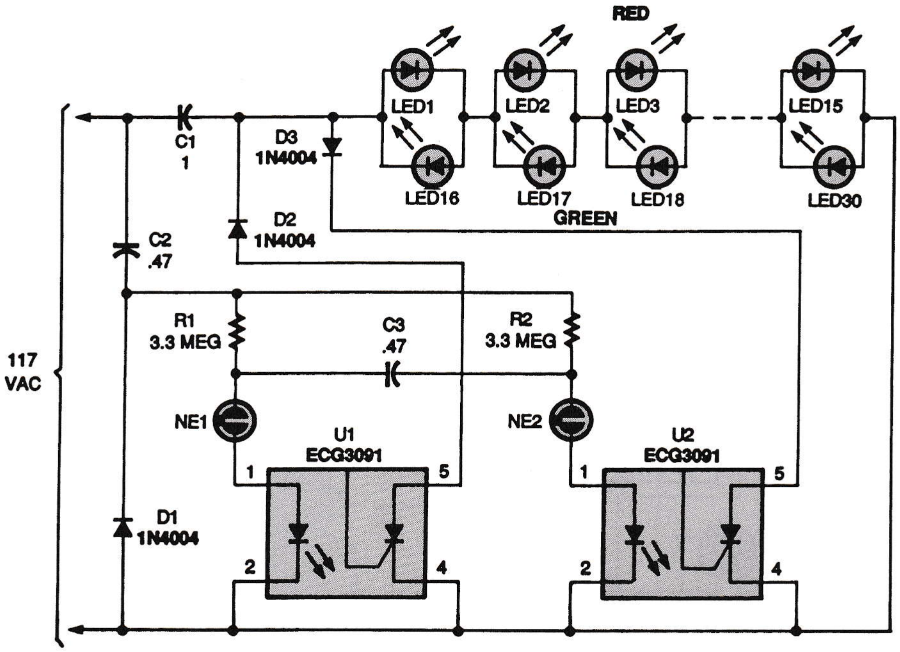
LED BAR-GRAPH CIRCUIT



ELECTRONICS EXPERIMENTERS HANDBOOK ***Fig. 31-27***

This circuit uses an LM3914 with either dc or audio input. R2 controls the input level. The display can be either ten discrete LEDs or a bar-graph LED assembly.

