WITH CUMULATIVE INDEX

Rudolf F. Graf
&
William Sheets

Encyclopedia of ELECTRONIC CIRCUITS

Volume 7

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The Electronics Authority

Volume 7 ; Partition #5
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Encyclopedia of

ELECTRONIC CIRCUITS

Volume 7

Rudolf F. Graf
and
William Sheets

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To Scott
With much love from Popsi

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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

Encyclopedia of

ELECTRONIC CIRCUITS

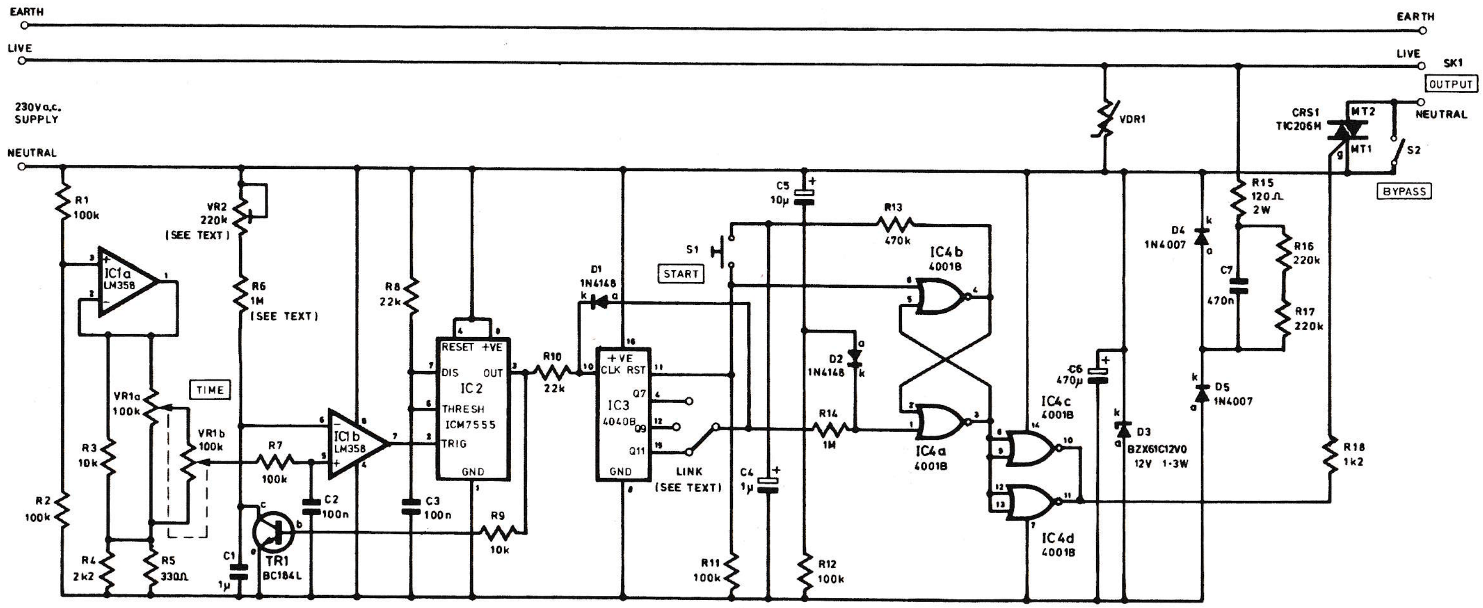
Volume 7

79

Photography-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.

DARKROOM EXPOSURE TIMER

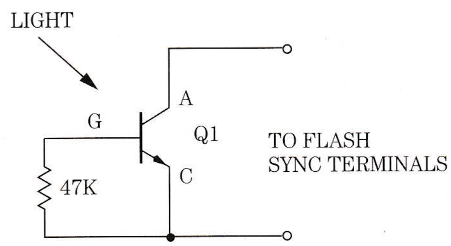


EVERYDAY PRACTICAL ELECTRONICS

Fig. 79-1

In this circuit, op-amp IC1b and timer IC2 form a voltage-controlled oscillator circuit with its frequency varied by the dual-ganged potentiometer (VR1). Resistor R3 effectively swamps any variations in VR1 value, preventing them from altering the lowest control voltage, as set by R4 and R5. The values of these resistors are chosen to give a ratio between the highest and lowest voltages of 32.5:1, which sets the timing range from 0.4 to 13 minutes, ensuring cover of the intended range of 0.5 to 12 minutes. Op-amp IC1b is used as a comparator. Capacitor C1 charges in exponential fashion from VR2 and R6 until the voltage across it reaches the selected control voltage from VR1b. When it does so, the output of IC1b goes low, triggering timer IC2, which then delivers a 2.5-ms pulse from output pin 3. This is used to discharge C1 via transistor TR1. VR2 provides the overall trimming adjustment for calibration. From IC2, the output pulses are applied through resistor R10 to the CLOCK input of binary counter IC3. This counts the pulses until the selected output goes high, blocking the CLOCK signal via diode D1. Pin 15 of IC3 is the 11th counter output, so 1024 clock pulses are counted. The final output of the circuit is controlled by quad NOR gate IC4. When the circuit is first energized, a positive pulse from C5 via D2 to IC4a pin 1 causes IC4a output pin 3 to go low and IC4b output pin 4 to go high, the OFF state. The high output of IC4b pin 4 charges C4 through R13. When START switch S1 is pressed, output pin 3 goes high, the ON state. At the same time, the pulse resets counter IC3 via its input, pin 11. Capacitor C4 will not be recharged until the output returns to the OFF state, ensuring that if switch S1 is held down or accidentally pressed again before timing is complete, the output time will not be affected. Timing ceases when the link-selected output of IC3 goes high and resets IC4a through R14.

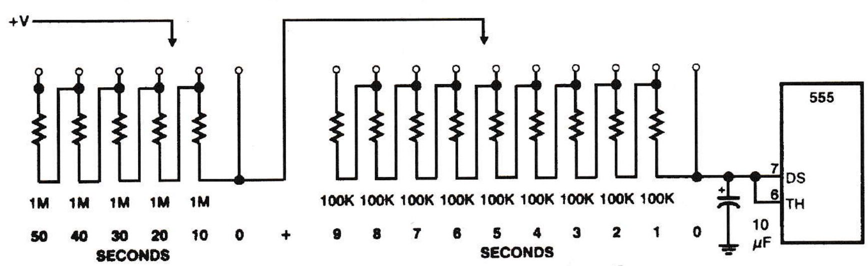
SIMPLE SYNCHRONIZED SLAVE PHOTO FLASH



WILLIAM SHEETS ***Fig. 79-2***

A light-activated silicon-controlled rectifier (Q1) is triggered by a flash of light from the master flash unit.

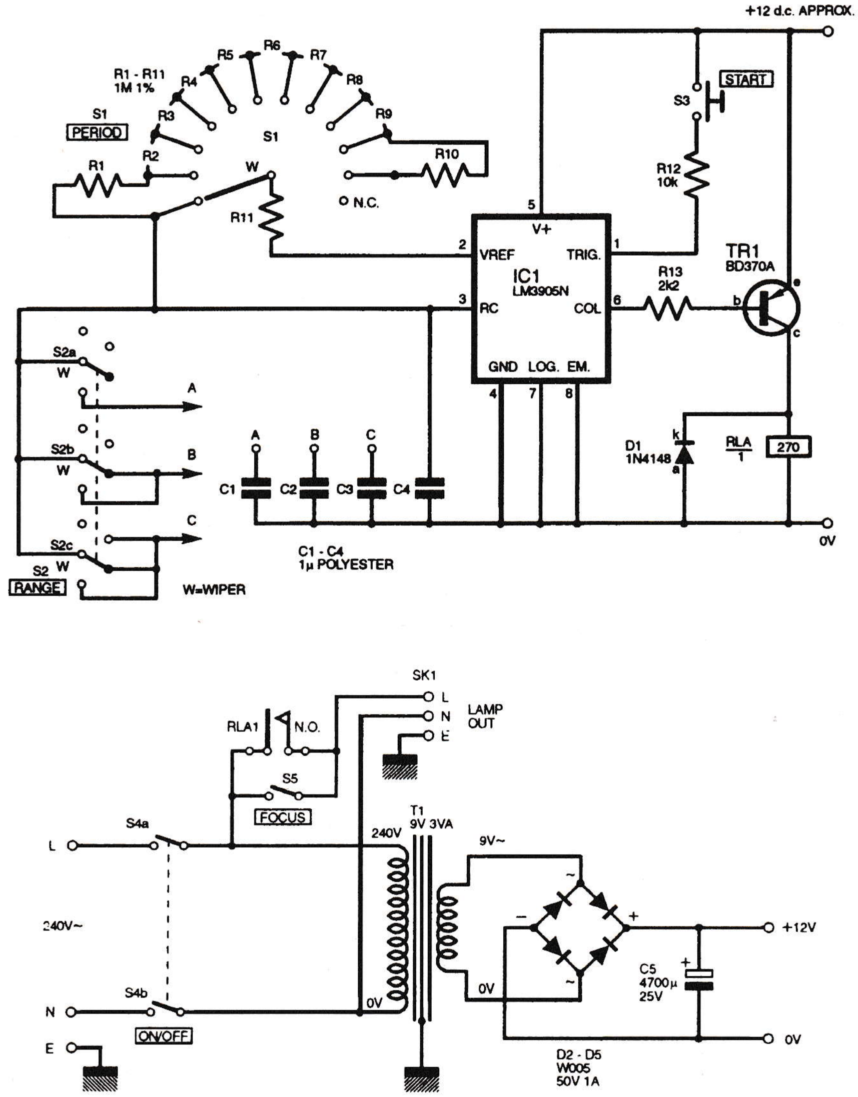
ENLARGER TIMER STEP CIRCUIT (0 TO 59 s)



ELECTRONICS NOW ***Fig. 79-3***

This circuit shows how to set up a NE555 timer to produce timing steps from 0 to 59 s in 1-s intervals.

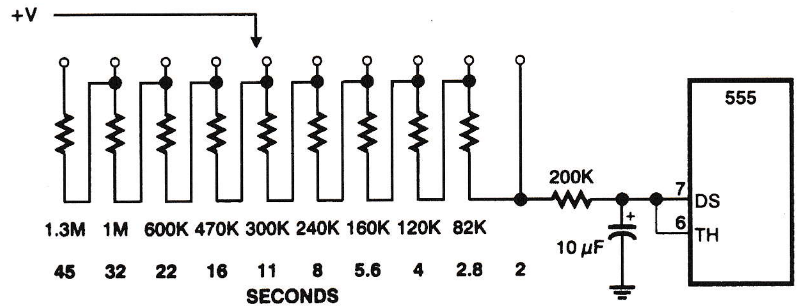
ENLARGER TIMER



EVERYDAY PRACTICAL ELECTRONICS ***Fig. 79-4***

This fairly accurate design is also suitable for color work. Unlike many simple timer designs, this unit is based around the LM3905N 8-pin D.I.L. precision timer IC, which repeats the timing period very consistently with little drift, although the accuracy of the timer depends on the tolerance of the components used. In the circuit diagram, IC1 is an LM3905N timer whose period is determined by an external RC network selected by switches S1 and S2. The formula for the time period is $t=RC$, where t is in seconds, R is in ohms, and C is in farads. Switch S1 is a single-pole, 12-way rotary type which selects among timing resistors R1 to R11. S2 is a three-pole, four-way rotary switch that progressively adds C1 to C3 *in parallel* with C4, thereby adjusting the timing capacitance range. In conjunction with the 1-percent resistor network (R1 to R11), each 1μ/1M pair represents a 1-s period; hence, the maximum possible period is 44 s. Timing is initiated by closing switch S3. A floating output transistor *within* IC1 drives a PNP buffer, which, in turn, operates relay RLA. The circuit requires roughly a 12-V rail, and the relay coil is chosen accordingly. The IC will operate from 4.5 to 40 Vdc, and a standard full-wave power supply can be used. The relay contacts RLA1 switch on the enlarger bulb, and a separate FOCUS switch (S5) can be included across the relay contacts (or perhaps drive the relay coil manually), if desired.

CONSTANT-EXPOSURE ENLARGER TIMER CIRCUIT

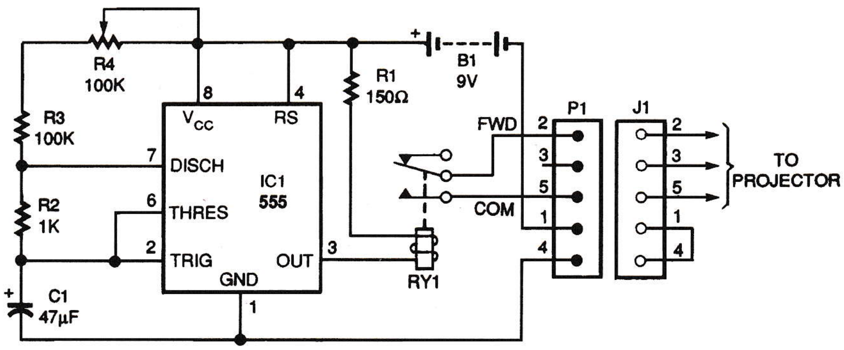


ELECTRONICS NOW

Fig. 79-5

This circuit shows how to set up a NE555 timer to produce time steps proportional to f/stops. Shown are values for switch-selected times of 2, 2.8, 4, 5.6, etc., through 45 s for constant exposure with various enlarger lens settings.

SLIDE-PROJECTOR STEPPER CIRCUIT



ELECTRONICS NOW

Fig. 79-6

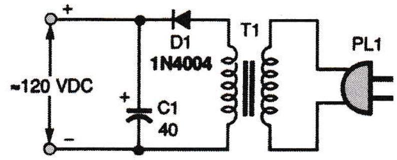
This circuit uses a 555 timer to drive a relay connected to a slide projector to provide automatic advance. R4 sets the time between slide changes.

80

Power-Supply Circuits—Ac to Dc

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.

135-VDC SUPPLY

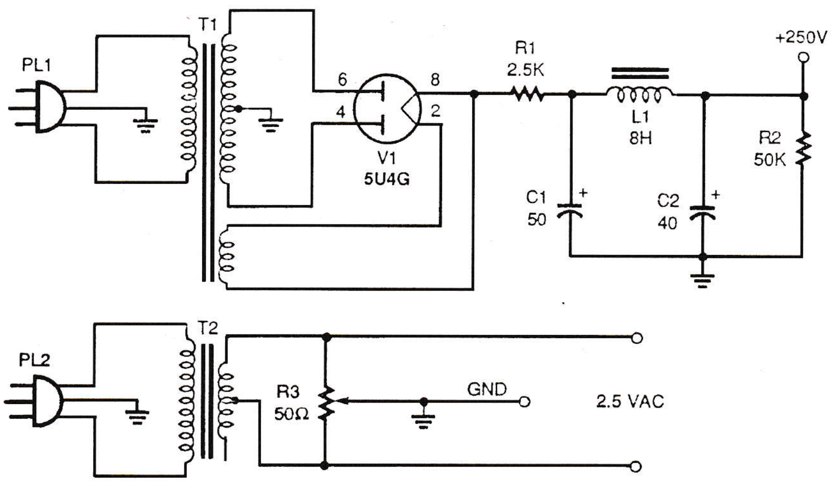


POPULAR ELECTRONICS

Fig. 80-1

This supply can be used for vacuum-tube experiments. It uses a 120:120 Vac isolation transformer to isolate the ac line from the dc output. T1 can be 30- to 100-mA capacity and C1 is a 40-μF 250-V electrolytic.

VACUUM TUBE EXPERIMENTER'S SUPPLY

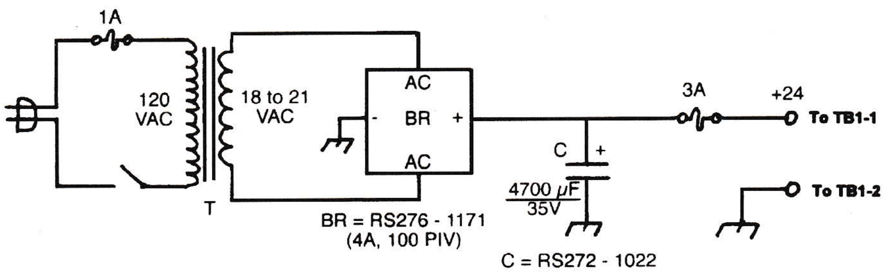


POPULAR ELECTRONICS

Fig. 80-2

This supply furnishes +250 V at about 60 mA, 2.5 Vac at 4.5 A, and it has a balance pot for the filament (B-return) center tap. T1 is a power transformer with 350-0-350 Vac, center tapped, 5 Vac at 3 A. T2 is 2.5 Vac at 4.5 A.

10-W CW TRANSCEIVER POWER SUPPLY

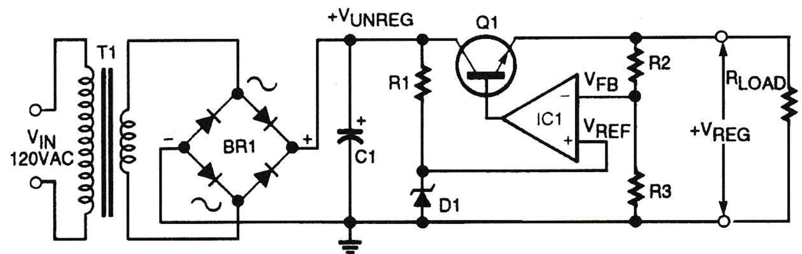


73 AMATEUR RADIO TODAY

Fig. 80-3

This power supply delivers about 24 Vdc at 1 A and was originally used for supplying power to a 10-W CW ham rig.

SERIES-REGULATED LINEAR POWER SUPPLY



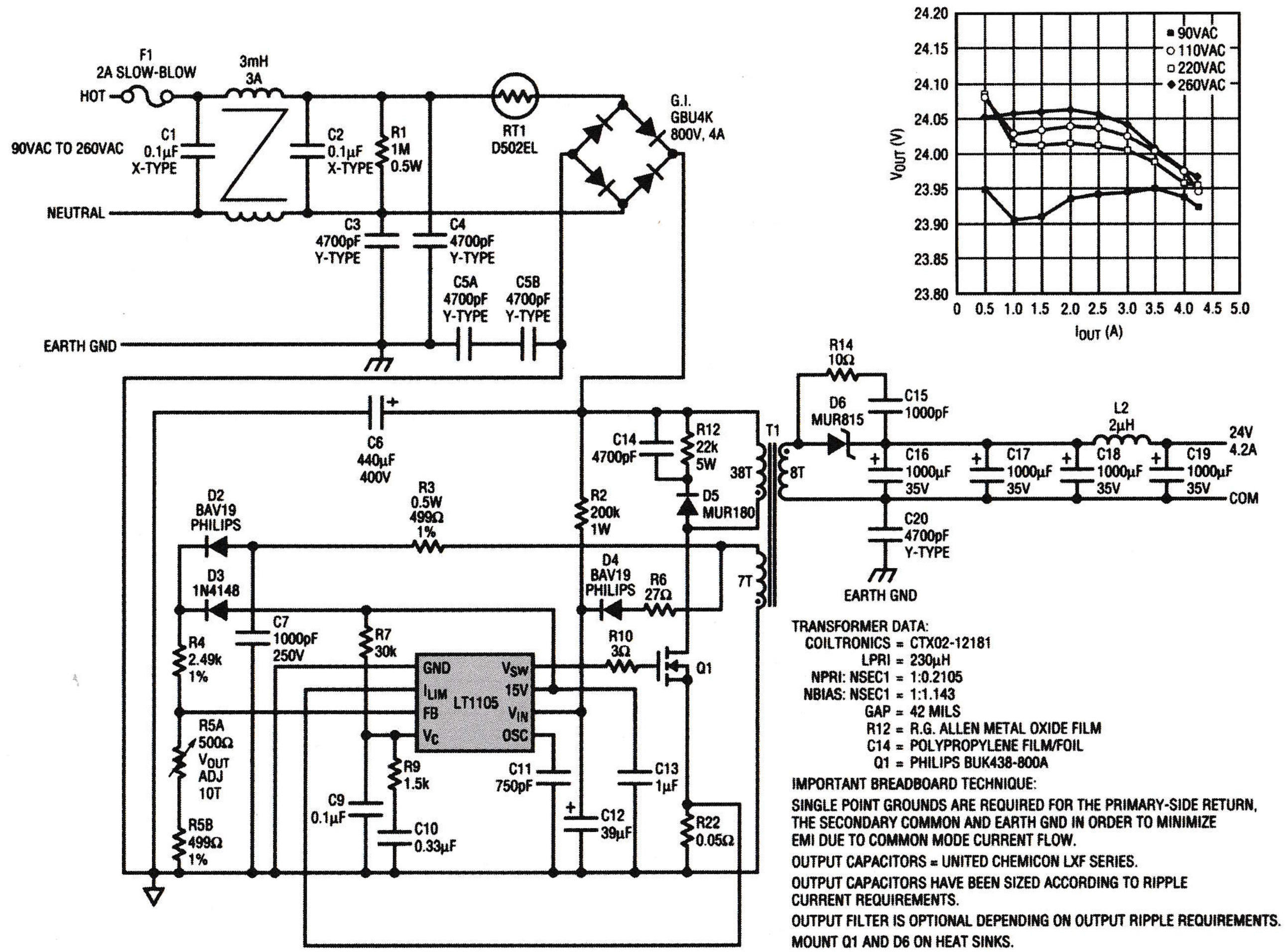
ELECTRONICS NOW

Fig. 80-4

The ac line is isolated from the power supply by transformer T1. Full-wave diode bridge BR1 delivers unregulated dc with ripple on it to the filter capacitor (C1.) The filtered dc is delivered to pass transistor Q1, shown here in series with the load. The series-pass regulator with a transistor pass element regulates the voltage to ensure that a constant output level is maintained, despite variations in the power line voltage or circuit loading. The basic linear series regulator consists of transistor Q1, reference resistor R1, sensing resistors R2 and R3, voltage-reference zener diode D1, and operational amplifier IC1, organized as an error amplifier. The zener diode D1 provides a fixed reference voltage at the positive input to amplifier IC1. The output voltage of the supply establishes the emitter voltage and provides a feedback voltage for the negative terminal of the amplifier IC1. The equation for the regulated output voltage is $V_{reg} = V_{ref}(1 + R_1 / R_2)$.

OFF-LINE 24-V 100-W DC SUPPLY

24V Load Regulation vs Line Voltage



TRANSFORMER DATA:
COILTRONICS = CTX02-12181
LPRI = 230µH
NPRI: NSEC1 = 1:0.2105
NBIAS: NSEC1 = 1:1.143
GAP = 42 MILS
R12 = R.G. ALLEN METAL OXIDE FILM
C14 = POLYPROPYLENE FILM/FOIL
Q1 = PHILIPS BUK438-800A

IMPORTANT BREADBOARD TECHNIQUE:
SINGLE POINT GROUNDS ARE REQUIRED FOR THE PRIMARY-SIDE RETURN, THE SECONDARY COMMON AND EARTH GND IN ORDER TO MINIMIZE EMI DUE TO COMMON MODE CURRENT FLOW.
OUTPUT CAPACITORS = UNITED CHEMICON LXF SERIES.
OUTPUT CAPACITORS HAVE BEEN SIZED ACCORDING TO RIPPLE CURRENT REQUIREMENTS.
OUTPUT FILTER IS OPTIONAL DEPENDING ON OUTPUT RIPPLE REQUIREMENTS.
MOUNT Q1 AND D6 ON HEAT SINKS.

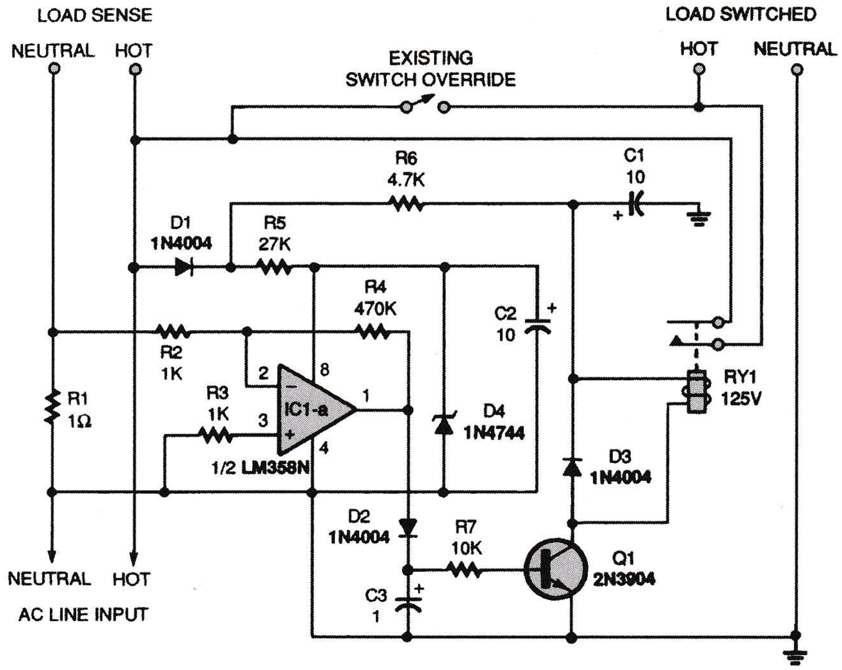
LINEAR TECHNOLOGY

Fig. 80-5

OFF-LINE 24-V 100-W DC SUPPLY *(Cont.)*

Today's electronic systems often rely on distributed power to support a myriad of control functions. This contrasts with historical approaches, which provided a regulated dc voltage to each of the subsystems with an off-line converter, often an expensive off-the-shelf box with less-than-optimal reliability. Shown here is a discrete approach that simplifies the task of distributed power design, saving time and money during system design. The LT1105 current-mode PWM control IC makes a simple, low-cost, yet highly reliable distributed power supply with the added advantage of a customizable footprint. The 24-V output is regulated to better than ±1 percent over a line range of 90 to 260 Vac and an 8:1 dynamic load range. A maximum output current of 4.2 A is available for a total of 100 W. All components, including the transformer, are specified in this design. The transformer meets international safety standards UL 1950 and IEC950. This transformer and others that provide 36 or 48 V at 100 W are available off the shelf. The LT1105 uses unique design techniques, eliminating the optocoupler feedback normally found in off-line supplies, yet enabling the regulator to provide tight line and load regulation. A totem-pole output drives the gate of an external high-voltage FET (Q1), and switch current is monitored by sense resistor R22. Short-circuit protection is provided by "burp" mode operation, whereby the LT1105 will continuously shut down and restart during the fault condition.

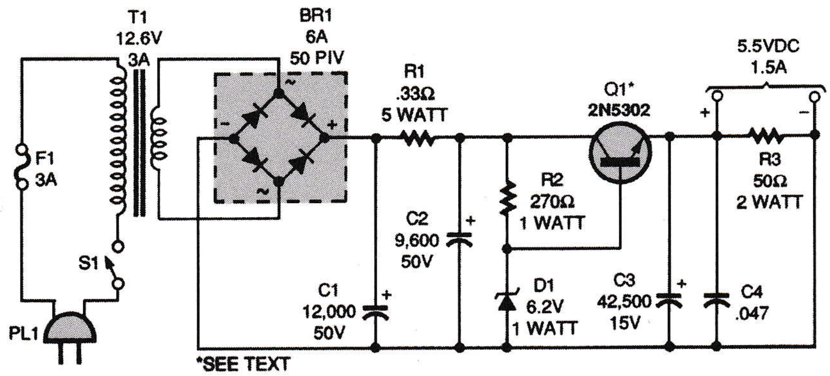
SMART AC POWER STRIP



POPULAR ELECTRONICS *Fig. 80-6*

The schematic of the Smart Strip circuit is shown. The ac line input is connected directly to the 117-Vac line of a power strip. The voltage is rectified by diode D1 and filtered by capacitor C2. The load-sense lines are connected to the ac socket in the power strip that will contain the device that will be used to turn the others on. When the load sense device is turned on, current flows through R1, a 1-Ω, 10-W resistor. To limit the power in R1 to 5 W, therefore, a maximum load of no more than 5 A should be connected to the load sense outlet. The resulting voltage drop across R1 is fed to one section of an LM358N op amp, IC1-a, through resistors R2 and R3. Zener diode D4 limits the supply for the op amp to 15 Vdc. The voltage drop across R1 could be very small if the device plugged into the load sense socket does not draw much current. To ensure that the circuit is sensitive enough to detect such small-load devices, the gain of IC1-a is set at 470 by resistors R2 and R4. Because the output IC1-a is halfway rectified, diode D2 and capacitor C3 are used to form a peak-hold circuit. As long as C3 is charged to 0.7 V or more (when a powered-up load sense device is detected), transistor Q1 will be on, and relay RY1 will close. When those normally open contacts close, the hot line is connected to the "load-switched" sockets, effectively turning on any devices that are connected to those outlets. Diode D1, resistor R6, and capacitor C1 provide a dc supply for the 12-V coil of the relay; diode D3 acts as a clamping diode.

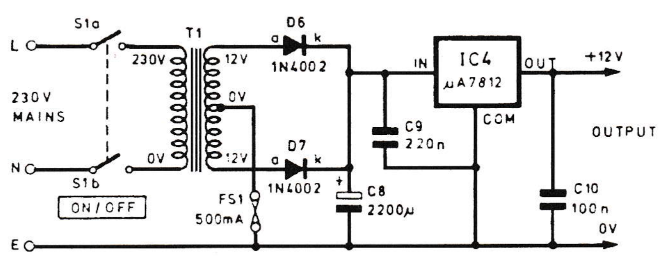
ANTIQUE RADIO POWER SUPPLY



POPULAR ELECTRONICS *Fig. 80-7*

This supply was intended for powering an antique radio using 01A triodes needing dc filament voltage. It is a straightforward zener regulator and pass transistor. The large values of capacitance used are for reducing 120-Hz hum to a minimum.

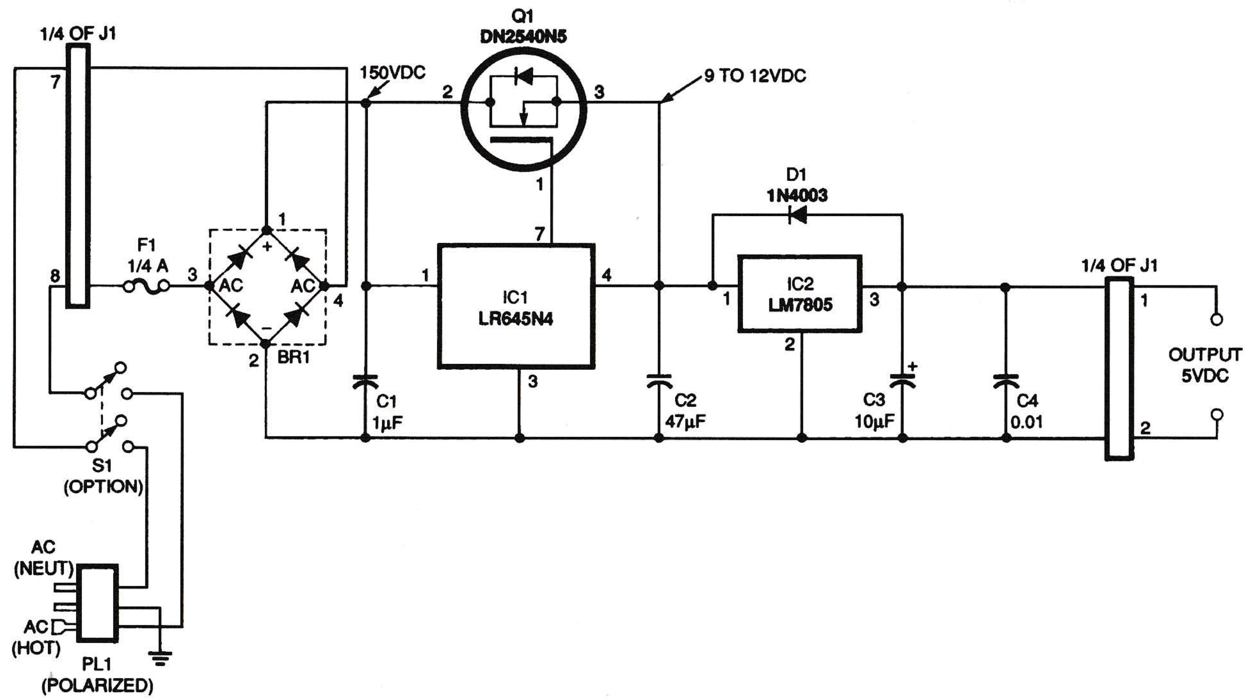
IR TRANSMITTER POWER SUPPLY



EVERYDAY PRACTICAL ELECTRONICS *Fig. 80-8*

This supply provides 12 Vdc for an IR transmitter or other circuit. The current is about 260 mA. A 120-V transformer can be substituted for the 230-V unit shown, if desired.

5-V OFF-LINE REGULATOR



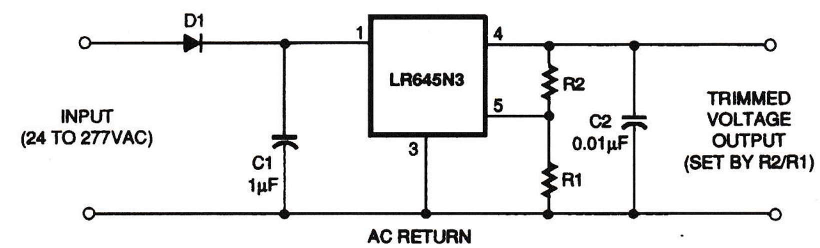
ELECTRONICS NOW

Fig. 80-9

This circuit produces 5 Vdc using an off-line regulator. An input from 12 to 120 Vac is applied to pins 7 and 8 of the eight-pin circuit-board-mounted header (J1). Although the LR645N4 (IC1) accepts voltages up to 450 V, the input of this circuit is limited by the 200 PIV (peak inverse voltage) rating of the bridge rectifier (BR1). The full-wave-rectified input is applied to the 1-μF filter capacitor (C1). The filtered 150 Vdc is applied directly to pin 1 of IC1. Filter capacitance is unusually low because IC1 has a ripple rejection ratio (V_{in}/V_{out}) of 60 dB at 120 Hz with no load. The filtered input dc is also applied to pin 2 of the N-channel, depletion-mode MOSFET Q1, made by Supertex. It was designed to be compatible with LR6 linear regulators. MOSFET Q1 conducts up to 100 mA from the high-voltage source through the gate control line of the IC1, thus bypassing it. The combined regulated voltage and current source from Q1 and IC1 is then filtered through capacitor C2 to stabilize the regulated output. The regulated output of IC1 is applied to the LM340 (7805) voltage regulator (IC2) that regulates the output voltage of the combination of IC1 and Q1 to a logic-compatible 5 Vdc. The total available current at the 5-Vdc output is 100 mA, more than adequate current for most logic circuitry. The 5-Vdc is also filtered by 10-μF tantalum capacitor C3 for additional circuit stability under full current load.

WARNING: There is no isolation between line and load, and a potentially dangerous shock hazard exists. Do not use this circuit if the potential for accidental contact exists with the circuit and any other person or device.

OFF-LINE REGULATOR



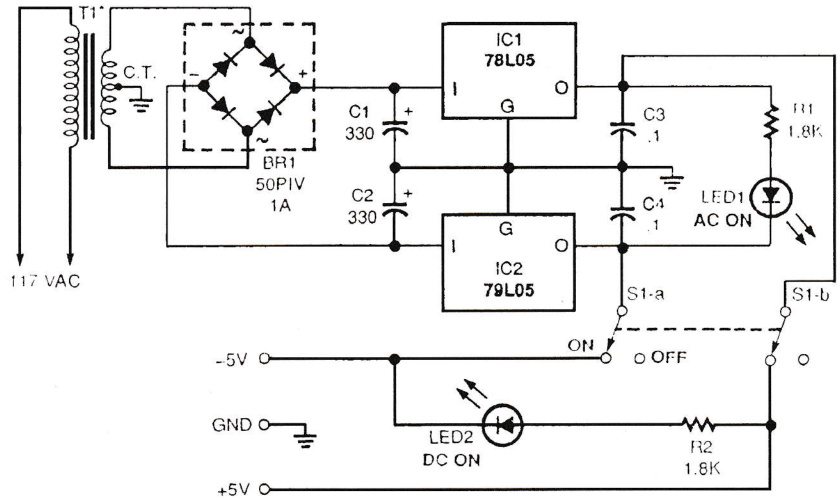
ELECTRONICS NOW

Fig. 80-10

This circuit produces 8 to 12 Vdc using an off-line regulator. The ratio of the resistors determines the output voltage. The best value for R_1 plus R_2 is 250 kΩ, although the data sheet allows values between 200 and 300 kΩ. The 250-kΩ value minimizes loading, permitting the circuit to provide more accurate output voltage.

WARNING: There is no isolation between line and load, and a potentially dangerous shock hazard exists. Do not use this circuit if the potential for accidental contact exists with the circuit and any other person or device.

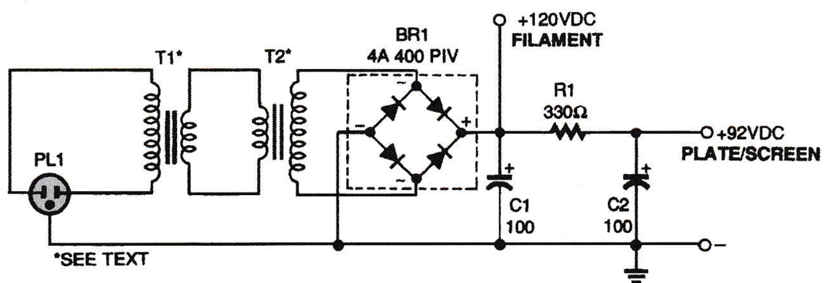
DUAL 5-V SUPPLY



POPULAR ELECTRONICS ***Fig. 80-11***

This is a circuit for a simple dual 5-V supply for experimental use. T1 is a 12-V center-tapped 0.3-A transformer.

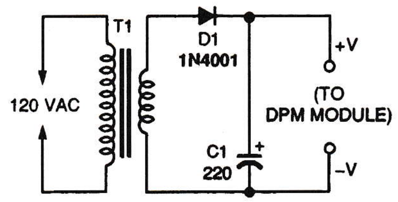
VACUUM-TUBE AUDIO-AMPLIFIER POWER SUPPLY



ELECTRONIC HOBBYISTS HANDBOOK ***Fig. 80-12***

A suitable power supply that provides isolation from the 120-Vac line is shown. The circuit uses two filament transformers connected back to back. The secondary voltages can be almost any value, as long as they are equal. A 1:1 isolation transformer can be substituted, if available. The transformers should be rated at least 25 VA or more.

SIMPLE DIGITAL-PANEL METER POWER SOURCE

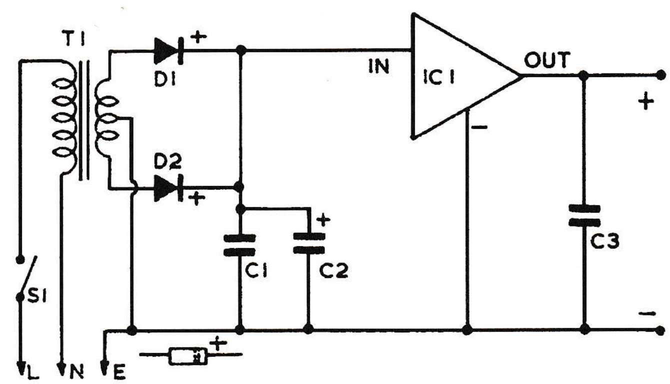


POPULAR ELECTRONICS

Fig. 80-13

This source will supply 9 to 12 Vdc with floating ground, needed by many digital panel meters.

5-V POWER SUPPLY

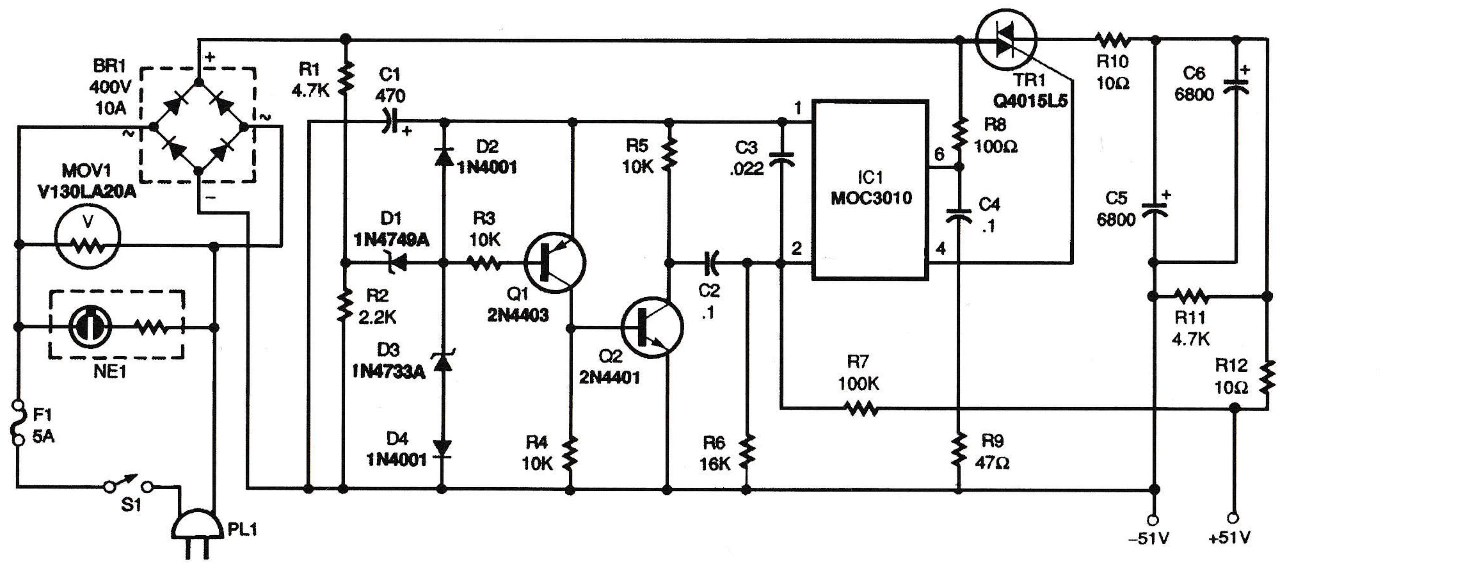


ELECTRONIC EXPERIMENTERS HANDBOOK

Fig. 80-14

The 5-V power supply shown here will provide voltage-regulated power for digital ICs needing up to 500 mA. With the 5-V power supply constructed as a separate unit, any circuit to be operated can be plugged in, and this allows it to provide power for various projects. It can also be used where a 5-Vdc, 500-mA supply is suitable, so it can, in some cases, be pressed into service where a 4.5- or 6-V battery would otherwise be fitted.

DUAL 51-V SWITCHING POWER SUPPLY

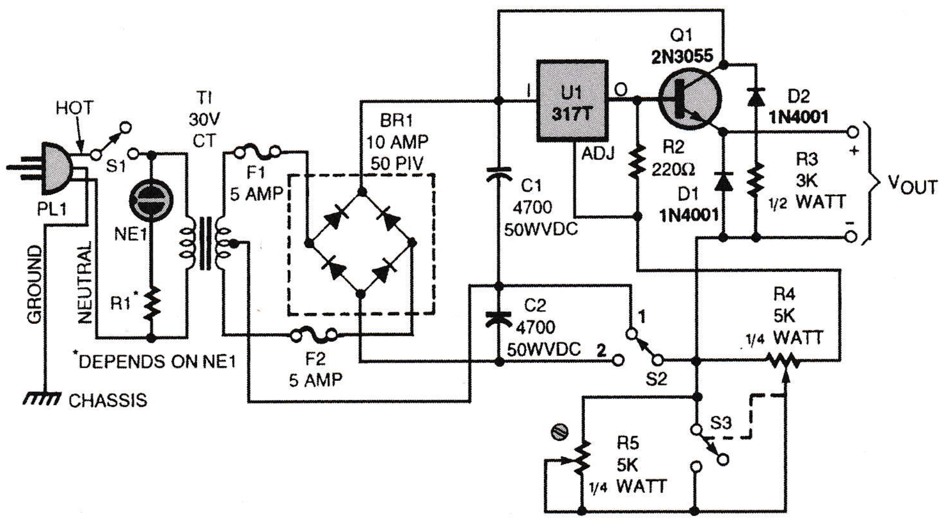


POPULAR ELECTRONICS

Fig. 80-15

The ac voltage taken from PL1 feeds into bridge rectifier BR1, which delivers a full-wave output of approximately 165 Vdc. The network composed of R1, R2, D1, D3, and D4 generates a series of 5-V pulses that perform two important functions: First, the pulses are used as a 5-V power source for the pulse shaping and monostable network through D2 and C1. Second, the pulses trigger optoisolator IC1 and power triac TR1 via the pulse-shaping network, composed of Q1, Q2, and R3 to R5, and the monostable circuit, made of C2 and R6. Resistor R2 sets the maximum pulse width and, therefore, the maximum output voltage. Without feedback, the unfiltered peak voltage is approximately 90 V. To obtain the required 51-V output, the feedback network (composed of R6, R7, and C3) reverse-biases the optoisolator whenever the output voltage exceeds 51 V. That, then forces TR1 to turn off as the unfiltered voltage goes to 0 V. The RC feedback network, therefore, regulates the output voltage by actively modifying IC1's conducting state. Resistor R8 limits the current through the optoisolator, and C4 and R9 ensure that the optoisolator's operation is stable and safe. Also, R10 limits surge current through TR1 when the supply is first turned on. Capacitors C5 and C6, along with R10, form a low-pass filter stage that minimizes ripple current. Resistor R11 discharges C5 and C6 when the power supply is turned off.

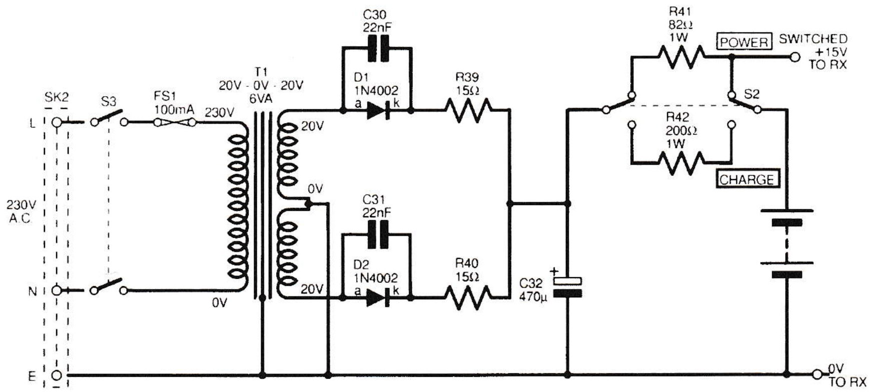
HIGH-CURRENT POWER SUPPLY



POPULAR ELECTRONICS ***Fig. 80-16***

This 10-A power supply uses a 24- to 30-V center-tapped power transformer that is capable of delivering 5 to 10 A. The voltage output is controlled by the circuit consisting of R4, R5, and S3; note that S3 is part of R4. For a fixed-voltage output, R4 should be set for zero ohms (fully counterclockwise). In that position, switch S3, will open. Trimmer potentiometer R5 should then be adjusted so that the circuit produces a 12-V output (or whatever output your application demands). For an adjustable output, R4 is turned clockwise, closing S3, and removing R5 from the circuit. The output voltage is then controlled by the resistance offered by R4 alone. When SPDT switch S2 is in position 1, the maximum output current is achieved, with both halves of T1 providing current to the filter section to double the overall current output. However, the maximum output voltage is halved in that position. That is a more efficient setting because the power transistor need not drop as large a voltage. In position 2, the maximum voltage almost equals the rating of T1. D1 and D2 are included in case power is turned off with an inductive load attached.