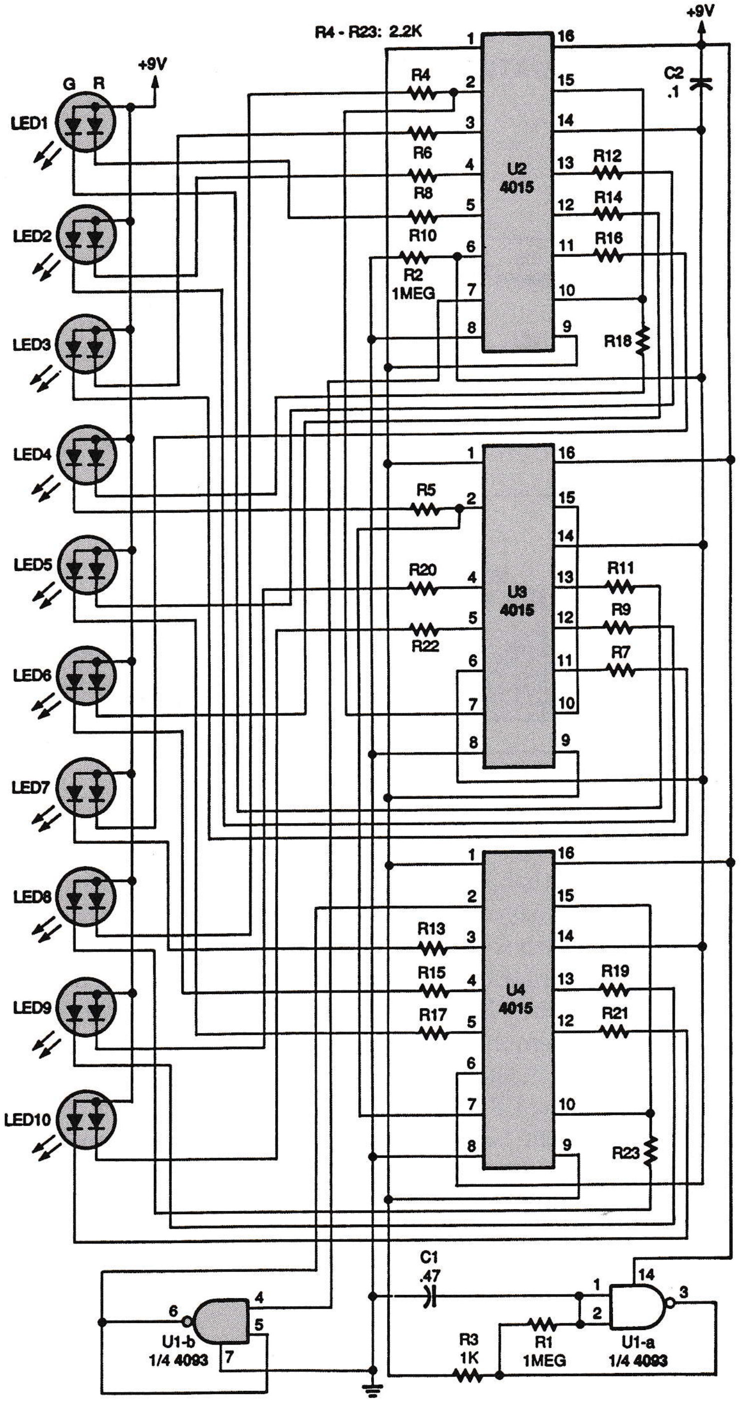
ALTERNATING-COLOR LED LIGHT STRING



POPULAR ELECTRONICS *Fig. 31-28*

This circuit produces a string that alternates between red and green at a steady 1-s rate, making it an attractive addition to any holiday display. Two neon bulbs, NE1 and NE2, are connected in a relaxation-oscillator circuit that switches back and forth at about a 1-Hz rate. The values of R_1, R_2, and C_3 set the switching rate. Dc power for the neon oscillator circuit is supplied via C2 and D1. No dc filter capacitor is used or needed. When NE1 turns on, current flows through the LED in U1, an optocoupler, turning on the SCR and grounding the anode of D2. Only the positive half cycle of the ac waveform passes to the LEDs, which lights only the red ones (LED1 to LED15). After about 1 s, NE1 turns off and NE2 turns on, causing U2 to ground the cathode of D3. Now only the negative half cycle of the ac waveform passes to the LEDs, which lights only the green ones. If you'd like a change rate of less than 1 s, lower the values of R_1 and R_2; to lengthen the rate, increase the value of capacitor C_3.

TRICOLOR LED SIGN DISPLAY

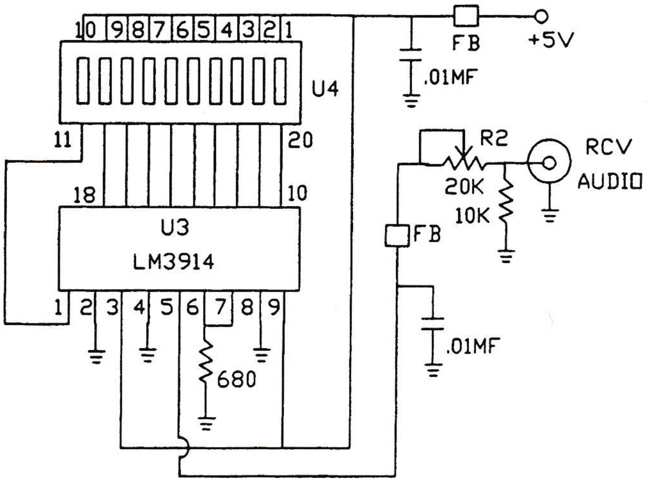


POPULAR ELECTRONICS

Fig. 31-29

The purpose of this circuit is to light three-terminal LEDs in sequence on a small sign for a model railroad. Capacitor C2 is connected to the resets of the three 4015 shift registers, U2 to U4. When the circuit is first turned on, C2 automatically sets all the outputs to 0, thus inputting a 1 through U1-b, a section of a 4093 NAND Schmitt trigger, to the A input (pin 7) of U2. The circuit is clocked by U1-a, which is connected as an oscillator, and U1-a inverts the 0s to 1s until the first 1 is recirculated to the output of the last shift register, U4. Then the 1s become 0s and they recirculate. That all repeats as U1-a clocks the shift registers. When the first 1 is received at the first output of U2, the LED segment connected to it lights. As U1-a clocks the shift register, the LEDs connected to the other outputs sequentially light up red. After ten clock cycles, the clock skips two, and then continues lighting up the green segments of the LEDs, giving a yellowish-orange tint to them. After all the LEDs are lit, the shift register starts turning off the red LED segments. That leaves the green segments on—the third color from the LEDs. The oscillator continues to clock the green LEDs off, leaving the sign dark. After that cycle is completed, the operation repeats, giving the effect of a sign that goes from red to yellow to green to dark.