15-V RECEIVER POWER SUPPLY/CHARGER

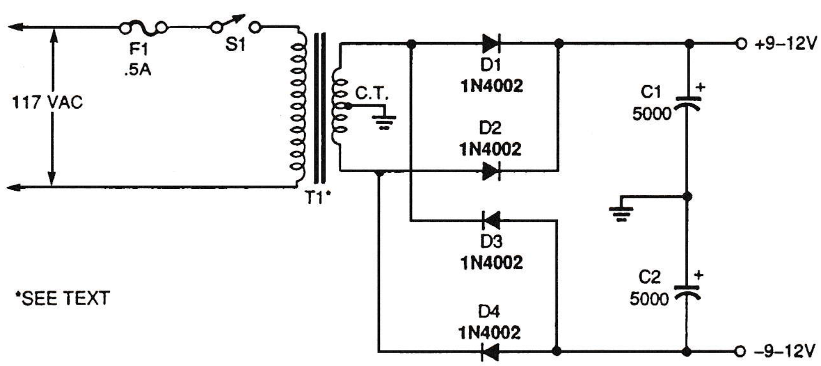


EVERYDAY PRACTICAL ELECTRONICS

Fig. 80-17

This power supply is for powering a receiver or similar load at 15 V, 100 mA. The NiCd battery pack is a 600-mAh AA cell assembly and is charged at 50 to 60 mA. A 120-V primary transformer with the same secondary voltage can be substituted for the 230-V unit shown.

SIMPLE DUAL-VOLTAGE POWER SUPPLY



POPULAR ELECTRONICS

Fig. 80-18

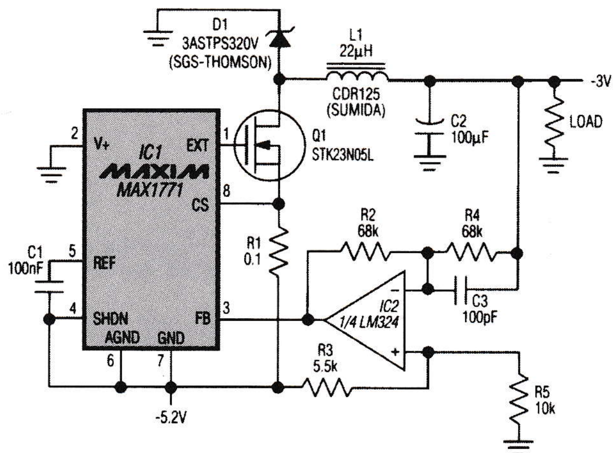
This circuit can be used to power op-amp circuits or other applications that require dual plus and minus supplies. This is a most basic circuit and is not regulated. T1 is a 120:12-V transformer of 100 mA (or more) capacity.

81

Power-Supply Circuits—Buck Converter

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.

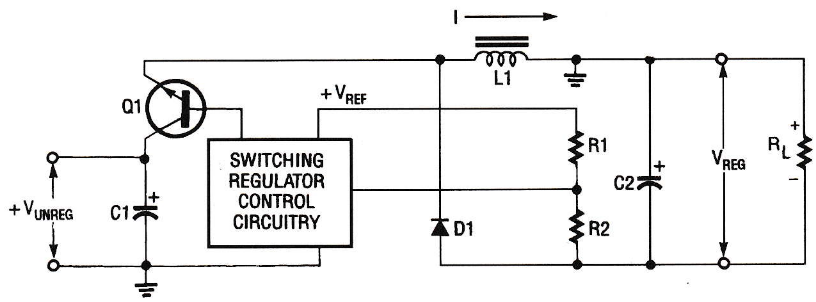
NEGATIVE BUCK REGULATOR



MAXIM *Fig. 81-1*

This circuit adopts a step-up (boost) dc-to-dc controller for use in a negative buck-regulator application. The supply voltage must be negative, and it must deliver 160 to 750 mA. Although the boost-regulator IC operates in a buck-regulator circuit, its standard connections enable proper control of Q1. The output voltage, however, must be inverted by an op amp for proper voltage feedback: The load is referred to the most positive supply rail instead of to IC1's ground terminal, so the controller must increase its duty cycle as V_{out} (referred to that terminal) increases. The op amp therefore inverts the feedback signal and shifts it to match the 1.5-V threshold internal to IC1. IC1 is configured in its nonbootstrapped mode, which provides an adequate gate-drive signal (ground to −5.2 V) for the external MOSFET (Q1). With V_{out} set to −3 V and the output current ranging from 160 mA to above 700 mA, the circuit's conversion efficiency ranges from 84 percent to as high as 87.5 percent.

BASIC BUCK CONVERTER CIRCUIT



ELECTRONICS NOW ***Fig. 81-2***

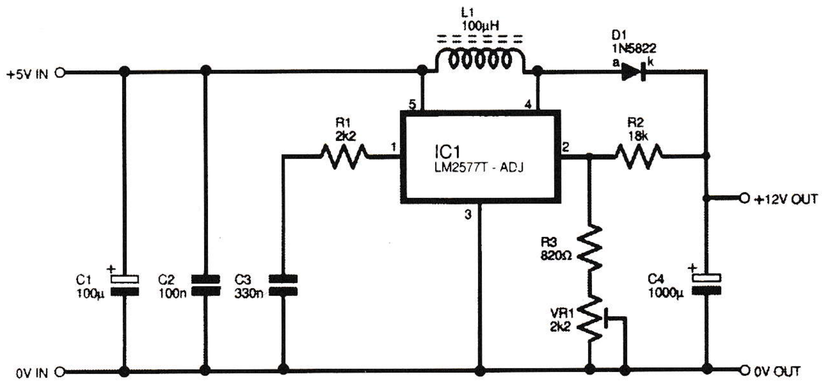
The buck regulator is an alternative single-transistor converter. Series transistor Q1 chops the input voltage and applies the pulse to an averaging inductive-capacitive filter, consisting of L1 and C1. The output voltage of this simple filter is lower than its input voltage.

82

Power-Supply Circuits—Dc-to-Dc

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.

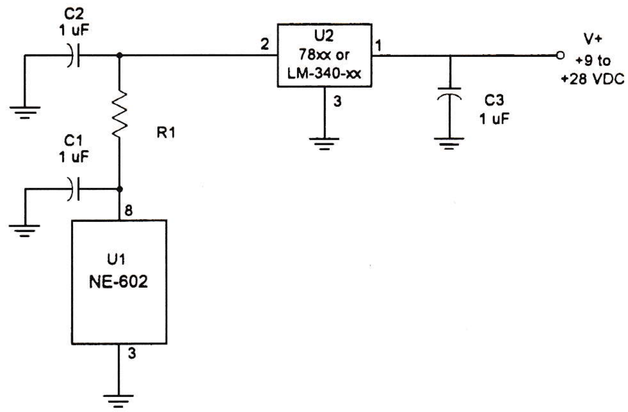
STEP-UP REGULATOR



EVERYDAY PRACTICAL ELECTRONICS ***Fig. 82-1***

Refer to the figure for the circuit diagram of the step-up regulator. This circuit is based on an LM2577T-ADJ, which is designed to give a combination of high performance and simplicity. It can provide output currents of up to 3 A, and it has both overcurrent and thermal-protection circuits built in. It requires a minimum input potential of 3.5 V, and it shuts down automatically if the input voltage is inadequate. The maximum input voltage is 40 V. Capacitors C1 and C2 provide supply decoupling at the input, and C3 and resistor R1 provide frequency compensation. Inductor L1, diode D1, and an internal switching transistor of IC1 form a standard step-up output stage, with output smoothing provided by capacitor C4. Resistors R2 and R3 and preset VR1 form a potential divider that controls the output voltage. IC1 has an internal 1.2-V reference generator, and the voltage at pin 2 is, therefore, stabilized at this figure. With the specified values in the potential divider circuit, the output voltage range is around 9.5 to 25 V.

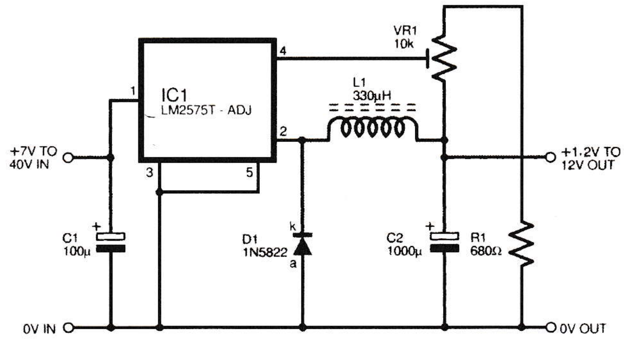
NE602 DC SUPPLY INTERFACE



73 AMATEUR RADIO TODAY ***Fig. 82-2***

This is one method of deriving the 4.5- to 8.0-Vdc supply needed by the NE602 chip.

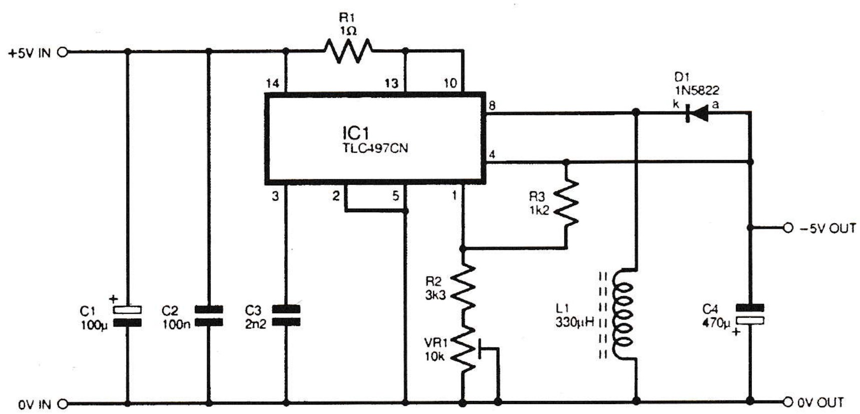
STEP-DOWN REGULATOR



EVERYDAY PRACTICAL ELECTRONICS ***Fig. 82-3***

There are several versions of the LM2575T. The device used here has an "ADJ" suffix, which indicates that it has an adjustable output voltage. Pin 4 connects to the inverting input of the internal error amplifier. This amplifier's noninverting input is fed from a 1.2-V reference source. A discrete potentiometer connected across the output and feeding into pin 4 enabling the output voltage to be set at any figure above 1.2 V. In this case, the potentiometer is formed by VR1 in series with resistor R1. The adjustment range provided by VR1 is from 1.2 V to a little over 16 V. Higher output voltages can be accommodated by making R1 lower in value, but a circuit of this type is mainly used where there is a large voltage difference between the input and the output. Consequently, it is unlikely to be used with output voltages of more than about 16 V. The absolute maximum input voltage is 40 V.

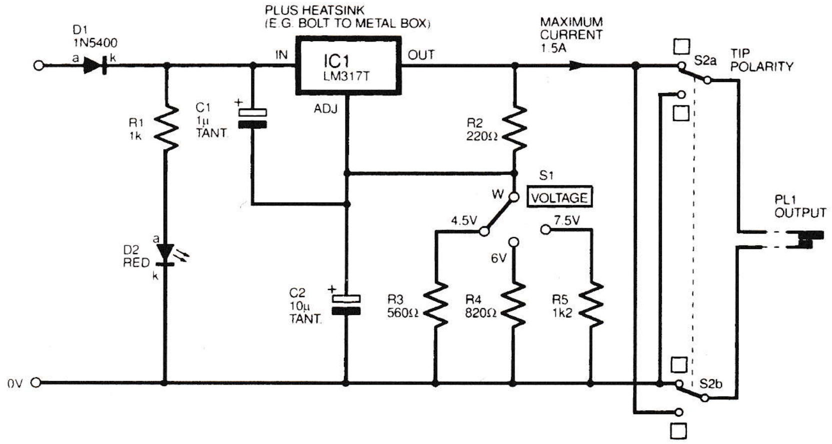
NEGATIVE SUPPLY GENERATOR



EVERYDAY PRACTICAL ELECTRONICS ***Fig. 82-4***

The TLC497CN is very useful for applications that do not involve high output currents. It provides a cost-effective means of providing a negative supply of up to about 150 mA. A circuit diagram for an inverter based on this device is shown. The efficiency of the circuit is typically a little over 50 percent with an input potential of 10 V, but is significantly under 50 percent with an input supply of 5 V. Capacitors C1 and C2 are supply-decoupling components on the input supply. Resistor R1 is the series resistance in the current-limiting circuit at the input to IC1. This is an essential safety feature because the circuit will often be fed from a high-current supply that could almost instantly "fry" IC1 in the event of an overload on the device's output. Capacitor C3 is the timing component in the oscillator section of the PWM. The TLC497CN uses a fixed pulse width and a variable clock frequency to control the average output voltage.

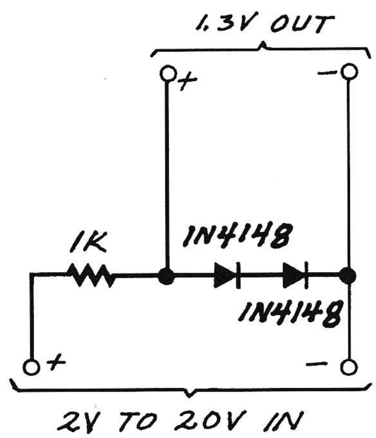
MINI POWER SOURCE



EVERYDAY PRACTICAL ELECTRONICS ***Fig. 82-5***

The figure shows a unit capable of offering different voltages to operate low-voltage appliances from a 12-V battery. Regulators of the LM317 type are current-limiting, short-circuit-proof, and overheat-proof, although they are still not indestructible. This circuit will provide up to 1.5 A. IC1 should be heatsinked, perhaps by bolting it with an insulating kit to a metal box.

1.3-V SUPPLY

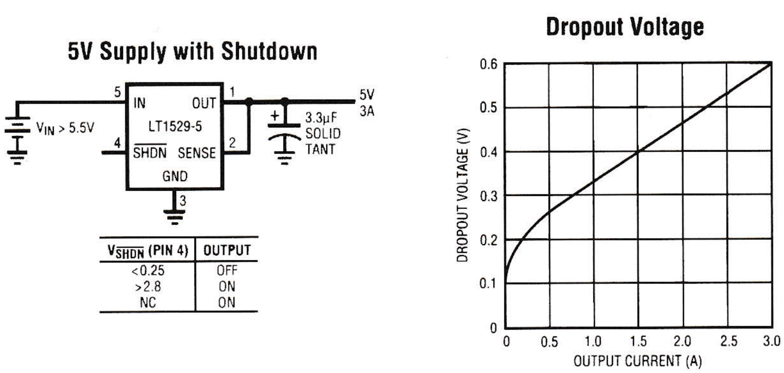


This is a simple 1.3-V regulator to power the ZN414 IC.

ELECTRONICS NOW

Fig. 82-6

3-A LOW-DROPOUT REGULATOR WITH 50-μA QUIESCENT CURRENT

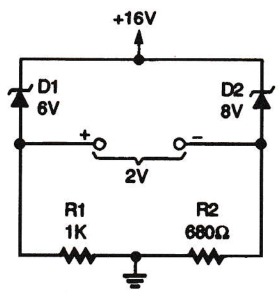


LINEAR TECHNOLOGY

Fig. 82-7

The LT1529 is a 3-A, 0.6-V dropout regulator with 50-μA no-load quiescent current and only 16 μA I_Q in shutdown. This makes the LT1529 useful for battery-powered applications where both long battery life and high-load current surges are expected. At 1.5-A load current, dropout voltage is just 0.43 V. The LT1529 needs no external diodes to protect against reverse battery or reverse output current faults. This allows the LT1529 to be used for backup power situations in which the output is held high while the input is at ground or reversed.

2-V REFERENCE

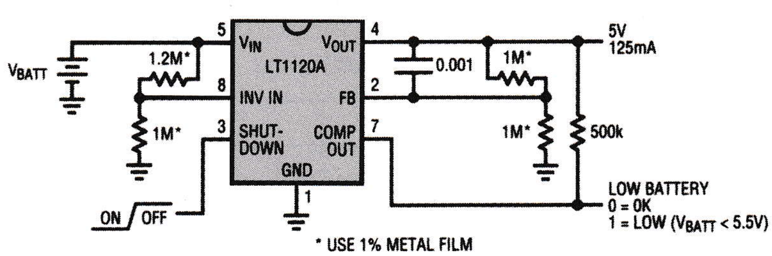


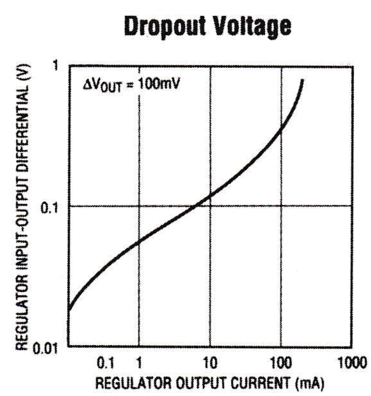
POPULAR ELECTRONICS

Fig. 82-8

Zener diodes that operate below the 3- or 4-V level do not perform as well as higher-voltage zeners, and are not normally used for low-voltage references. The 2-V reference uses two higher-voltage zeners, D1 and D2, to obtain a stable operating reference voltage. Any possible voltage changes from temperature variations are almost completely canceled out with the two-zener circuit, making it a more accurate reference source than a circuit with a single zener. Other low-reference-voltage sources can be created by substituting different-valued zeners for D1 and D2.

20-μA QUIESCENT CURRENT REGULATOR



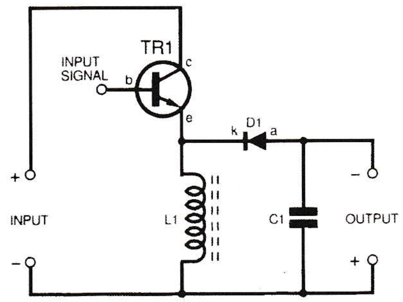


LINEAR TECHNOLOGY

Fig. 82-9

Knowing when the battery voltage is getting low allows equipment to arrange time to save valuable information. The LT1120A not only provides micropower, low-dropout regulation, but also includes a low-battery detection comparator, all in an eight-lead DIP or SO package. The LT1120A supplies up to 125 mA at regulated voltages from 2.5 to 20 V. The low dropout voltage of 0.6 V (max.) lowers the battery input voltage requirements, and the small 40-μA (max.) quiescent current extends battery life. The LT1120A has yet more functions. The logic-compatible SHUTDOWN pin removes power to the load. The precision 2.5-V reference has the ability to both sink and source current to supply low-power backup circuits. Also, the LT1120A's design prevents excessive current draw when in dropout.

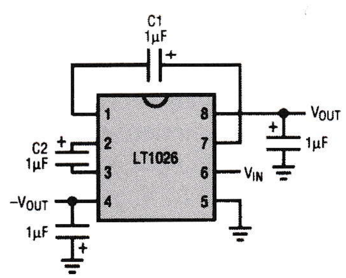
INVERTER OUTPUT STAGE OF A DC-TO-DC CONVERTER

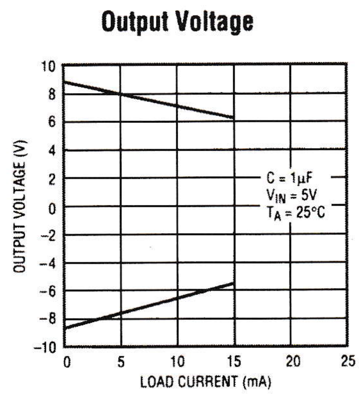


EVERYDAY PRACTICAL ELECTRONICS *Fig. 82-10*

This figure shows the circuit diagram for an inverter output stage.

INDUCTORLESS BIPOLAR SUPPLY GENERATOR

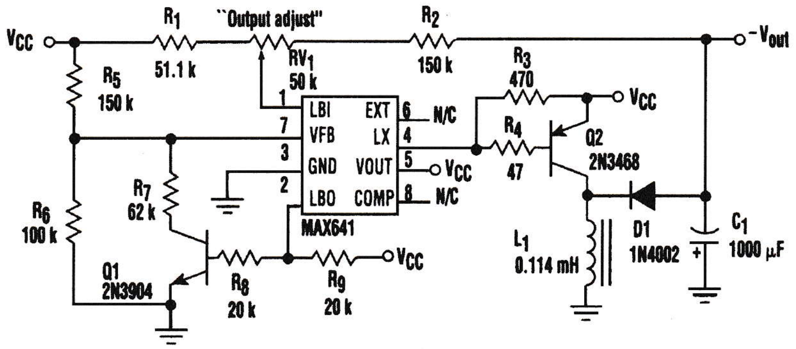




LINEAR TECHNOLOGY *Fig. 82-11*

Localized generation of bipolar supply rails is useful in many op-amp, data-conversion, and interface applications. To avoid the design time and effort of putting together a switching regulator circuit, switched-capacitor conversion should be considered as a simple, effective alternative. The LT1026 is shown here in a useful application circuit that can generate rail voltages of both polarities from a 5-V logic supply. Output voltage will vary with load (as shown on the graph), from ±9 V at minimal load currents to ±6 V at a load current of 15 mA. These boosted rails can be used to extend common-mode input and output ranges of circuits without doing level shifting, ac coupling, or signal clipping. Because the LT1026 is supplied in an eight-lead SO package, the entire circuit can be surface-mounted using tantalum or ceramic capacitors.

STEP-UP SWITCHING IC/INVERTER

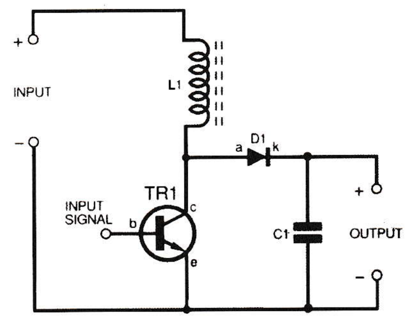


ELECTRONIC DESIGN

Fig. 82-12

A popular step-up switching IC can be made to supply a negative voltage. The MAX641BCPA is a boost converter intended for use with 3-V batteries. To get the 641 to function as an inverter, some of its pin functions must be altered. Pin 1 is used as the voltage-feedback input, and pin 2 is used as the overvoltage-detector output. When the voltage on pin 1 falls below +1.31 V, pin 2 becomes a low-impedance path to ground. This will force Q1 to cut off and allow the voltage on pin 7 to rise. When the voltage on pin 7 exceeds +1.31 V, the internal oscillator shuts off. At this point, the output voltage is equal to or less than the set level. When C1 discharges to a point where the voltage on pin 1 rises above +1.31 V, pin 2 will change to a high impedance, allowing Q1 to saturate and pull pin 7 below +1.31 V. This causes the internal oscillator to turn on. Pin 4, the output of the internal oscillator, will pump C1 negative while the oscillator is running. For the values shown in the figure, the adjustable output voltage range is approximately −4 to −13 V. The magnitude of the drivable load depends on how much ripple can be tolerated. The values shown will easily drive a 50- to-75-mA load and provide good regulation.

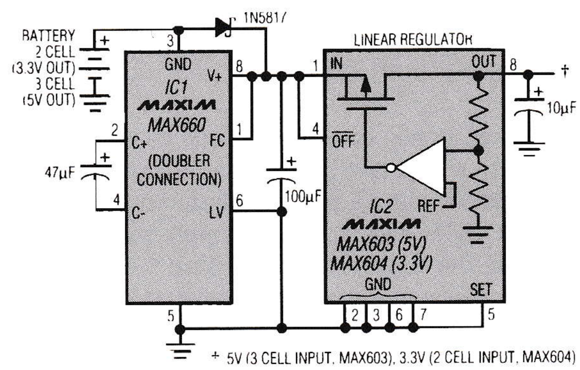
BASIC STEP-UP OUTPUT STAGE OF A DC-TO-DC CONVERTER



EVERYDAY PRACTICAL ELECTRONICS ***Fig. 82-13***

This figure shows the basic circuit configuration for a step-up output stage.