BAR-GRAPH DISPLAY

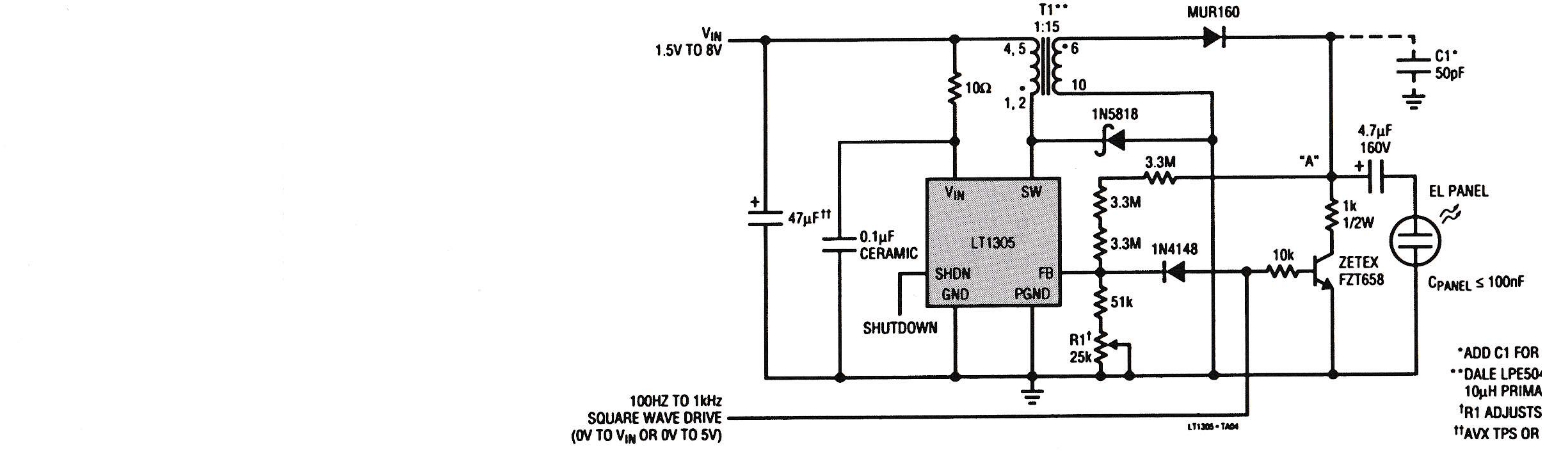


73 AMATEUR RADIO TODAY

Fig. 31-30

This bar-graph display monitors received audio level and can be useful for tuning, peaking, etc.

ELECTROLUMINESCENT PANEL DRIVER



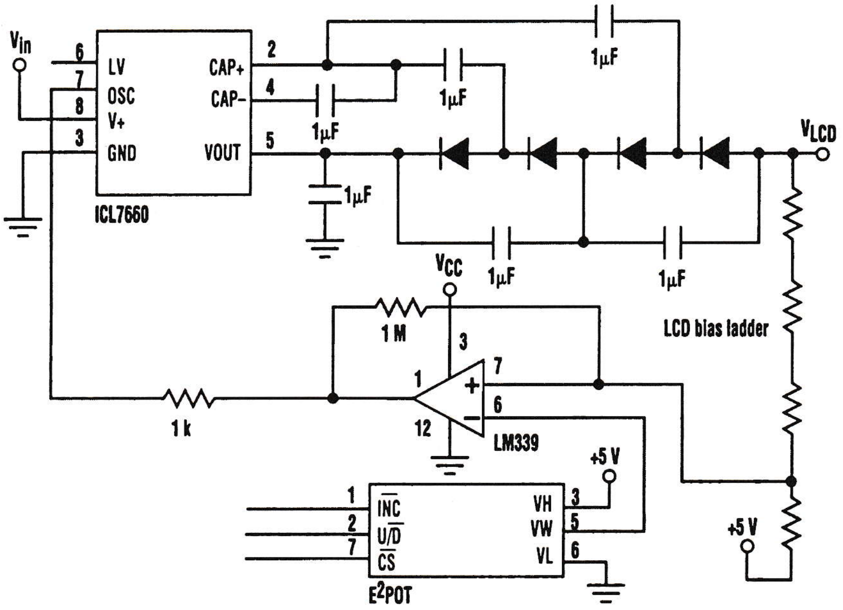
*ADD C1 FOR OPEN-PANEL PROTECTION
**DALE LPE5047-A132 1:15 TURNS RATIO
10µH PRIMARY INDUCTANCE (605) 666-9301
†R1 ADJUSTS V_{OUT} 83V_{RMS} TO 115V_{RMS}
††AVX TPS OR SANYO OS-CON MUST HAVE ESR ≤0.15Ω