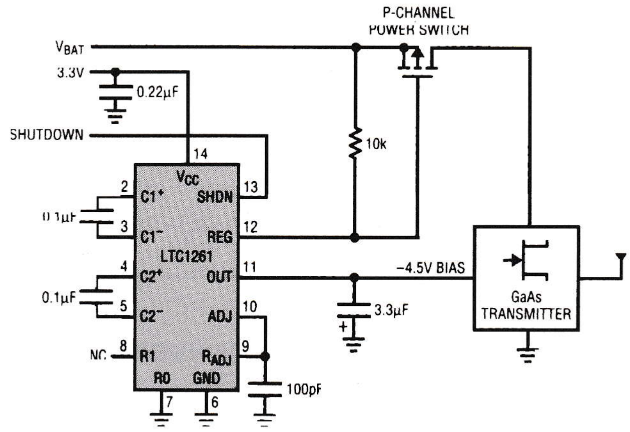
CHARGE PUMP BOOST CONVERTER



MAXIM ***Fig. 82-14***

The circuit overcomes the charge pump's lack of regulation by adding a regulator externally. Another option—if load currents are modest—is to add regulation on the chip. Regulation in a monolithic chip is generally accomplished either as linear regulation or as charge-pump modulation. Linear regulation offers lower output noise; therefore, provides better performance in (for example) a GaAsFET-bias circuit for RF amplifiers. Charge-pump modulation (which controls the switch resistance) offers more output current for a given die size (or cost) because the IC need not include a series pass transistor.

GaAsFET BIAS SUPPLY

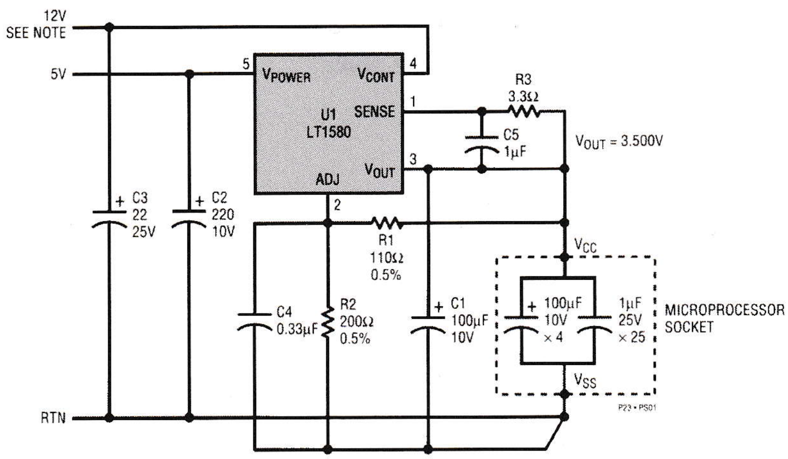


LINEAR TECHNOLOGY

Fig. 82-15

Cellular telephones and other mobile communications gear use depletion-mode GaAsFET RF output transistors, which require a negative bias voltage for proper operation. This LTC1261 circuit generates a regulated negative voltage using no inductors, and will give plenty of drive for GaAsFET bias circuits. The LTC1261CS8 inverts the supply voltage (5 V to −4.5 V), whereas the LTC1261CS can invert or double the supply voltage (3 V to −4 or −5 V). Both parts regulate the generated output voltage. The quiescent current is just 600 μA, and the shutdown current is only 5 μA. The combination of high oscillator frequency, which reduces the switched capacitor size, and the variety of fixed-output regulated negative voltages allows for a minimum-space power supply. The LTC1261 comparator output controls a P-channel MOSFET to ensure that the drain current for the GaAsFET is switched off until the regulated negative output voltage is valid. This ensures that the gate voltage is sufficient to keep the GaAsFET off during power-up, preventing unsaturated operation and excessive operation.

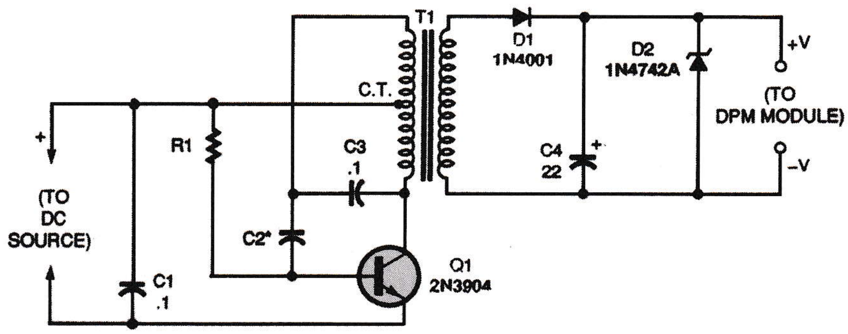
3.5-V 7-A LINEAR REGULATOR SUPPLY



LINEAR TECHNOLOGY **Fig. 82-16**

The LT1580 linear regulator circuit shown achieves ±2 percent dc output-voltage accuracy at up to 7 A load current. This circuit restricts the output-voltage transients because of 200-mA to 4-A load-current steps to 65 mV p-p. The LT1580 has a separate remote sense input that maintains the dc voltage at the load accurately, independent of the load current. Output-voltage variation over the full load-current range, known as *load regulation,* with remote sense connected (R_3=0 Ω) is very close to ±0 percent. The LT1580 transient response to 3.8-A-load current steps is 88.7 mV p-p (R_3=0 Ω). Resistor R3 is added to intentionally introduce some dc load regulation. The feedback resistors are chosen to set the no-load output voltage slightly higher than 3.5 V. At 4-A load current, the output voltage is regulated slightly below 3.5 V.

DC-TO-DC CONVERTER FOR DIGITAL PANEL METERS

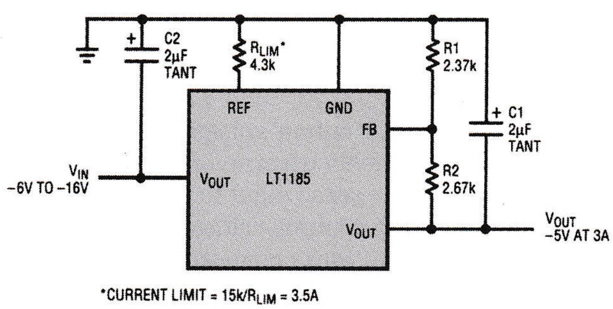


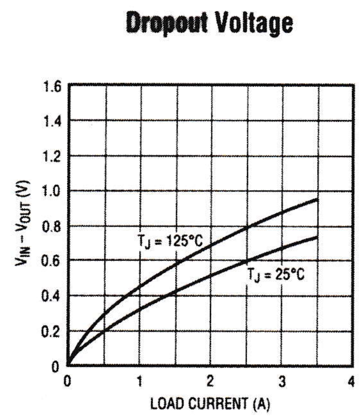
POPULAR ELECTRONICS

Fig. 82-17

Often a digital panel meter is used in an application where the meter is on the hot side of a circuit. This supply will provide the 9- to 12-Vdc floating supply for the meter.

NEGATIVE REGULATOR



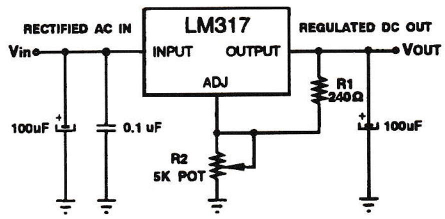


LINEAR TECHNOLOGY

Fig. 82-18

Regulating negative voltages with minimal dropout is now possible with the LT1185 universal voltage regulator. It supplies up to 3 A of output current with a dropout voltage guaranteed to be less than 1.2 V. The five-lead TO-220 package includes a pin that allows accurate current-limit adjustment for lower-current applications. Although aimed primarily at negative regulation applications, the LT1185 works equally well as a floating positive regulator. Output voltage is programmable from 2.3 to 30 V.

LM317 CIRCUIT

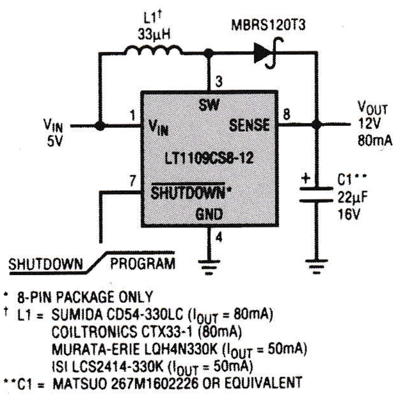


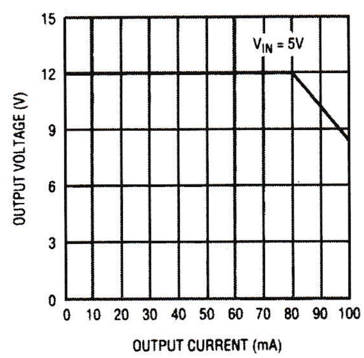
NUTS AND VOLTS

Fig. 82-19

The figure shows a typical simplified wiring diagram. Note that the output voltage is determined by resistors R1 and R2 (the value of R2 is recommended to be around 240 Ω). The regulated output voltage is given by the formula $V_{out}=1.25\ (1+R_2/R_1)$.

FLASH MEMORY V_{PP} GENERATOR



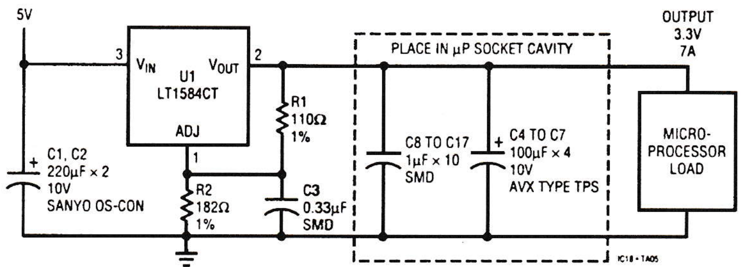


LINEAR TECHNOLOGY

Fig. 82-20

Generating 12 V for flash memory programming is a common requirement in portable systems and PCMIA cards. The LT1109-12 dc-to-dc converter simplifies this task and uses only 0.75 in^2 of PC board space. The LT1109-12 is offered in an eight-lead SO package and requires only three other surface-mount components to construct a complete 12-V V_{PP} generator. At 12 V, 60 mA of programming current is produced, enough for simultaneous programming of two flash memories. The circuit draws 320 μA (max.) of standby current while shut down and provides a clean transition from 5 to 12 V at its output with no overshoot.

3.3-V 7-A SUPPLY



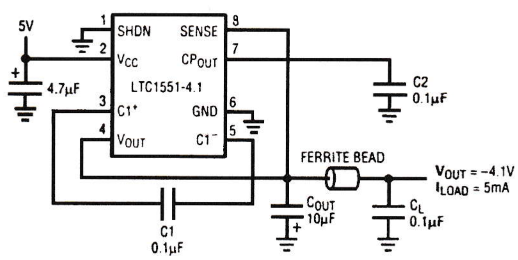
LINEAR TECHNOLOGY

Fig. 82-21

Many microprocessor systems use 3.3-V microprocessors, cache RAM, and chip sets. This system configuration increases the current requirements of the 3.3-V supply. In addition, many of these microprocessors have a stop-clock feature for power savings, which introduces a load-current step to the power supply. Adjustable regulators are recommended for microprocessors that have power-saving (stop-clock) modes. The circuit shown has good transient response to load steps for most 3.3-V microprocessors. An external capacitor at the ADJUST pin can reduce the total filter capacitance required by one half to take care of large load transients.

GaAsFET BIAS SUPPLY

−4.1V Generator with 1mV$_{P-P}$ Noise

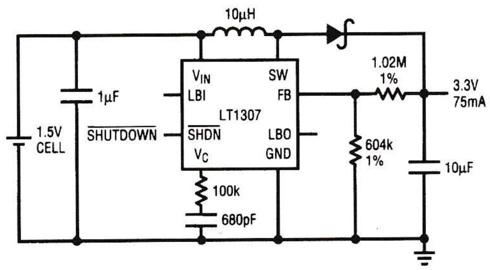


LINEAR TECHNOLOGY

Fig. 82-22

The LTC1550 and LTC1551CS8-4.1 are switched-capacitor voltage inverters that generate a regulated −4.1-V output at up to 20-mA load current. An internal linear postregulator reduces the output-voltage ripple to less than 1 mV, making the LTC1550 and LTC1551CS8-4.1 excellent for use as bias-voltage generators for transmitter GaAsFETs in portable RF and cellular telephone applications. The single supply voltage can range from 4.5 to 6.5 V (7 V absolute maximum). The charge pump uses four small external capacitors and operates at 900 kHz, eliminating interference with the 400- to 600-kHz IF signals commonly used in RF systems.

1-V 600-kHz SWITCHING SUPPLY

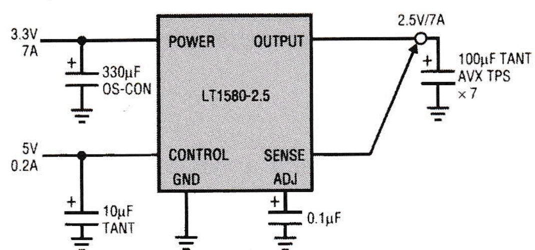


LINEAR TECHNOLOGY

Fig. 82-23

The LT1307 chip will produce 5 V at 40 mA or 3.3 V at 75 mA from a single AA-cell power source. It operates at 600 kHz and uses 60-μA standby current, and it has a low-battery detector.

7-A 2.5-V SUPPLY

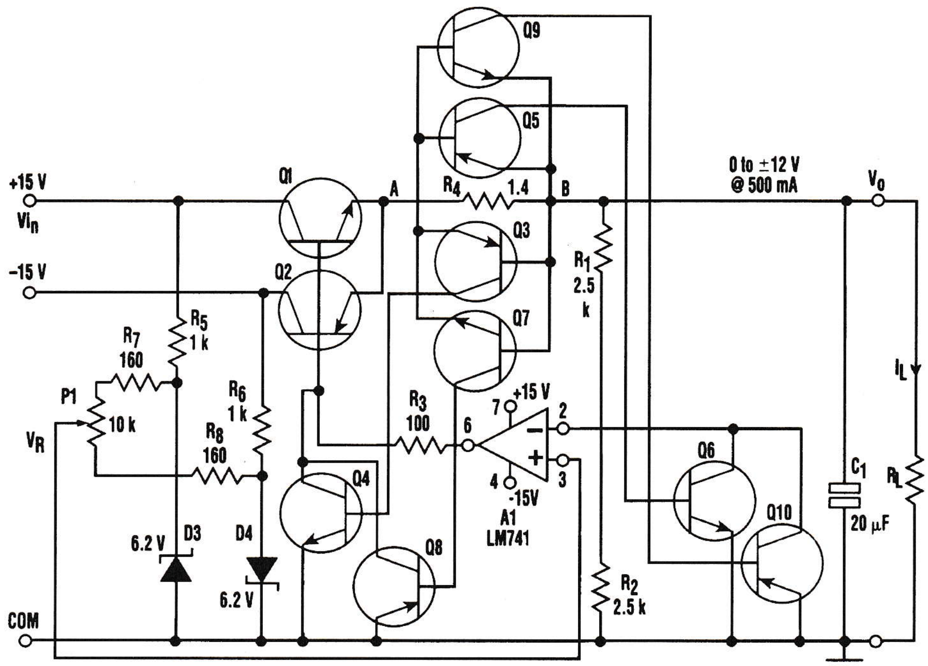


LINEAR TECHNOLOGY

Fig. 82-24

The latest microprocessors use low-voltage processes that allow the clock frequencies to increase dramatically. Increased clock frequencies result in higher core-supply currents. Several next-generation microprocessors will use a 2.5-V supply voltage and require greater than 5-A supply current. The LT1580-2.5 in the circuit shown has the lowest dropout of any 7-A linear regulator, only 0.6 V typical. This allows conversion from a standard 3.3-V main supply down to 2.5 V. In order to achieve this low dropout performance, a second low-current control supply 1.3 V greater than the 2.5 V output is needed. A system 5-V supply conveniently provides this voltage, and only 200 mA is required from the control supply. The LT1580-2.5 also has fast transient response to load-current steps, minimizing required bulk output capacitance. An internal reference voltage with ±0.5 percent initial tolerance and Kelvin sense input make the output regulation very tight.

VOLTAGE REGULATOR SINKS AND SOURCES



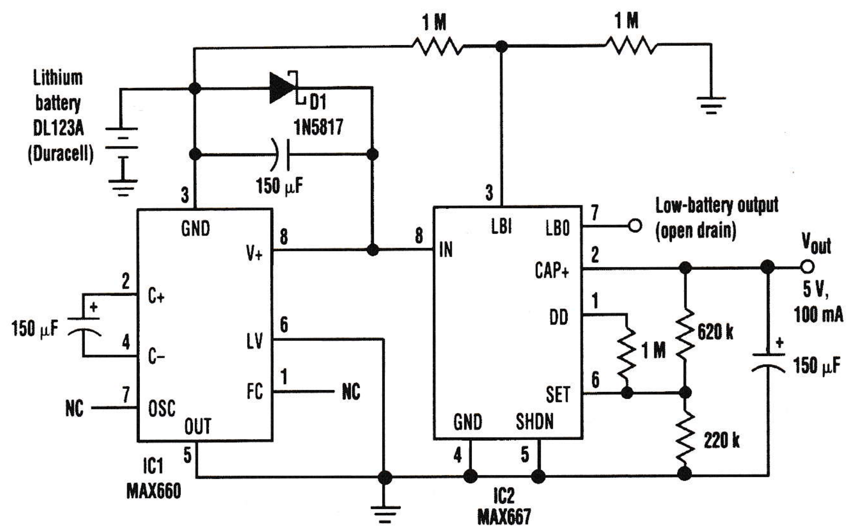
Q1 = 2N3055 Q2 = 2N2955 Q3, Q5, Q8, Q10 = 2N2907 Q4, Q6, Q7, Q9 = 2N2222 D3, D4 = 1N753

ELECTRONIC DESIGN ***Fig. 82-25***

It is possible to build a circuit that provides a variable output from −12 to +12 V (passing smoothly through 0 V) that can source or sink at any voltage. The basic regulator consists of an op amp (A1), series pass transistors Q1 and Q2, a reference voltage from P1, and a voltage divider (R1 and R2). The rest of the elements provide short-circuit protection for the regulator. The reference voltage is generated by zener diodes D3 and D4. With a 10-turn potentiometer (P1), the reference voltage (V_R) for the op amp can be varied from −6 to +6 V. The output voltage is given by $V_O = V_R(1 + R_1/R_2)$. Because $R_1 = R_2$, the output can be varied from 0 to ±12 V. When V_O is positive and the regulator is sourcing current (I_L positive), the base of Q1 is at V_O + 0.7m and Q1 is conducting. When V_O is positive and R_L is terminated in a supply voltage higher than V_O, the regulator is forced to sink current (I_L negative). At this time, Q2 conducts and sinks the current, and A1 maintains the base of Q2 at V_O − 0.7. Similar arguments apply when the output voltage is negative. C1, a nonpolarized electrolytic capacitor, prevents oscillations. R4 is a current-sensing resistor for short-circuit protection and limits the output current to 55 mA. For a positive V_O, if I_L is positive (sourcing) and reaches 500 mA, the voltage drop V_{AB} across R4 approaches 0.7 V and forward-biases the E-B junction of Q3. Q3 conducts and drives the base of Q4. Because Q4 goes into saturation as a result of the drop across R3, it clamps the base voltage of Q1 to ground and the output voltage drops, limiting the current in

Q1 to 500 mA. Similarly, under a positive V_O, if I_L is negative (sinking) and reaches 500 mA, V_{AB} across R4 approaches −0.7 V and forward-biases the E-B junction of Q5. Q5 drives Q6 into saturation, and the inverting input of the op amp is clamped to ground. Because the noninverting input is held at V_R (which is still positive), the output starts climbing toward +15 V. This prevents Q2 from sinking more current than 500 mA. Under a negative V_O, with I_L negative, Q7 and Q8 provide short-circuit protection. With V_O negative and I_L positive, Q9 and Q10 provide short-circuit protection.

EFFICIENT REGULATED STEP-UP CONVERTER



ELECTRONIC DESIGN *Fig. 82-26*

Two eight-pin ICs form a regulator circuit that can convert a lithium battery's 3-V output to 5 V and deliver load currents as high as 100 mA. It operates without inductors or transformers, and draws only 200 µA of quiescent current. At V_{in} = 3 V, it offers 81-percent efficiency with a 100-mA load and 84 percent with a 20-mA load. Efficiency will increase as V_{in} falls. For example, at V_{in} = 2.7 V (the cell's loaded output for most of its operating life), efficiency for a 40-mA load current is 90 percent. Voltage from the lithium battery (a 2/3-A size Duracell DS123A) is doubled by the high-current charge pump (IC1). The Schottky diode (D1) is included to assure startup in this configuration. D1 won't affect efficiency because it doesn't conduct load current during normal operation. IC2 is a linear regulator with a dropout voltage of only 40 mV at I_{load} = 40 mA. This load, allowed to drain the battery until V_{out} = 4.5 V, yields a battery life of 16 hours. Reducing the load to 20 mA extends the battery life to 36 hours.

LT1580 CIRCUIT

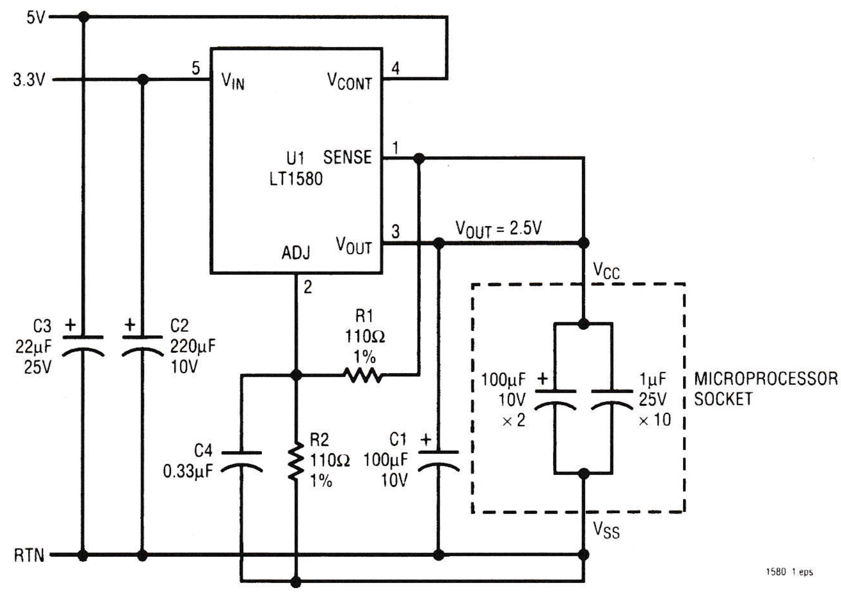


Figure 1. LT1580 Delivers 2.5V from 3.3V at Up to 6A

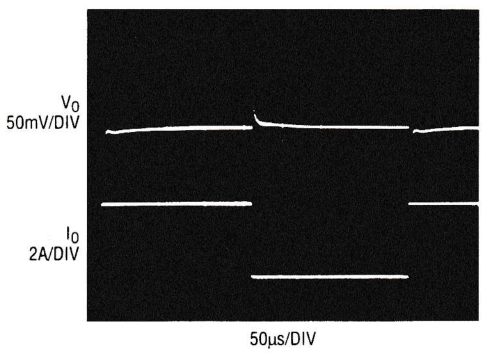


Figure 2. Transient Response of Figure 1's Circuit with Adjust-Pin Bypass Capacitor. Load Step Is from 200mA to 4 Amps

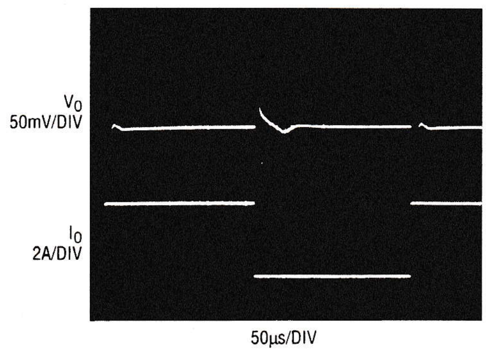


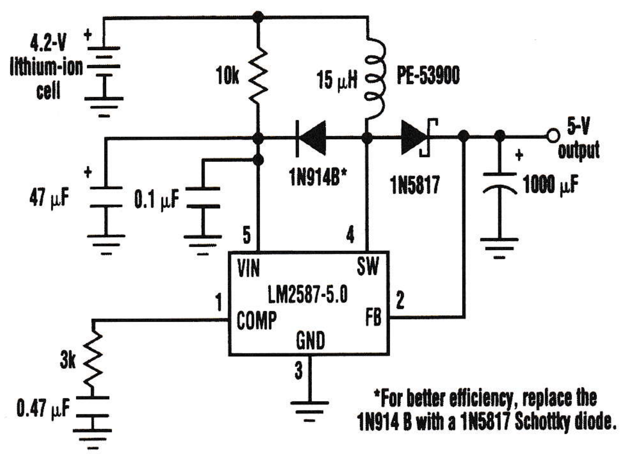
Figure 3. Transient Response Without Adjust-Pin Bypass Capacitor. Otherwise, Conditions Are the Same as in Figure 2

LINEAR TECHNOLOGY

Fig. 82-27

Figure 1 shows a circuit designed to deliver 2.5 V from a 3.3-V source with 5 V available for the control voltage. Figure 2 shows the response to a load step of 200 mA to 4.0 A. The circuit is configured with a 0.33-μF ADJUST-pin bypass capacitor. The performance without this capacitor is shown in Fig. 3. The difference in performance is the reason for providing the ADJUST pin on the fixed-voltage devices. A substantial savings in expensive output decoupling capacitance can be realized by adding a small ceramic capacitor at this pin.

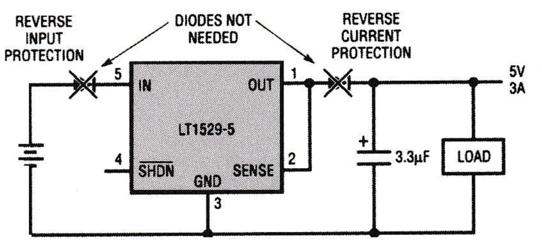
ONE-CELL CONVERTER



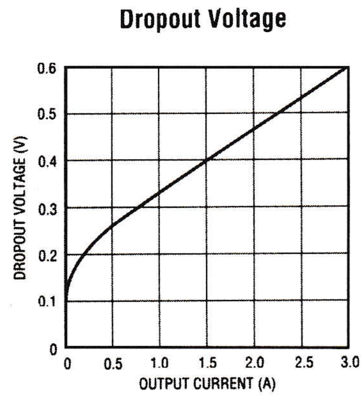
ELECTRONIC DESIGN *Fig. 82-28*

The regulator generates a 5-V output from a single lithium-ion cell. Initially, the lithium-ion cell is at 4.2 V, which is greater than the 3.75-V undervoltage-lockout (UVL) limit of the LM2587 Simple Switcher. Once it starts up, the boost circuit will continue to regulate—even when the battery voltage drops lower than the UVL limit. The level that the input voltage can drop to depends on the maximum load current desired. Of course, the source can be any type of battery—three alkaline, four NiCd, or even two lithium batteries. When power is applied to the circuit, the 10-kΩ resistor charges up the 47-μF input capacitor and supplies the startup current to the LM2587. After startup, the LM2587 input and the input capacitor draw current from the switch node through the 1N914B bootstrap diode. When that happens, the IC input pin gets charged up to the output voltage minus a diode drop. In the circuit, with a 5-V output, the IC input voltage is 4.5 V after startup. It stays at 4.5 V—even when the input voltage drops to below 3.75 V. The input voltage can drop to 1.25 V when the regulator is supplying 250 mA. At 2.4 V, the regulator is 84 percent efficient if the 1N914B bootstrap diode is replaced with a 1N5817 Schottky diode.

5-V MICROPOWER LINEAR REGULATOR



$V_{\overline{SHDN}}$ (PIN 4)	OUTPUT
<0.25	OFF
>2.80	ON
NC	ON



LINEAR TECHNOLOGY

Fig. 82-29

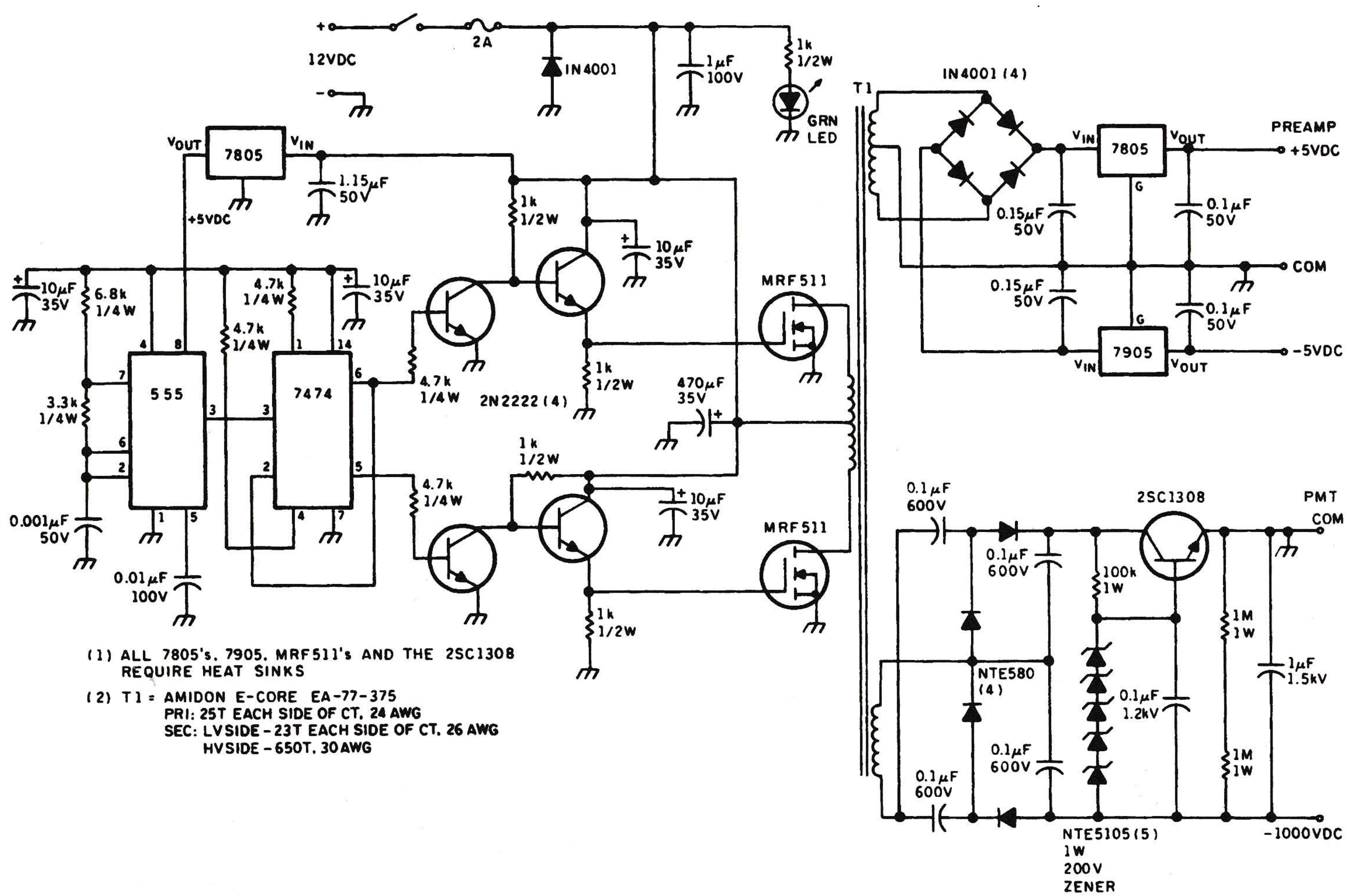
In battery systems where high load current is required intermittently and the system must remain in standby mode between uses, a linear regulator with micropower quiescent current and shutdown capability is needed. These situations arise in powering laptop disk drives, portable radio transmission modems, and peripheral motors, which are intermittently used. The LT1529 has 3 A current capability, 50 μA quiescent current, and just 16 μA shutdown current. As shown in the circuit and chart, the LT1529-5 is a low-component-count solution with a very low dropout voltage of 0.6 V at 3-A output current. This low dropout is ideal for battery-powered systems in which extracting the maximum energy from the battery is important. In dropout, the output voltage will decrease smoothly, following the input. The quiescent current of the LT1529 increases only slightly in dropout, unlike the situation with many other low-dropout PNP regulators.

83

Power-Supply Circuits—High Voltage

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.

LASER RECEIVER PHOTOMULTIPLIER TUBE SUPPLY



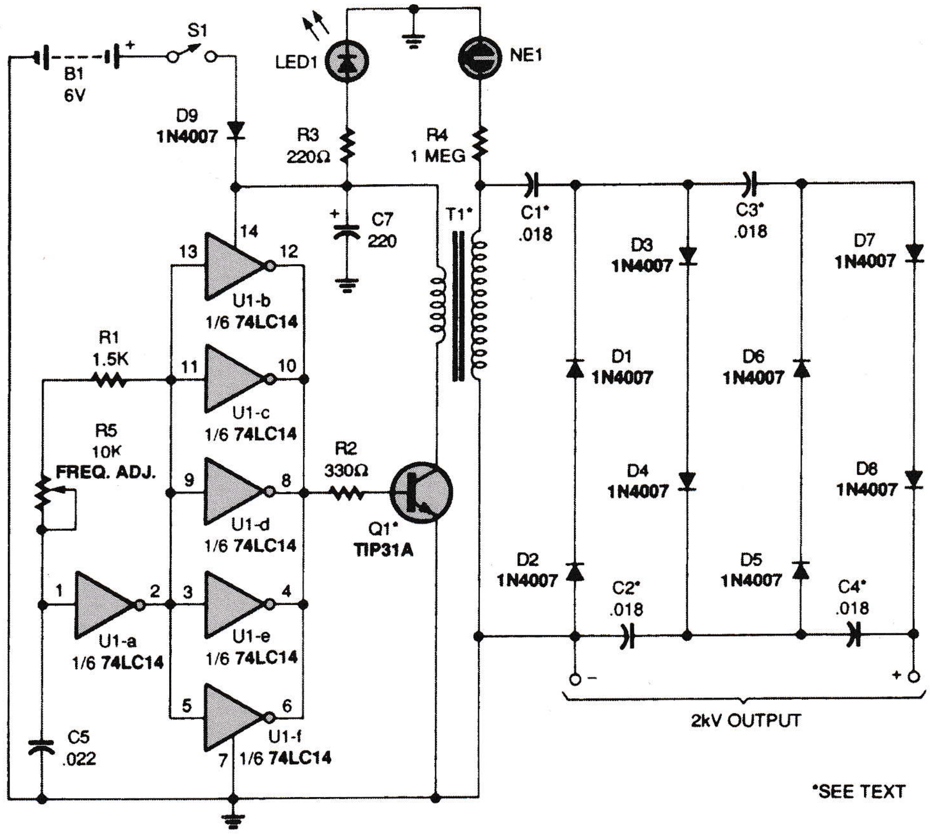
(1) ALL 7805's, 7905, MRF511's AND THE 2SC1308 REQUIRE HEAT SINKS

(2) T1 = AMIDON E-CORE EA-77-375
PRI: 25T EACH SIDE OF CT, 24 AWG
SEC: LVSIDE - 23T EACH SIDE OF CT, 26 AWG
HVSIDE - 650T, 30 AWG

Fig. 83-1

The figure shows the circuit diagram of a regulated 1000-Vdc power supply driven from a 12-Vdc source. A low-voltage secondary regulated power source supplying power to the PMT video preamplifier is included. Again, follow the caution regarding PMT power supplies. All precautions must be observed when working with the PMT high-voltage supply.

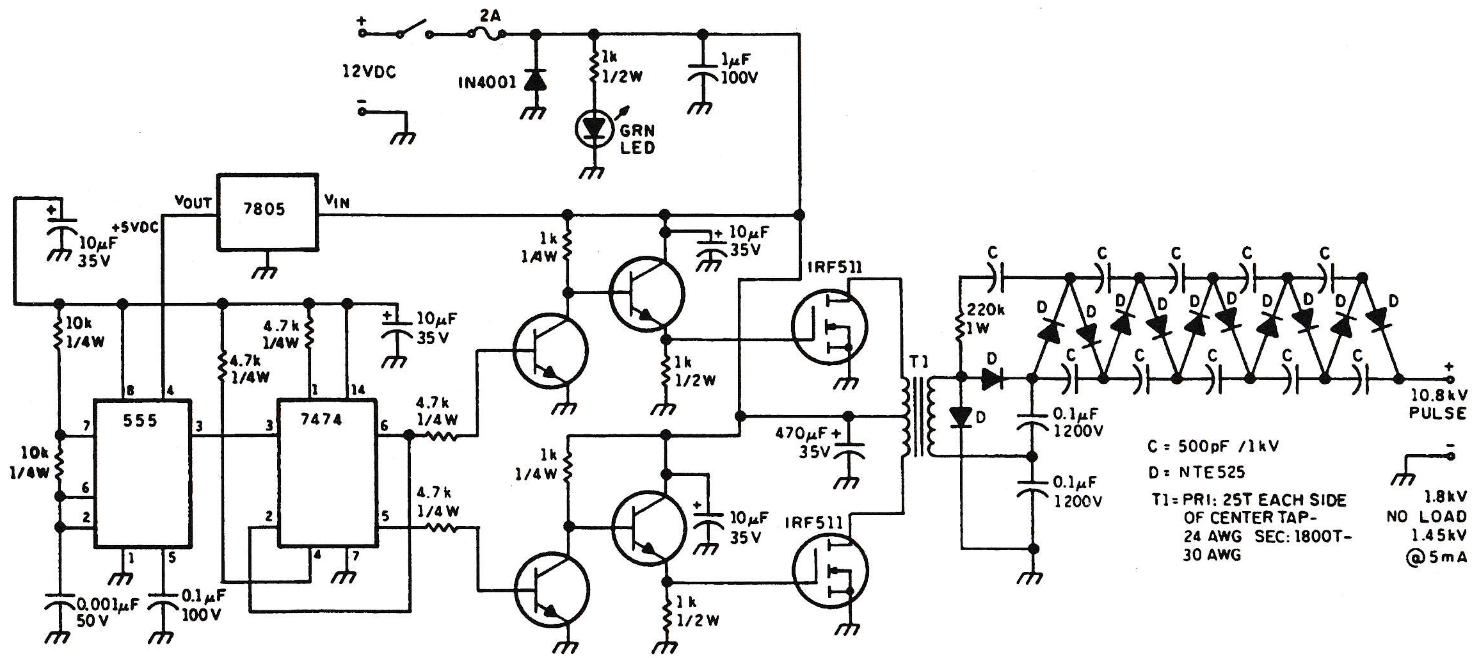
HIGH-VOLTAGE POWER SUPPLY



POPULAR ELECTRONICS *Fig. 83-2*

This circuit uses a transformer to generate a high-voltage output (up to 20,000 V) from just four C cells. T1 can be a 50 to 100:1 turns ratio unit or can be made from a flyback transformer from a junked B/W TV.

HELIUM-NEON LASER SUPPLY WITH HV MULTIPLIER IGNITION

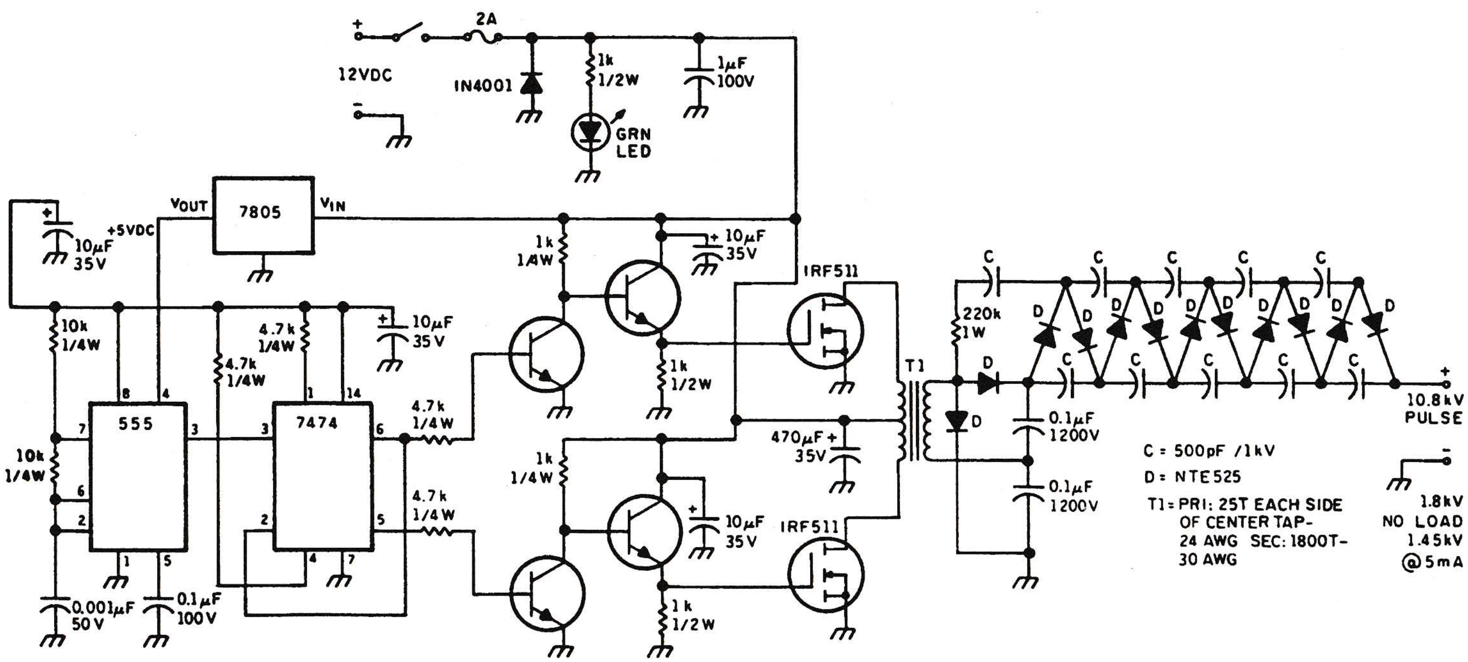


COMMUNICATIONS QUARTERLY

Fig. 83-3

This figure illustrates a way in which a momentary 10-kV voltage pulse can be generated to initiate the plasma discharge across the laser tube. A Diode voltage-multiplier circuit is connected in series with the main supply and obtains its input power across one of the voltage-multiplier diodes in the main supply. The voltage across this diode is typically 1.8 kV p-p. With a ten-section multiplier, the output voltage is approximately 9 kV in series with a 1.8-kV sustaining supply. The capacitance value of the capacitors in the multiplier chain is much smaller than that of the capacitors for the main supply. When the power supply is first turned on, the capacitors in the voltage multiplier charge up to the ignition voltage. As the plasma forms, the laser tube draws more current and the multiplier capacitors cannot maintain their charge. As a result, the voltage immediately drops to that of the main sustaining supply, with all the diodes in the multiplier chain forward-biased. In this manner, an HV pulse is generated to ionize the gases.

HELIUM-NEON LASER SUPPLY WITH HV MULTIPLIER IGNITION



COMMUNICATIONS QUARTERLY

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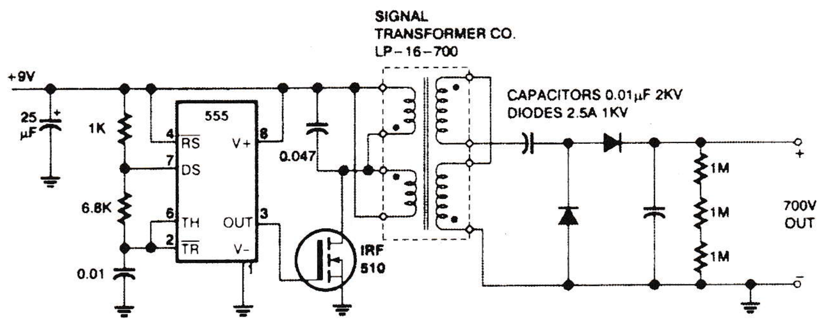
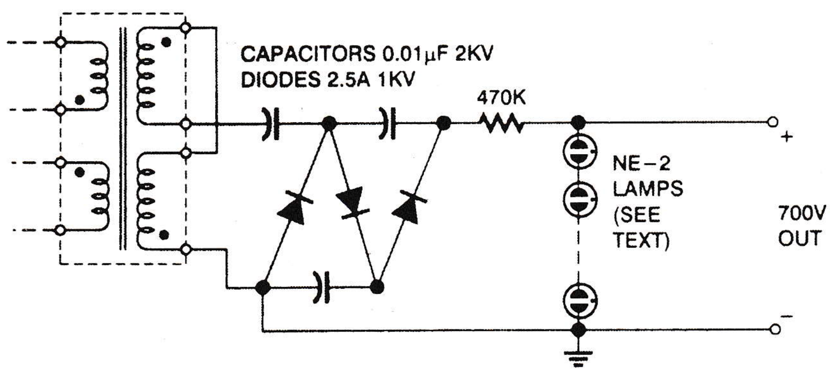
GEIGER COUNTER 700-V LOW-CURRENT SUPPLY



ELECTRONICS NOW *Fig. 83-4*

This 700-V, 0.25-mA power supply converts a +9-Vdc input to 10-kHz ac, then uses the setup transformer and the voltage-doubler circuit to produce the required output.

REGULATOR FOR 700-V LOW-CURRENT SUPPLY



ELECTRONICS NOW *Fig. 83-5*

If you need a regulated output, change the voltage doubler to a tripler, and use neon lamps as a regulator. The number of lamps you will need will depend on the characteristics of the lamps used, and will have to be found by experimentation. Each lamp has approximately a 55- to 70-V the breakdown voltage. The lamps should be shielded from light (or painted black) because light can influence the breakdown voltage.