LINEAR TECHNOLOGY POWER SOLUTIONS

Fig. 31-31

Driving electroluminescent (EL) panels, such as those used for backlighting LCD screens in portable devices, is a challenge because they are capacitive loads and require high-voltage ac drive signals. Typically, EL panels exhibit about 3 nF/in^2 capacitance. The LT1305 circuit shown can drive an EL panel with up to 100 nF total capacitance. The LT1305 micropower dc-to-dc converter contains an internal power switch capable of up to 2 A switch current. The high-power switch drives the primary of flyback transformer T1. A minimum input voltage of 1.8 V ensures operation with two-cell supplies. The input voltage is boosted to a voltage that ranges from 166 to 248 Vdc, as set by R1. The ac drive waveform is created by an external square-wave control signal turning on and off the NPN transistor, bringing point A to ground and inverting the voltage across the panel and then returning to a high positive voltage. By adjusting R1, the panel ac drive voltage can be set from 83 to 115 V_{rms} to alter the display brightness. The color or hue of the display can also be slightly varied by changing the frequency of the square-wave drive signal. This control signal can be from a system microprocessor output pin.

VARYING LCD BIAS CIRCUIT

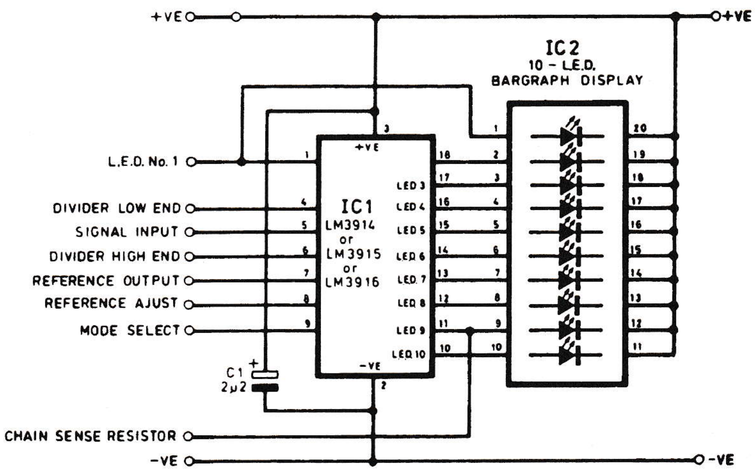


ELECTRONIC DESIGN

Fig. 31-32

Large dot-matrix LCD drivers require a negative bias voltage of up to 24 V, depending on the LCD multiplex ratio. One alternative is to combine the 7660 with a diode/capacitor voltage multiplier, using the 7660's internal square-wave generator as the signal source. This circuit will deliver an output of $3V_{in} - 4V_f$, thus generating approximately 24 V from a 9-V input. Additional stages could be added to the multiplier to allow 24 V to be generated from a 5-V regulated supply. In this circuit, the output voltage is set by the input voltage, which might be inconvenient. If a variable voltage is required for contrast adjustment, some form of microprocessor control over the output voltage will be needed. One particular configuration used a Xicor E^{2}POT to control the output by using a feedback circuit that pulls the oscillator pin of the 7660 low when the bias voltage exceeds the desired levels. This prevents further pumping of charge until the output returns to the required voltage. The output ripple is set by the hysteresis resistor in the comparator circuit.

BASIC BAR-GRAPH DISPLAY CIRCUIT



EVERYDAY PRACTICAL ELECTRONICS

Fig. 31-33

An LM3914 is shown connected to an LED bar-graph display.