HELIUM-NEON LASER POWER SUPPLY WITH HV PULSE IGNITION

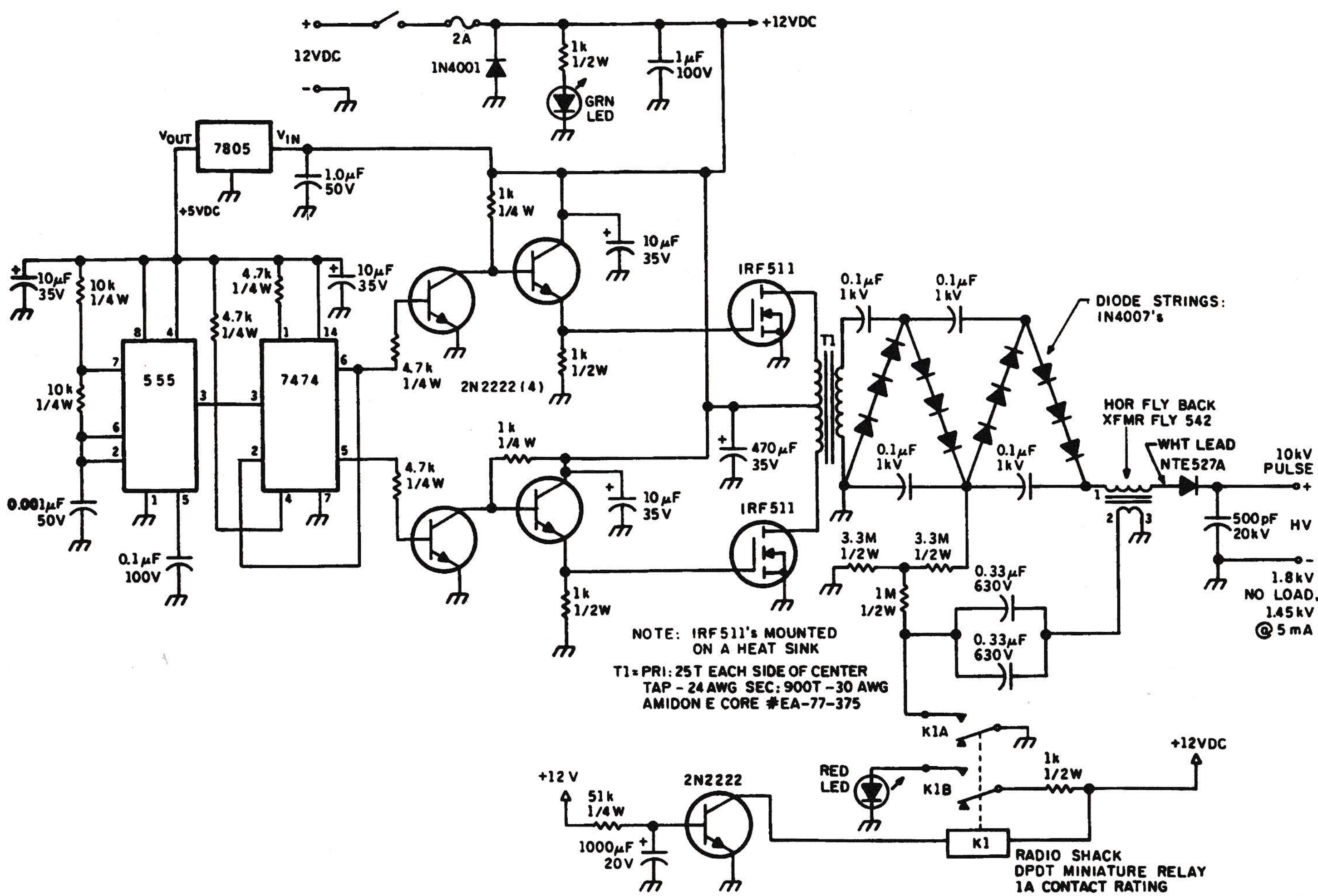
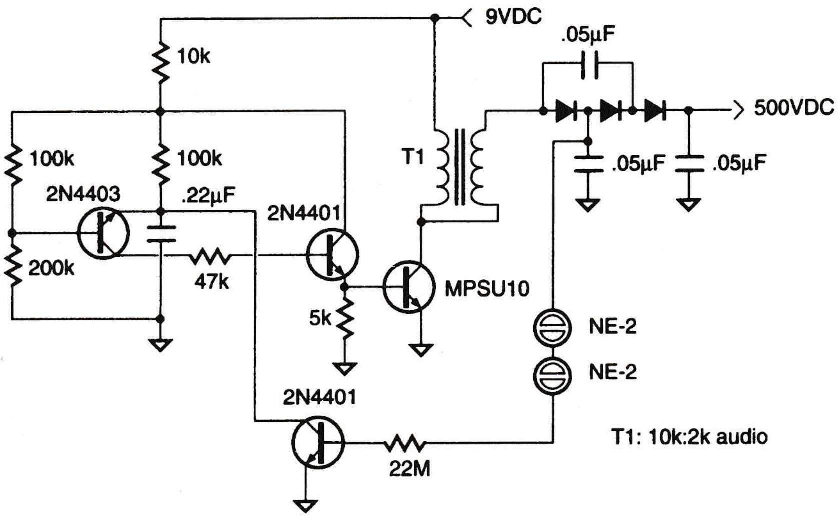


Fig. 83-6

The helium-neon laser requires two voltages: a voltage in the range of 10 kV that starts the laser and then turns off once the discharge begins, and a lower-voltage power supply to sustain the discharge. The circuit diagram illustrates one method of generating the laser ignition voltage. A fraction of the main supply voltage is used to charge up a capacitor. When triggered, it is discharged through a high-voltage ignition transformer in series with the main power supply output. When the supply is first turned on, a delay circuit allows the main supply to stabilize at full voltage and charge up the capacitor. A nonlatching relay operates to discharge the capacitor into the ignition coil on a one-shot basis after the timing delay. The HV diode in series with the ignition coil and the capacitor across the supply rectifies the damped oscillatory waveform out of the ignition coil, producing a single positive pulse across the laser tube to ionize the gas in the laser. Once the laser is ignited by the HV pulse, the main power supply maintains the discharge.

PHOTOMULTIPLIER TUBE SUPPLY

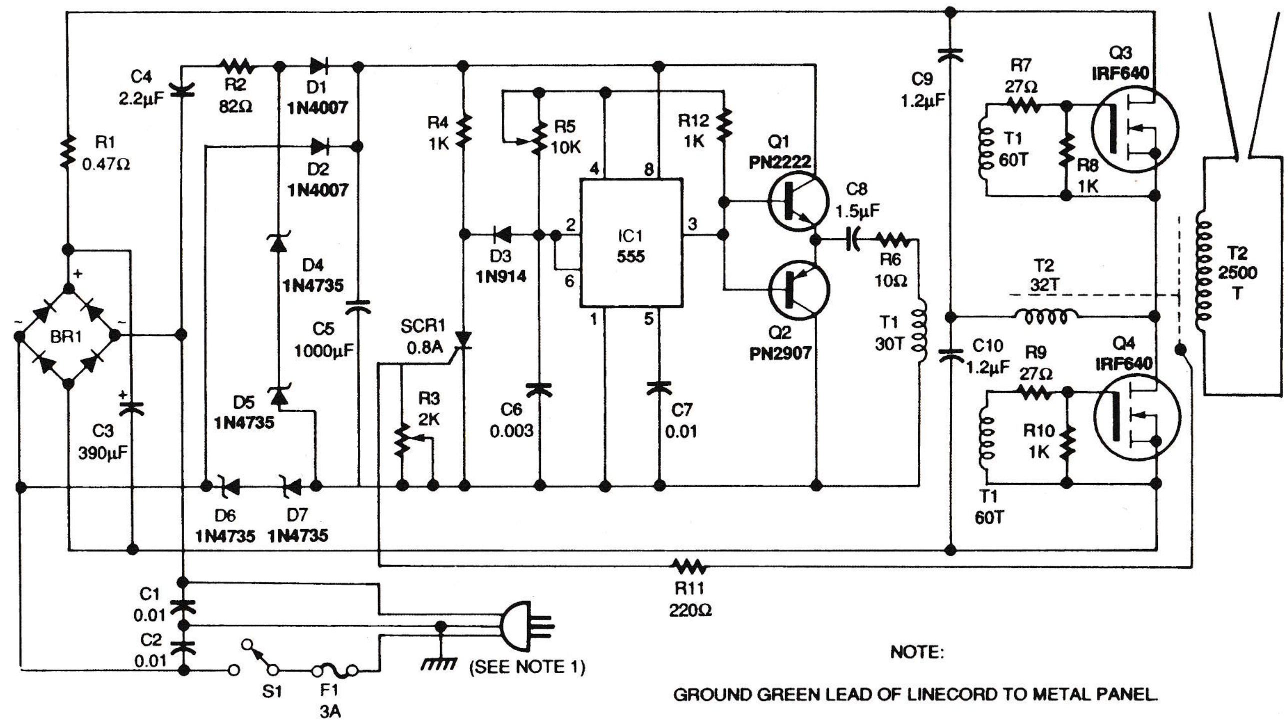


NUTS AND VOLTS

Fig. 83-7

This circuit is quite efficient, drawing virtually no current when the load is a photomultiplier (PM) used as a scintillation detector. Be sure that the voltage-divider resistors on the PM tube are very high to conserve power—the higher the better. If the high-voltage circuit uses a diode voltage-multiplier chain, then connect the chain to the transformer, just as the three-diode doubler is connected. Lower the regulated voltage by removing one of the neons or by selecting an appropriate zener. If a higher voltage is needed, simply extend the diode multiplier.

JACOBS LADDER HV SUPPLY



ELECTRONICS NOW

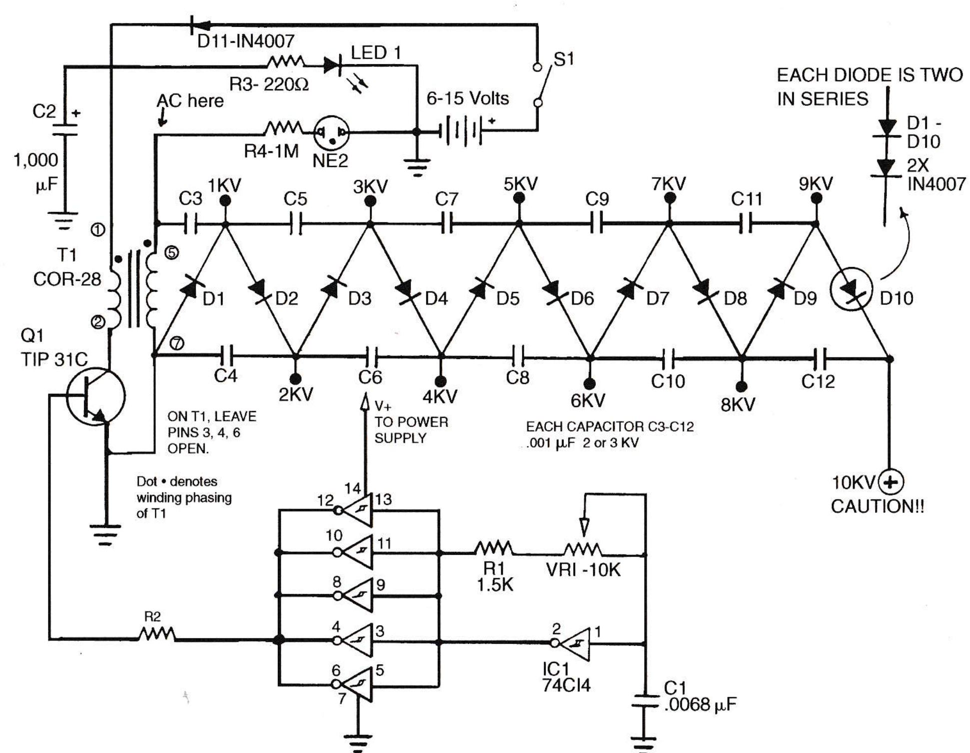
Fig. 83-8

The operation of the Jacobs's Ladder depends on the current-limited power supply that delivers 12,000 V at 40 mA from the 120-Vac line. The full-wave bridge BR1 rectifies the 120-Vac line input, and resistor R1 limits the dc charging current of capacitor C3 to a safe value. The drive circuit power is obtained by dropping the 120-Vac line through capacitor C4 and current-limiting resistor R2. Capacitor C4 and resistor R2 present a complex impedance, so most of the ac line voltage is dropped across the reactance. The 555 timer IC is configured as a square-wave oscillator. The output frequency of its square waves is determined by the setting of trimmer potentiometer R5 and capacitor C6. The frequency is about 25 kHz for the values of R5 and C6 shown.

JACOBS LADDER HV SUPPLY *(Cont.)*

Potentiometer R5 can be used to adjust the circuit's power output. Increasing the frequency reduces the circuit's output by increasing the inductive reactance of the transformer leakage inductance. The output of IC1 on output pin 3 appears at the bases of the current "source," NPN transistor Q1, and "sink," PNP transistor Q2. The emitters of this transistor pair are ac-coupled through capacitor C8 and resistor R6 to drive the primary of driver-isolation transformer T1. This drive prevents dc from flowing through the primary. Transformer T1 is wound on a high-permeability core with as few turns as possible to eliminate leakage inductance. The gate circuits of MOSFETs Q3 and Q4 contain 27-Ω resistors (R7 and R9) to slow their switching times. This eliminates possible parasitic oscillations that could occur if the MOSFETs were switched at their speed limit. The primary of output transformer T2 contains 32 turns, but its secondary contains 2500 turns. The ratio of these turns is approximately 1 to 78. When this is multiplied by the rectified line voltage of 160 Vdc, an output of about 12,000 peak volts is obtained across the secondary. This 12,000-V output is the peak open-circuit voltage of the system, and it produces a short-circuit current of approximately 40 mA. This current is limited by the leakage inductance caused by the loose magnetic coupling between the primary and secondary circuits of transformer T2.

HV POWER SUPPLY



NUTS AND VOLTS

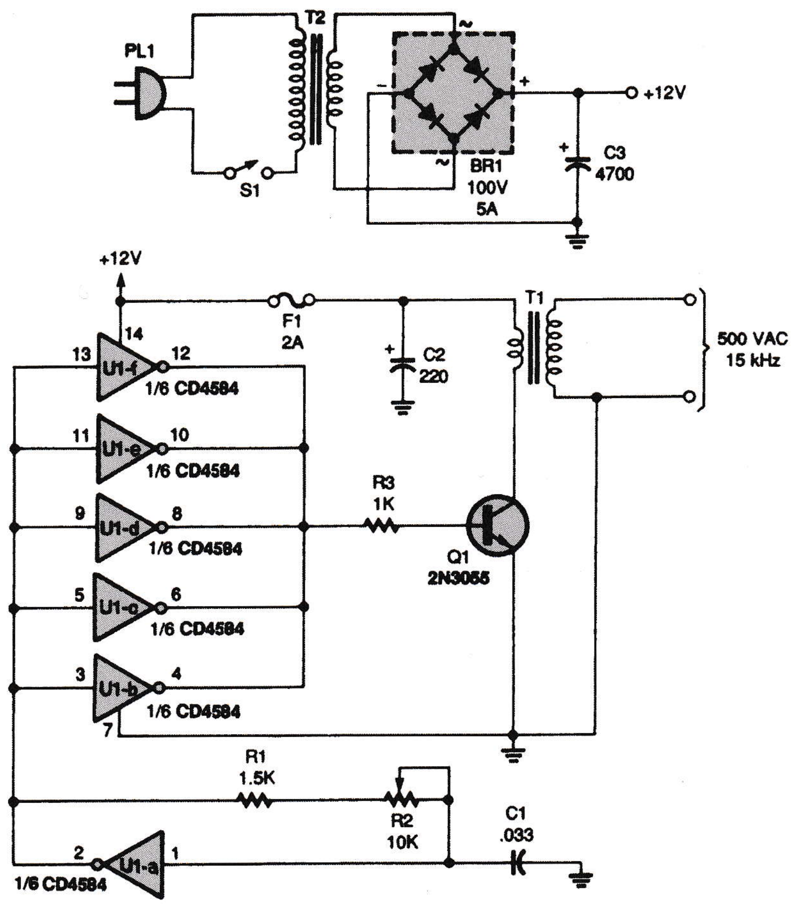
PARTS LIST

T1 — 12V to 1,000V step-up transformer, Allegro #COR-2B or equivalent
IC1 — Hex Schmitt Trigger integrated circuit, Allegro #74C14 or equivalent
D1-D10 — 1N4007 1-A, 1,000 PIV rectifier (two rectifiers in series for each listed, 20 in total)
D11 — 1N4007 1-A, 1,000 PIV rectifier
I1 — Ultrabright red LED
I2 — NE2 neon indicator lamp
C1 — .0068 uF, polyester or Mylar capacitor
C2 — 1,000 uF, 16 WVDC aluminum electrolytic capacitor
C3-C12 —.001 uF, 2 or 3 KVDC ceramic capacitor
R1 — 1,500 ohm, 5% carbon film resistor
R2 — See text — will be 220, 390, or 470 ohm depending upon supply voltage
R3 — 220 ohm, 5% carbon film resistor
R4 — 1 megohm, 5% carbon film resistor
VR1 — 10K potentiometer
F1 — 2A fast-blow fuse
S1 — SPST switch
1 — Special 14-pin integrated circuit socket w/integral bypass capacitor, Allegro #ED2124 or similar
1 — TO-3 heatsink and #6-32 mounting hardware

Fig. 83-9

This power supply uses a Cockcroft-Walton HV multiplier circuit to produce up to 10 kV from a 12-V source. Up to 5 W is available from this circuit.

NEON TUBE HIGH-VOLTAGE POWER SUPPLY



POPULAR ELECTRONICS

Fig. 83-10

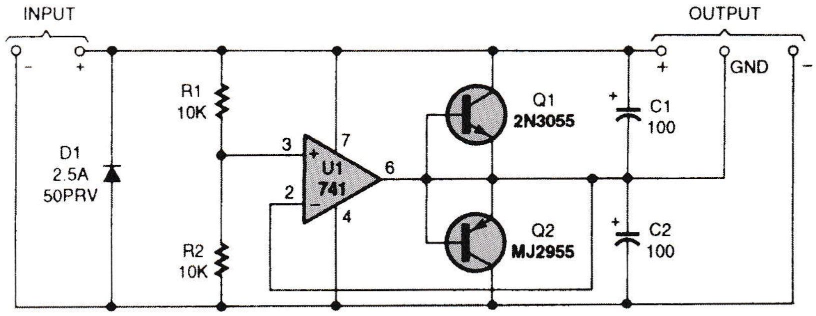
Power for the circuit is supplied by a step-down transformer (T2) and a full-wave bridge rectifier (BR1), which convert 117-Vac to 12-Vdc. Capacitor C3 acts as a filter. The heart of the circuit is a Schmitt-trigger hex inverter, U1. Capacitor C1, resistor R1, and potentiometer R2 are connected to one section of the inverter, U1-a, to form an oscillator that runs at approximately 15 kHz (because U1 is a Schmitt trigger, the output square wave is very clean). Adjusting R2 varies the frequency. The output of the oscillator is fed into the remaining five inverters (U1-b through U1-f), which are connected in parallel to create a buffer that is capable of increasing the drive current of the oscillator. The square-wave output is used to drive the switching transistor (Q1), which, in turn, switches the primary windings of the ferrite-core transformer (T1). Approximately 500-Vac at 15 kHz are output from the secondary of the transformer. T1 is made from a ferrite pot core. Wind 500 turns of #30-gauge wire for the secondary. Coat it with insulating varnish and add a layer of insulating tape, over which a 20-turn winding of #22 wire is wound to form the primary winding.

84

Power-Supply Circuits—Multiple Output

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 SUPPLY

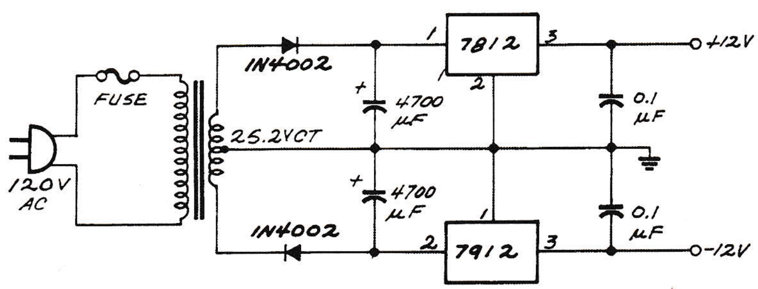


POPULAR ELECTRONICS

Fig. 84-1

The key idea is that in a dual-supply powered circuit, "ground" is midway between the positive and negative supply voltages. Unfortunately, ordinary voltage regulators can't do the job. The reason is that they can only source current, not sink it, and the ground terminal in a dual supply might have to either source or sink current, depending on which half of the load is drawing more current at the time. In the circuit, R1 and R2 divide the input voltage in half. Op amp U1 reproduces that voltage at the "ground" output terminal by making either Q1 or Q2 conduct as much as necessary. Capacitors C1 and C2 hold the output voltage steady when the load changes suddenly. Diode D1 is present to protect the circuit's input from reversed polarity by blowing the fuse of the main power supply. If your power supply has no fuse, place D1 in series with the circuit. That will afford the same protection with only slightly reduced regulation and voltage output.

SPLIT 12-V POWER SUPPLY

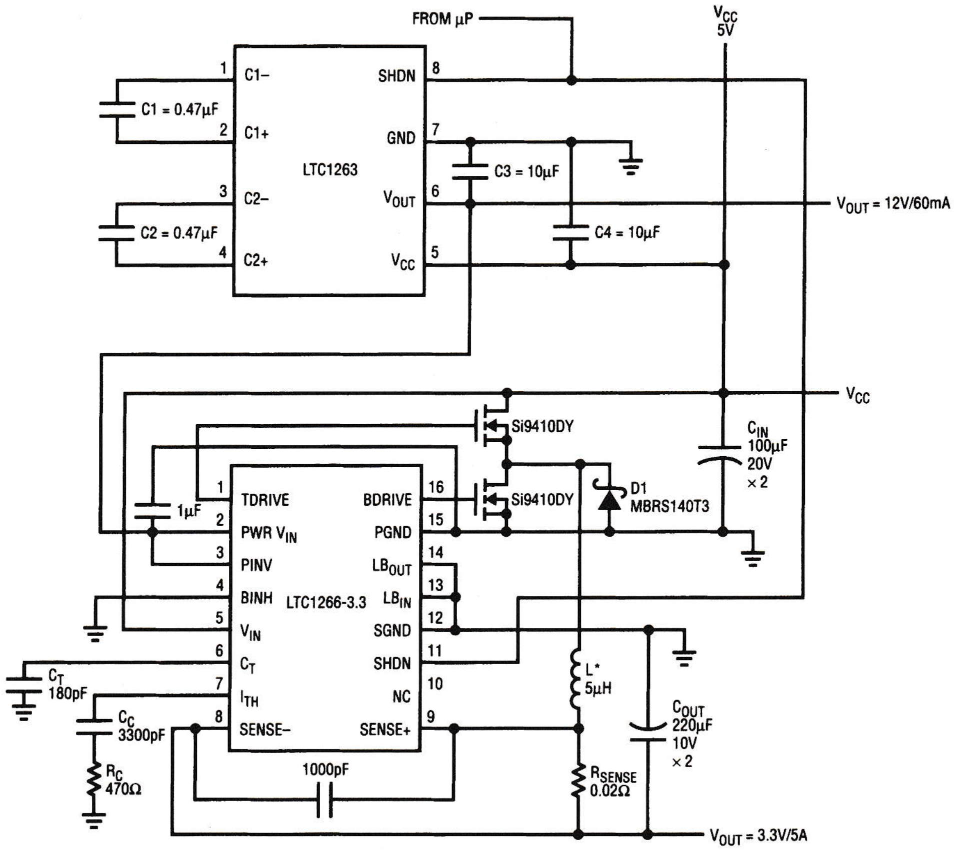


ELECTRONICS NOW

Fig. 84-2

Two IC regulators and a bridge circuit supply ±12 V.

DUAL-OUTPUT VOLTAGE REGULATOR



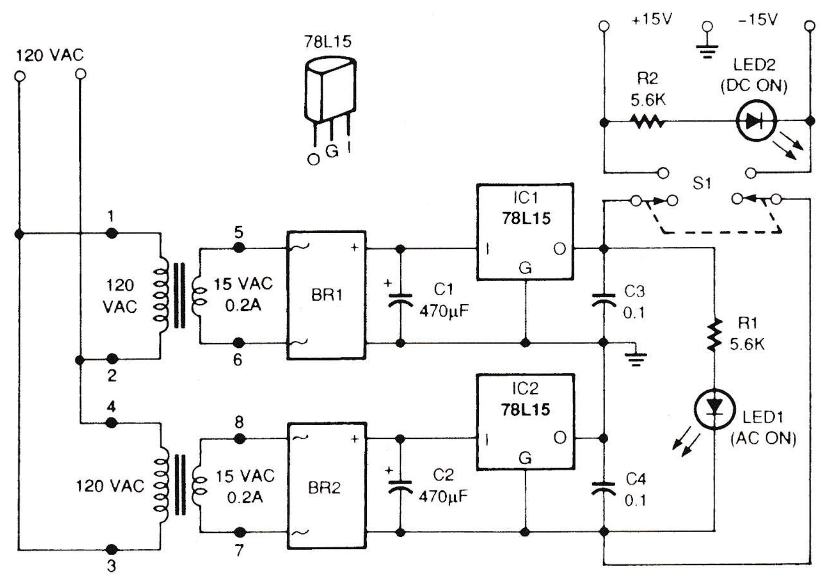
*COILTRONICS CTX0212801

LINEAR TECHNOLOGY

Fig. 84-3

The LTC1266-3.3 and the LTC1263 are perfect complements for one another. The combination of the two parts provides two regulated outputs of 3.3 V/5 A and 12 V/60 mA from an input range of 4.75 to 5.5 V. The LTC1263, using only four external components (two 0.47-μF charge capacitors, one 10-μF bypass capacitor, and one 10-μF output capacitor), generates the regulated 12-V/60-mA output from a 5-V input using a charge-pump tripler. During every period of the 300-kHz oscillator, the two charge capacitors are first charged to V_{CC} and then stacked in series, with the bottom plate of the bottom capacitor shorted to V_{CC} and the top plate of the top capacitor connected to the output capacitor. As a result, the output capacitor is slowly charged up from 5 to 12 V. The 12-V output is regulated by a gated oscillator scheme that turns the charge pump on when V_{out} is below 12 V and turns it off when it exceeds 12 V. The LTC1266-3.3 then uses the 5-V input, along with the 12-V output from the LTC1263 and various external components, including bypass capacitors, sense resistors, and Schottky diodes, to switch two external N-channel MOSFETs and a 5-μH inductor to charge and regulate the 3.3-V/5-A output. The charging scheme for this part, however, is very different from that of the LTC1263. The LTC1266-3.3 first charges the output capacitor by turning on the top N-channel MOSFET, allowing current to flow from the 5-V input supply through the inductor. The amount of current flow in the inductor is monitored with a sense resistor, and the 3.3-V output is regulated by turning on and off the top and bottom N-channel MOSFETs to charge and discharge the output capacitor.

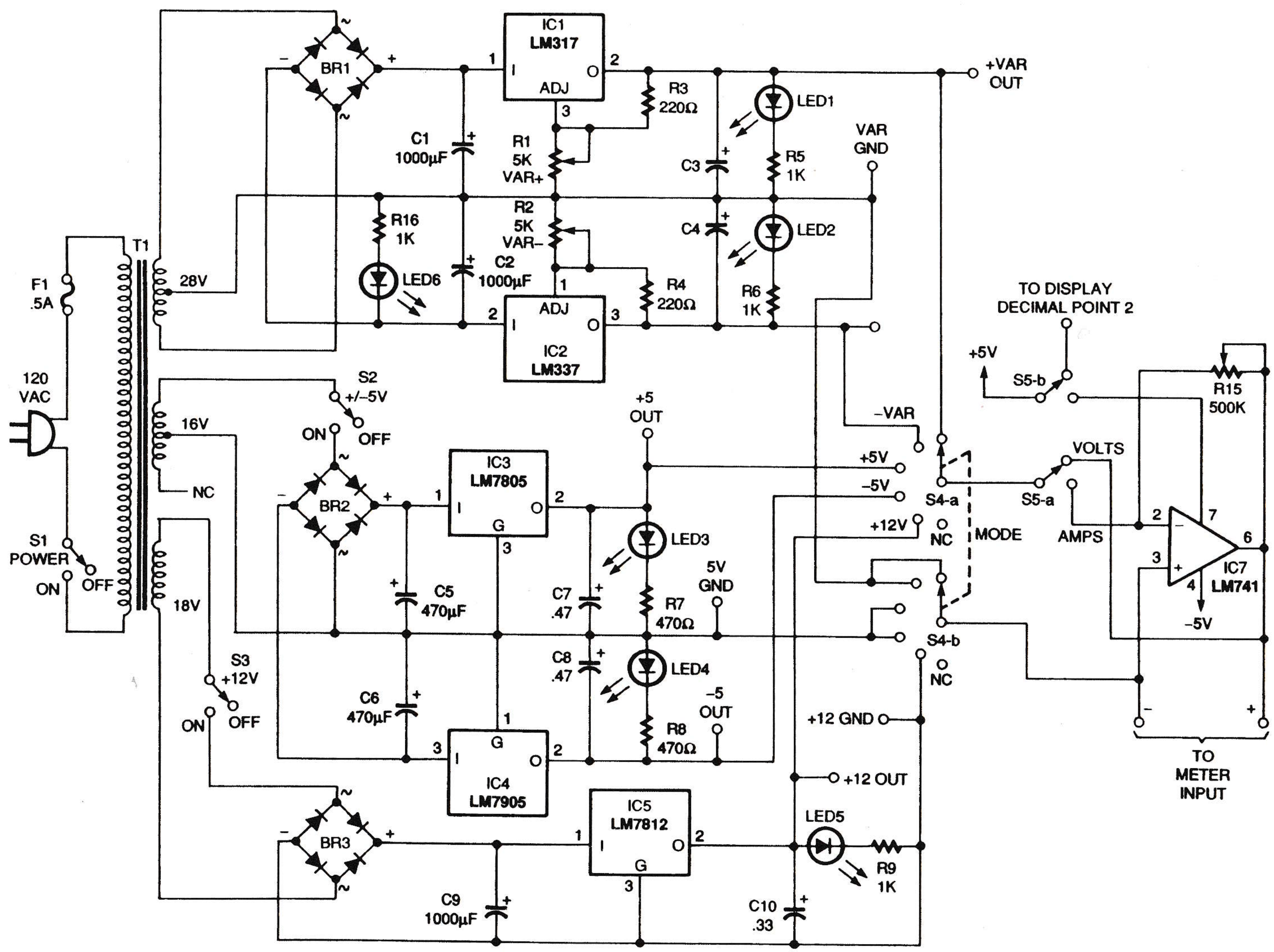
±15-V 100-mA DUAL POWER SUPPLY



ELECTRONICS NOW *Fig. 84-4*

A simple supply such as this is useful for many small projects, op amp circuits, etc.

BENCH POWER SUPPLY

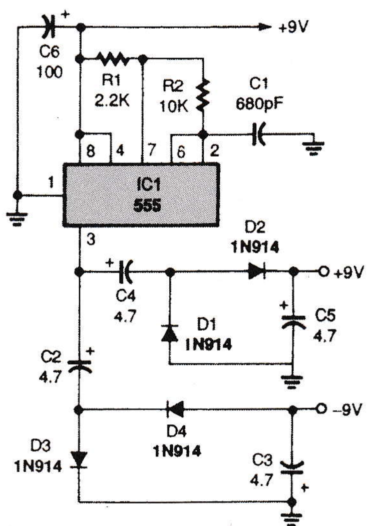


ELECTRONICS NOW

Fig. 84-5

The ac voltage from transformer T1 is rectified by bridges BR1, BR2, and BR3 and filtered by capacitors C1, C2, C5, C6, and C9. Voltage regulators IC1 to IC5 reduce the voltage to the desired fixed or variable levels. The LM317 regulator, IC1, provides a positive variable output from 1.2 to 28 Vdc, and an LM337, IC2, provides a negative variable output with the same range. The LM7805 regulator, IC3, supplies a fixed +5 V, and the LM7905, IC4, supplies a fixed −5 V. The LM7812 regulator, IC5, supplies a fixed +12 V. Capacitors C3, C4, C7, C8, and C10 improve transient response and prevent oscillation. Resistor networks R1 through R3 and R2 through R4 for IC1 and IC2, respectively, provide the necessary feedback to obtain the variable output voltages. An LED and current-limiting resistor are wired across each output to indicate when each output voltage is present. The main power indicator for the entire unit consists of LED5 and R18. Switch S1 controls ac power to the transformer primary, and switches S2 and S3 connect the secondary voltages to the 5- and 12-V regulator circuits. The ±5-V supply powers the voltage meter and display circuitry, so this section must be turned on to power the output meter. Switch S4 is a two-pole, six-throw (2P6T) rotary unit. Pole A switches the positive input to the voltmeter and pole B switches the ground input. (Three separate grounds are in the circuit.) Pole A of S4 is connected to one pole of DPDT switch S5 so that the signal can be routed directly to the meter for voltage readings or to the LM741 current-to-voltage converter IC7 for current readings. The second pole of S5 is connected to the +5-V supply. This pole is switched to the second decimal point of the display in the Voltage mode or to pin 7 of the LM741 in the Current mode.

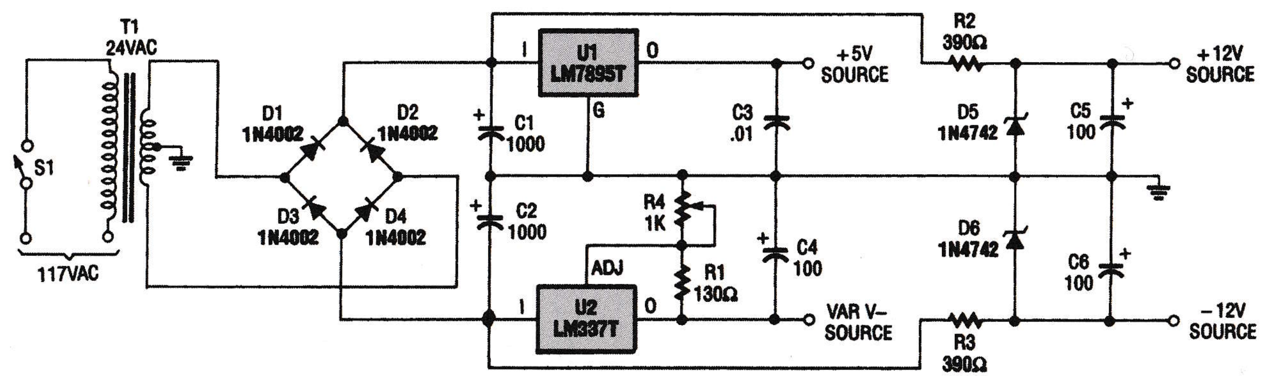
DUAL-POLARITY LOW-CURRENT POWER SUPPLY



POPULAR ELECTRONICS *Fig. 84-6*

The 555 is operating in a free-running oscillator at about 120 kHz, producing a near-9-V square-wave output at pin 3. Diodes D1 and D2, along with capacitors C4 and C5, make up the rectifier circuit for the positive supply, while D3, D4, C2, and C3 make up the rectifier for the negative supply.

POWER SUPPLY FOR ±12 V AND ±5 V

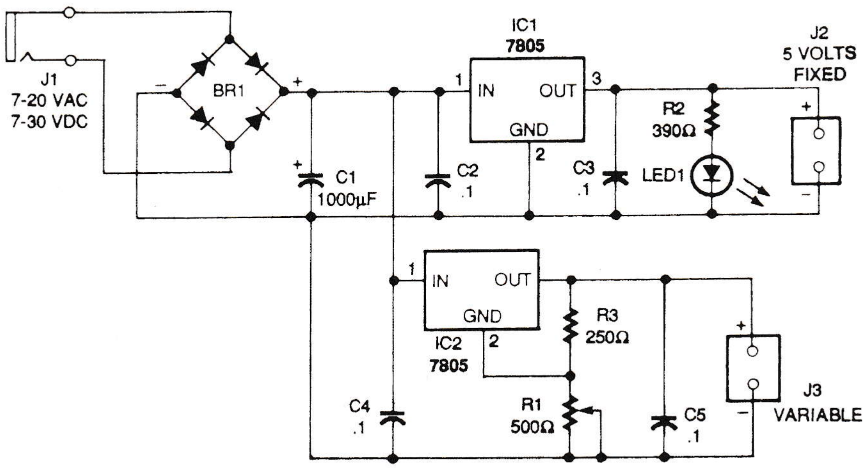


POPULAR ELECTRONICS

Fig. 84-7

This supply is suitable for small projects that need up to 30 mA at ±12 V and 0.5 A at ±5 V.

HANDY HOBBY POWER SUPPLY



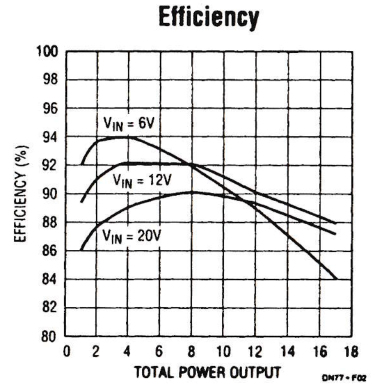
ELECTRONICS NOW

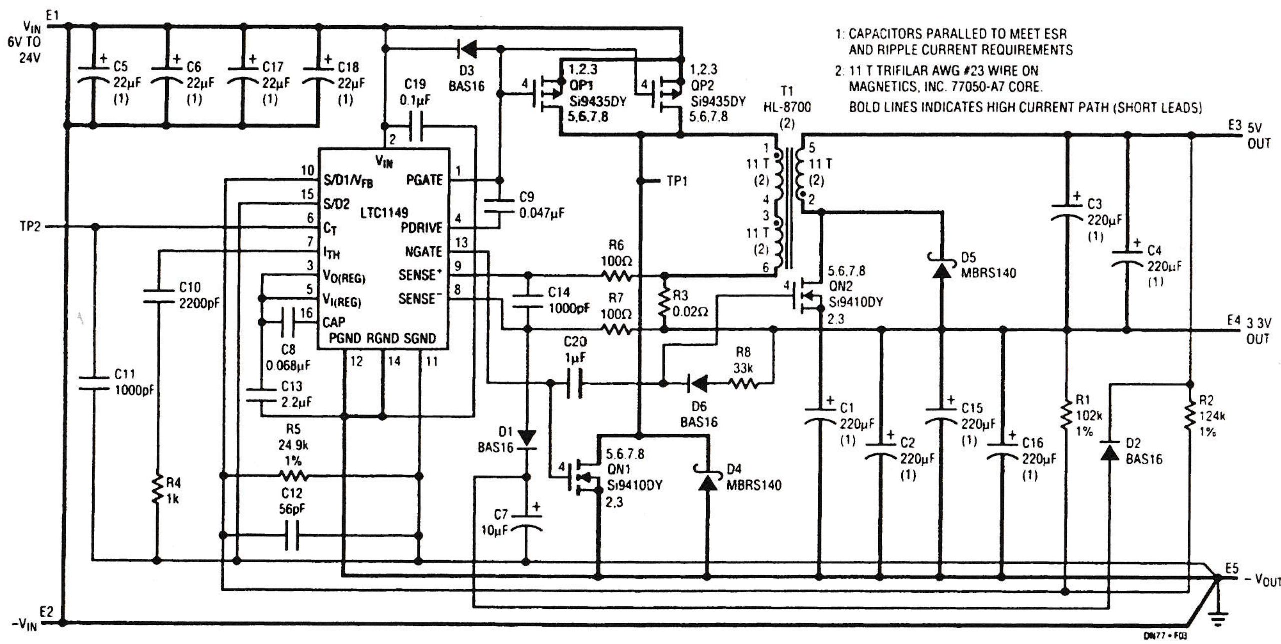
Fig. 84-8

The input voltage to the power supply at mini phono jack J1 must be from 7 to 20 Vac or from 7 to 30 Vdc. You can use any transformer or ac-to-dc wall adapter that meets those input requirements. An ac input at J1 is rectified by bridge rectifier BR1; a dc input passes through half of the rectifier unmodified, except that its value drops by the sum of two diode voltage drops. Two MC7805 5-V regulators are in the circuit: IC1 provides a fixed 5-Vdc output at J2, while IC2 has a variable dc output at J3. The variable output ranges from +5 Vdc to 2 V less than the input voltage to the power supply. The output of the fixed regulator is made variable by varying the voltage at pin 2 with potentiometer R1. (Pin 2 is normally grounded to produce the fixed-voltage output.) Each voltage regulator can safely handle up to 1 A of current, provided that the transformer or power adapter can handle the demand and that the regulator is properly heatsinked. The voltage regulators must be heatsinked if more than a few milliamperes is to be drawn from the supply. Power indicator LED1 is connected across the fixed 5-V output; it lights whenever the supply is powered.

17-W, 5-V AND 3.3-V POWER SUPPLY

Efficiency



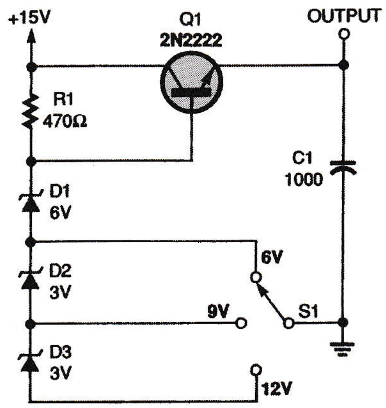


LINEAR TECHNOLOGY

Fig. 84-9

The low concerns of today's notebook computer designs do not have to restrict designers to low-performance solutions. The logic power supply is usually required to furnish excellent regulation at extremely high efficiency, but also carry a small price tag. This LTC1149 circuit addresses these requirements by using a single synchronous rectifier controller IC to generate both 3.3- and 5-V logic supplies. The 3.3-V output is generated in normal step-down regulator fashion using synchronous switches and an inductor. The key to circuit operation is the extra winding on the inductor and its corresponding synchronous rectifier, QN2. These provide the 5-V output by using transformer action. Cross regulation with this circuit is excellent because of the use of a trifilar-wound inductor and a "split feedback," which combines both outputs into the same feedback network. Efficiency exceeds 90 percent over most of the operating range. In addition, the 3.3- and 5-V outputs are inherently synchronous in switching frequency, and they will reach their rated voltage at the same time after power-up. Another bonus is that is if one logic supply is short-circuited, the other output will be disabled.

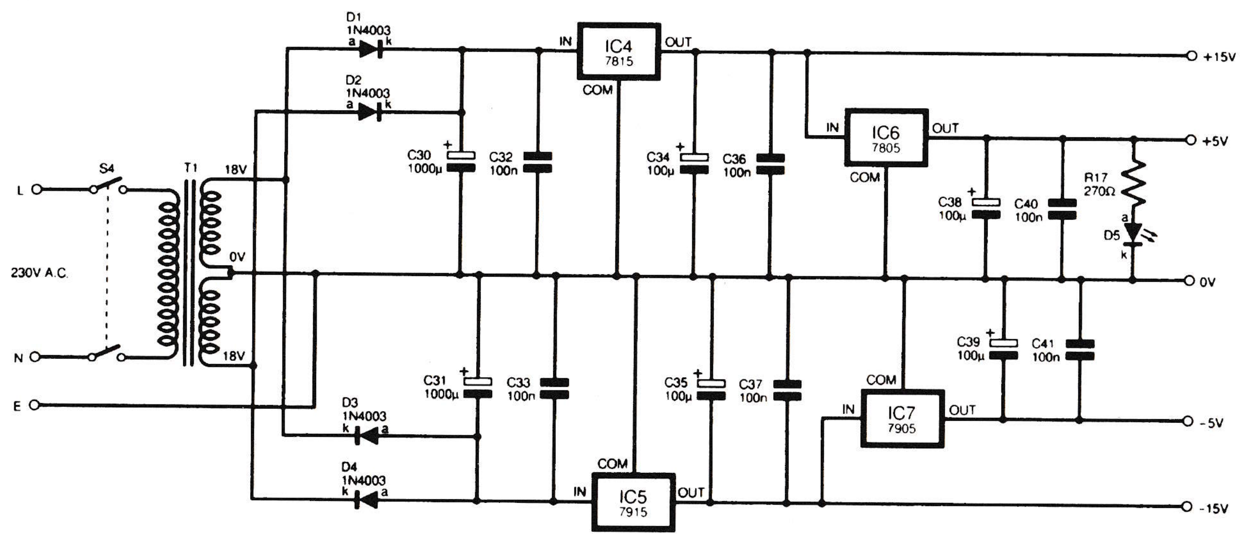
SWITCHABLE LINEAR VOLTAGE REGULATOR



POPULAR ELECTRONICS *Fig. 84-10*

This three-voltage regulated supply can be added to for more voltage ranges.

5- AND 15-V DUAL-POLARITY SUPPLY

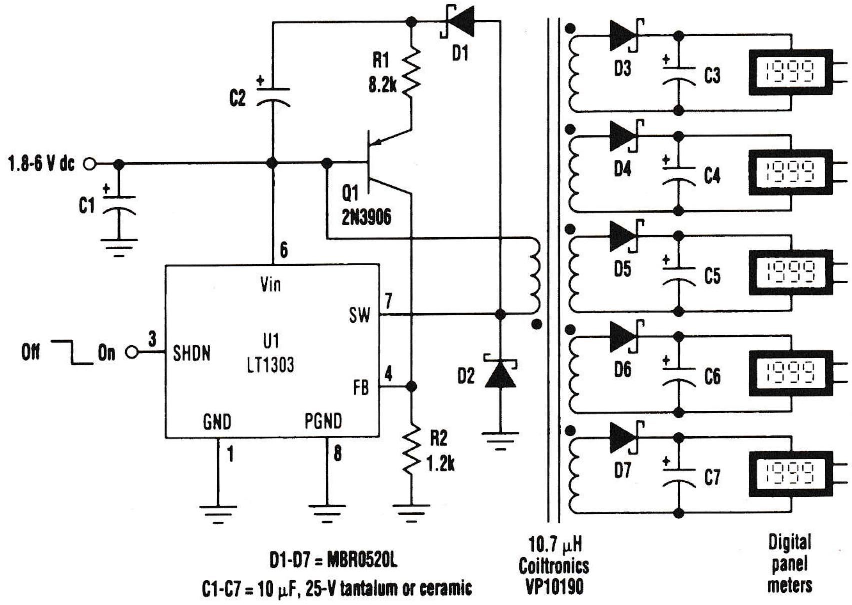


EVERYDAY PRACTICAL ELECTRONICS

Fig. 84-11

This supply will provide 5- and 15-V positive and negative voltages. It was used to power a MAX038 function generator, but it has other applications as well.

FIVE-OUTPUT CONVERTER



ELECTRONIC DESIGN *Fig. 84-12*

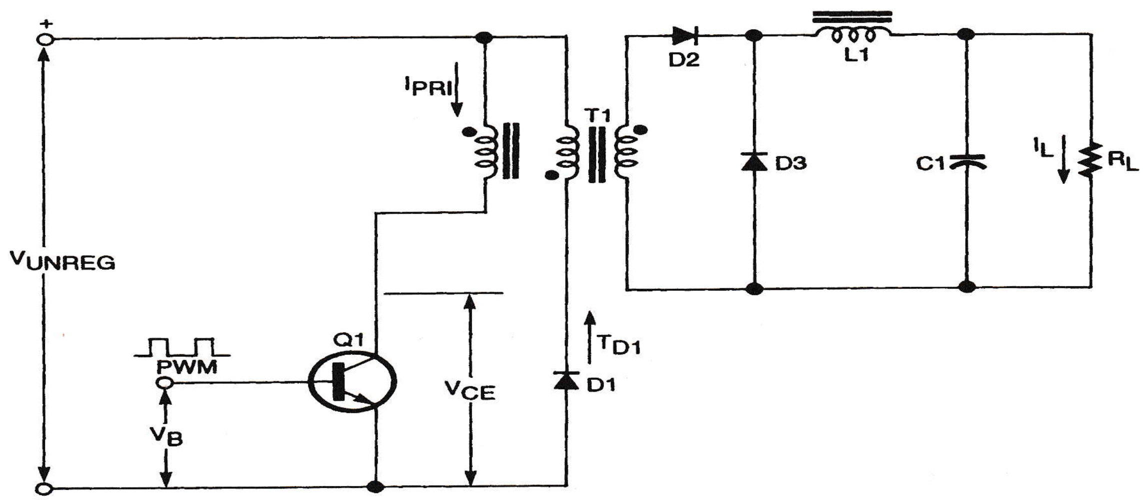
Digital panel meters (DPMs) make excellent displays for instruments and test equipment, but they suffer from one major flaw: They require a floating power supply, usually in the form of a 9-V battery. This circuit powers up to five meters from a single 1.8- to 6-V source. Each of the five outputs is fully floating, isolated, and independent in every respect. The converter is based on a flyback design, and it uses a micropower, high-efficiency regulator (LT1303) and an off-the-shelf, surface-mount inductor. The coil has six identical windings and is high-voltage-tested to 500 V rms—more than adequate isolation for the application. Operation is as follows: Feedback is extracted from the primary by Q1, which samples the flyback pedestal during the switch-off time. Typical DPMs draw approximately 1-mA supply current. The primary also is loaded with 1 mA for optimum regulation and ripple. Snubbing components, a necessity in most flyback circuits, are obviated by the action of C1 and C2. The converter also can be used with a battery. In this case, a sixth panel meter can be powered by the primary across C2. All that is required to balance the load current is to increase R_1 and R_2 by a factor of 10. Although this circuit is set up for 9-V output (actually 9.3 V), some DPMs need 5 or 7 V. As a result, a 4.3- or 6.2-kΩ resistor should be used in place of R1 for these voltages. The output voltage is set by $R_1 = (V_{out} - 0.7)/1$ mA. If any outputs aren't needed, omit the associated components and parallel the unused winding with the primary, observing the phasing. With each output loaded at 1 mA, the input current is 16.5 mA on a 5-V supply. This figure rises to about 45 mA on a 1.8-V (two-cell) input.

85

Power-Supply Circuits—Transformer-Coupled

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.

BASIC FORWARD-CONVERTER CIRCUIT

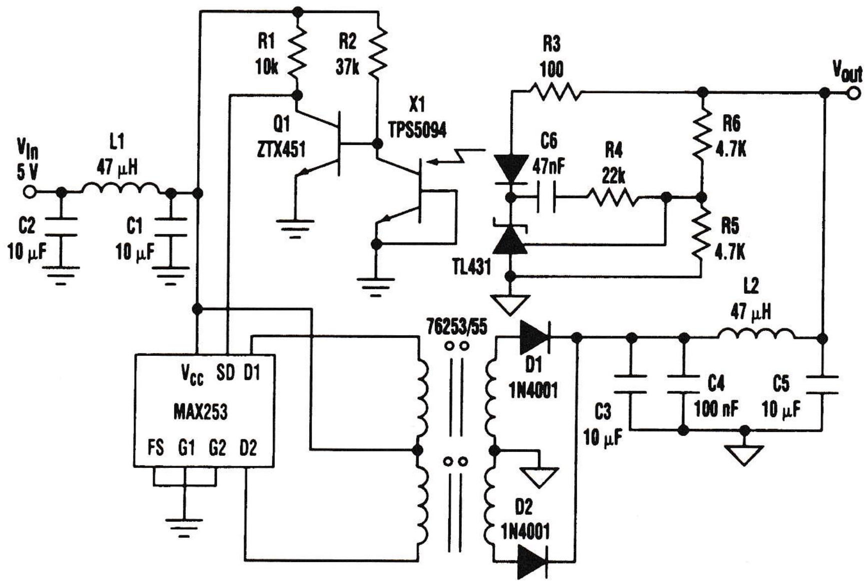


ELECTRONICS NOW

Fig. 85-1

The figure is a simplified schematic for a transformer-coupled forward converter. Based on the buck converter, it is similar to the flyback converter. Inductor L1, rather than transformer T1, stores the energy. When switching transistor Q1 turns on, current builds in the primary winding of transformer T1, storing energy. Because the secondary winding has the same polarity as the primary winding, energy is transferred forward to the output. Energy is also stored in inductor L2 through forward-biased diode D2. At this time, flywheel diode D3 is back-biased. When Q1 turns off, the transformer winding voltage reverses, back-biasing diode D2. Diode D3 becomes forward-biased, causing current to flow through R_L and delivering energy to the load through inductor L1. The third winding and diode D1 return transformer T1's magnetic energy to the dc input when Q1 is off.

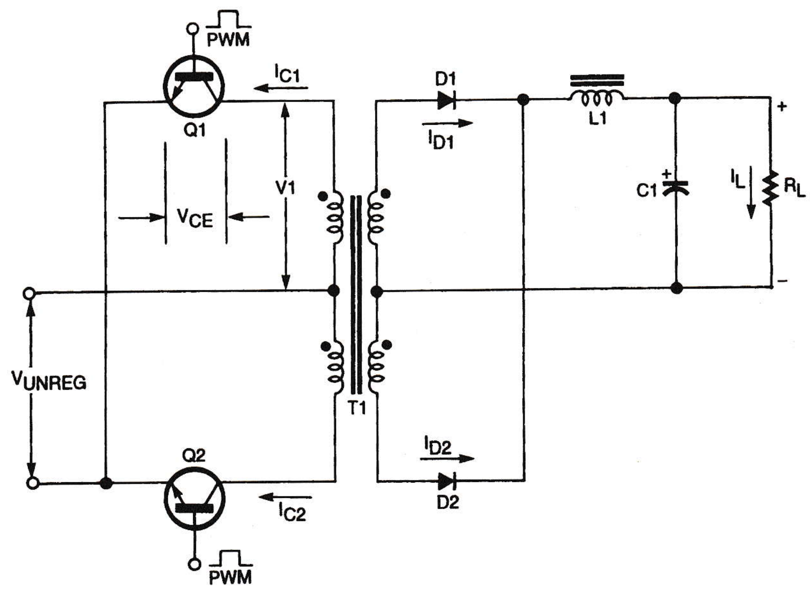
FEEDBACK CONTROL FOR MAX253



ELECTRONIC DESIGN ***Fig. 85-2***

The MAX253 and associated 76253 transformers were designed to allow easy implementation of simple dc-to-dc converter circuits. The main problem with the basic circuit is that there is no feedback, resulting in no control over the output voltage at light loads. When transformer isolators designed for 1-W power levels are used, output voltages can be observed rising above 5.5 V at less than 20-percent load. The circuit provides feedback control from the output via an optoisolator and voltage-reference device in a single pack (TPS5094). This results in an output voltage that is static at light loads. The circuit uses the internal TL431 reference devices of the TPS5904 to set a value at which the optoisolator is switched (V_{ref}=2.51 V). Using two 4.7-kΩ resistors (R5 and R6) gives an ideal output voltage of 5 V; with only 500 μA of drain current, the measured value was 4.95 V. The output of the optoisolator then controls the shutdown pin (SD) on the MAX253, via the ZTX451 buffer transistor, and switches the device off when the output voltage exceeds the predefined value. Therefore, the circuit works in a burst mode at light loads, with the switching being turned on and off as necessary. As the load increases, the device eventually reaches the stage where switching is occurring all the time.

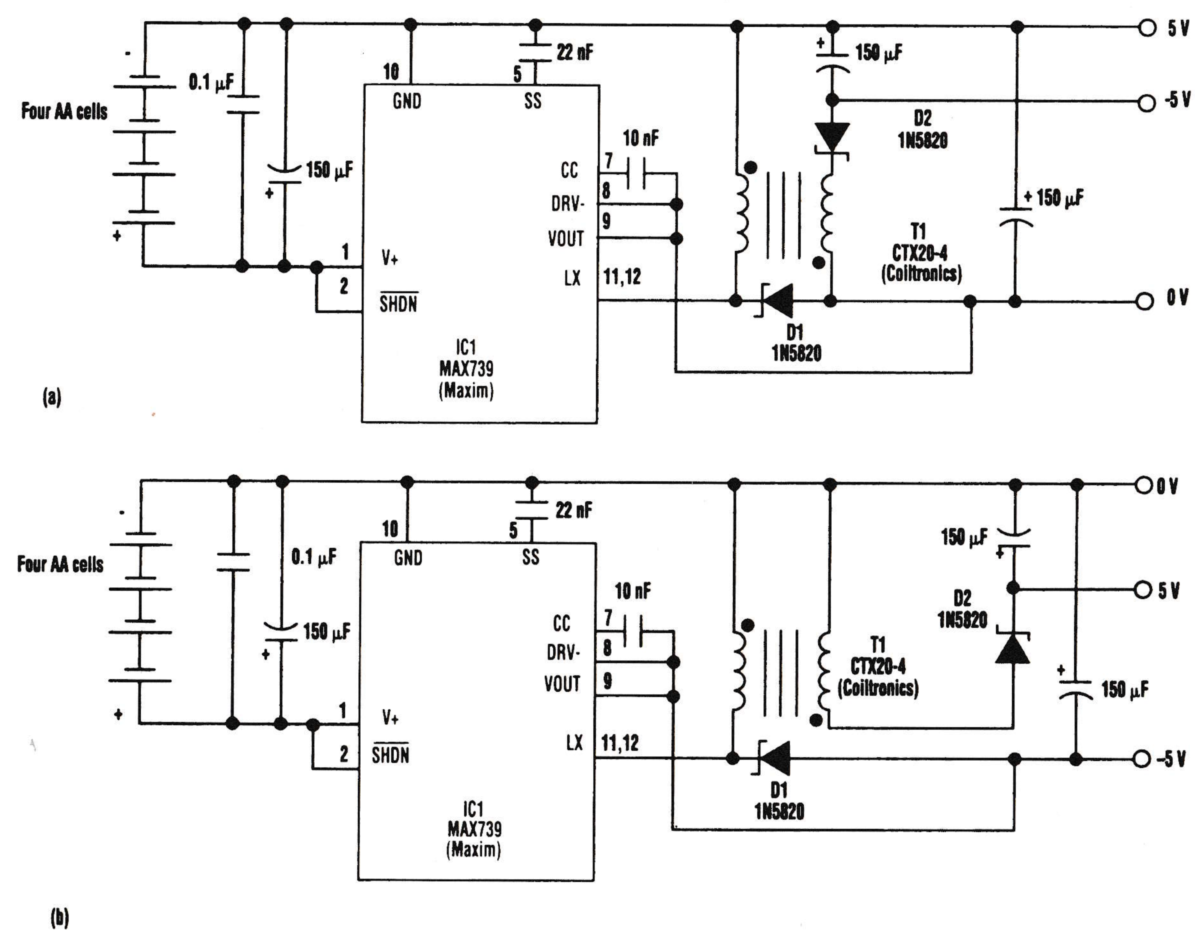
BASIC PUSH-PULL CONVERTER CIRCUIT



ELECTRONICS NOW *Fig. 85-3*

The push-pull converter consists of two forward converters working 180° out of phase. Both halves of the push-pull converter deliver current to the load at each half cycle, and the inductor stores energy. Diodes D1 and D2 conduct simultaneously between transistor conduction, effectively short-circuiting the secondary isolation transformers. Acting as flywheel diodes, these diodes deliver useful power to the output.

5-V SUPPLY

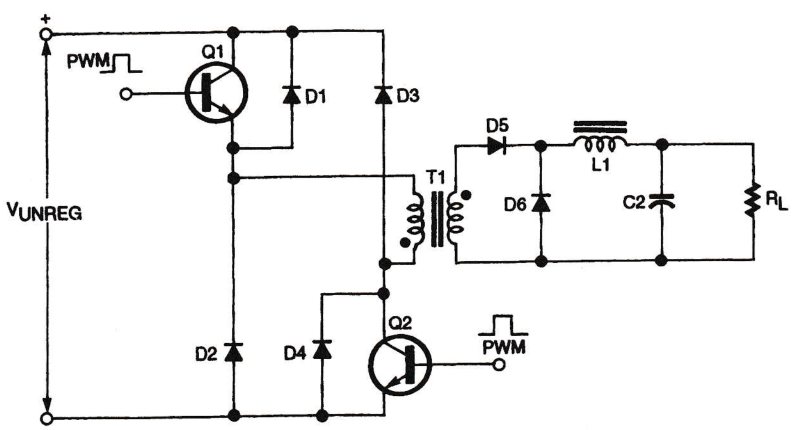


ELECTRONIC DESIGN

Fig. 85-4

The inverter circuit substitutes a transformer with two matched windings for the usual inductor (see figure *a*). When IC1's internal switch turns off, the circuit impresses V_{out} plus a diode drop across each winding. With the reference connection properly chosen, as shown, the second (right-hand) winding can generate an additional supply voltage (−5 V, in this case). V_{out} (pin 8) is the feedback connection. For stability, the regulated output (5 V, in this case) should have the heavier load. It usually does because the negative rail in most systems is only a bias supply. But if the system demands more load current from the −5-V output, the second winding should be reconnected to produce the 5-V output (see figure *b*). The transformer should have side-by-side bifilar windings for best coupling. The *V*− value (nominally −5 V) depends on load currents and the transformer turns ratio (which can deviate from 1:1). Loads of 5 to 50 mA at 5 V, for example cause a *V*− change of less than 300 mV—less than that expected from a charge pump. When unloaded, *V*− increases because of rectification of the ringing that occurs when D2 turns on.

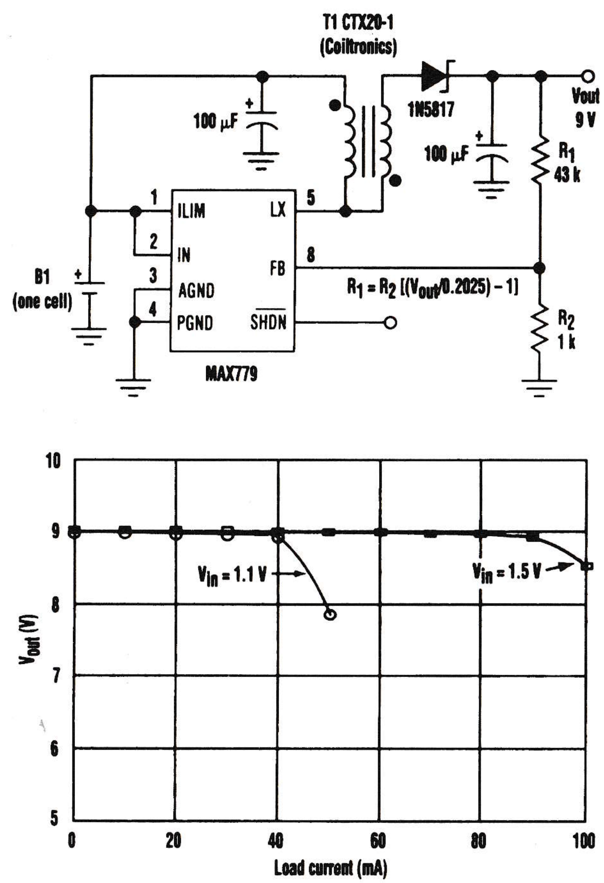
BASIC HALF-BRIDGE CONVERTER CIRCUIT



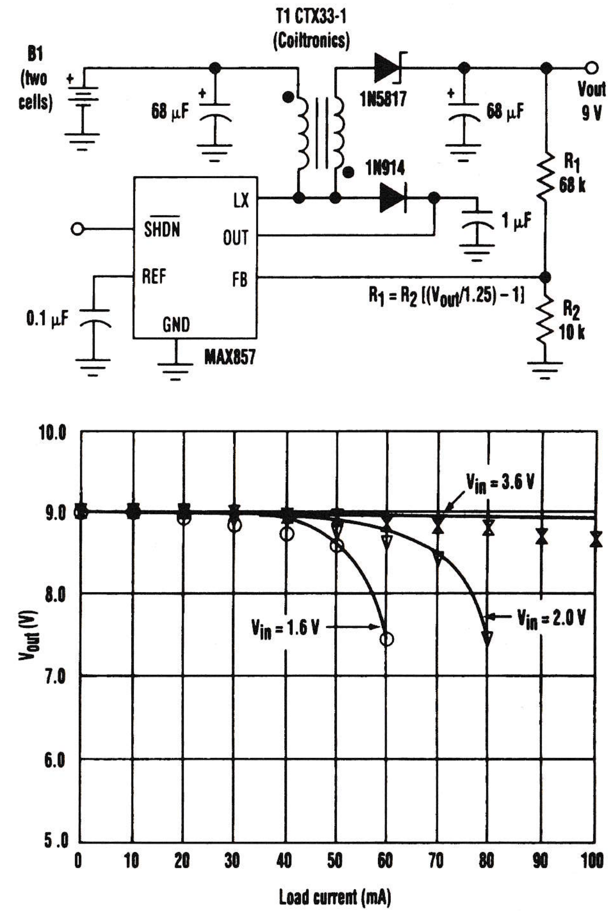
ELECTRONICS NOW *Fig. 85-5*

A popular and established switching power-supply topology is the half-bridge converter. The same converter will work from either a 120- or 240-Vac input; it is simply necessary to change terminals. It is cost-effective over the 150- to 500-W range, and offers very good output noise characteristics and excellent transient response.

V_{OUT} BOOSTER



1. AN AUTOTRANSFORMER allows a low-voltage step-up converter to boost single-cell inputs as high as 10 V.

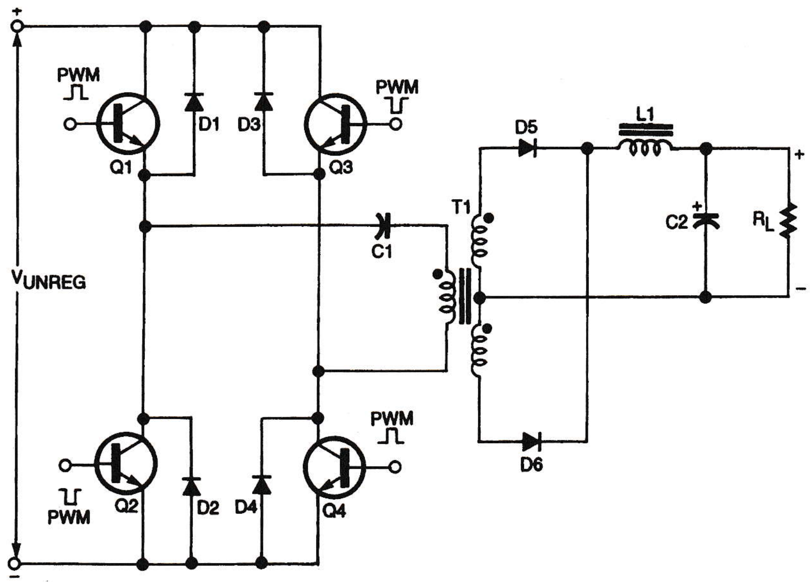


2. IN A SIMILAR SETUP to Figure 1, this circuit accepts two-cell inputs and generates regulated outputs as high as 10 V.

Fig. 85-6

Step-up dc-to-dc converters that operate from small input voltages often possess correspondingly low maximum breakdown voltages of 5 to 6 V. This limits the maximum output voltage available from such devices. However, by adding an autotransformer, the output voltage (V_{out}) can be doubled without exceeding the IC's breakdown voltage. A properly wound center-tapped inductor acts like a transformer with a 1:1 turns ratio. Combined with an IC that typically boosts single-cell inputs as high as 6 V, it produces a regulated 9-V output with no more than 4.5 V across the IC (Fig. 1). The circuit can be applied in smoke alarms as well as in other battery-operated equipment. It delivers an output of 30 mA at 9 V from a 1.1-V input, and as much as 90 mA at 9 V from a 1.5-V input. A similar circuit setup for two-cell inputs delivers 30 mA at 9 V from 1.6 V, and a current of 80 mA at 9 V from 3.6 V (Fig. 2).

BASIC FULL-BRIDGE CONVERTER CIRCUIT

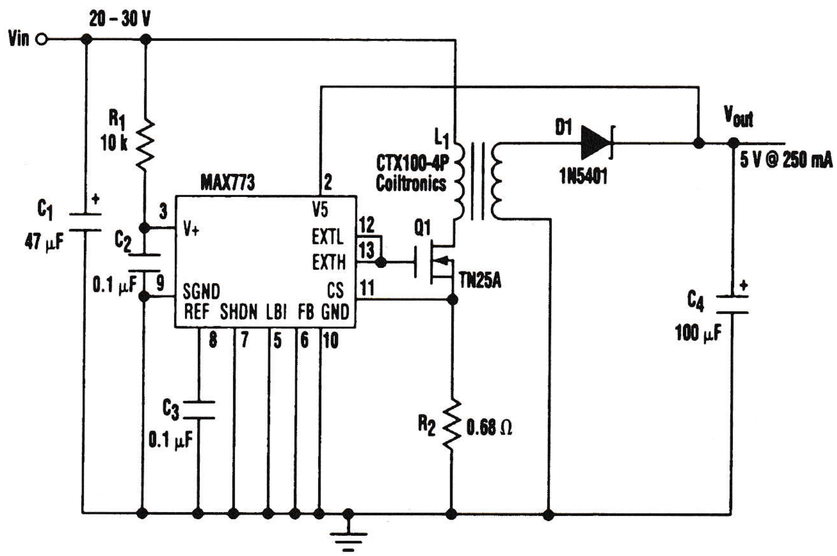


ELECTRONICS NOW

Fig. 85-7

Today, most switching power supplies rated for more than 500 W are variations on the full-bridge converter topology shown. This design has four transistors; because diagonally opposite transistors are on at the same time, each transistor must have an isolated base drive. Full-bridge converters are usually manufactured as enclosed modules for such applications as powering mainframe computers and supercomputers.

STEP-UP/STEP-DOWN REGULATOR

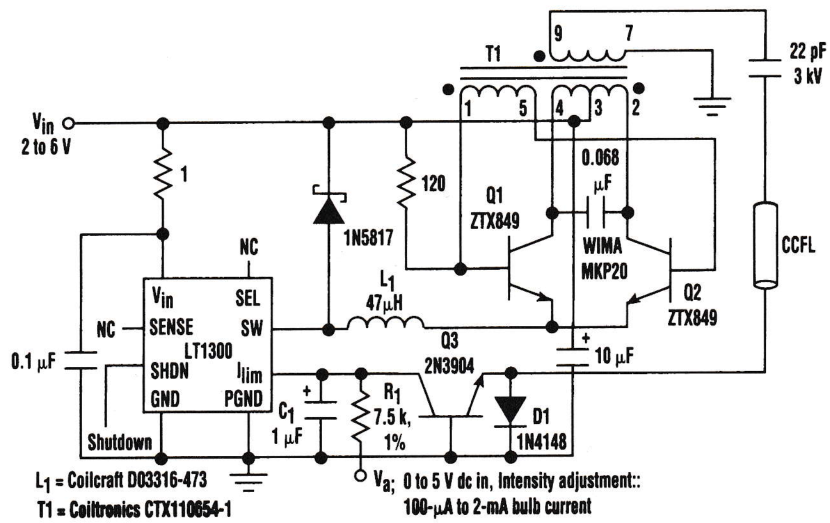


ELECTRONIC DESIGN

Fig. 85-8

Adding a transformer to a step-up dc-to-dc regulator allows inputs of 20 V and higher to be accepted while operating in a step-down mode. The circuit handles inputs to 30 V, but is easily modifiable for high specific voltages. The transformer's 1:1 turns ratio simplifiers procurement by allowing the use of a standard product (here, the Coiltronics CTX100-4P). Its 1:1 ratio also enhances stability by producing a duty cycle well below 50 percent. An ideal 1:1 transformer would generate $V_{in} + V_{out}$ at the bottom of the primary, but real transformers produce somewhat higher voltages. That voltage appears across Q1, so Q1's minimum breakdown voltage should be approximately $2V_{in} + V_{out}$. R2 limits the peak current (through Q1 and L1) to 0.33 A. The internal shunt regulator is a zener diode that is biased by R1 at approximately 2 mA. To cope with a wide range of input voltages, R1 can be replaced with a constant-current source.

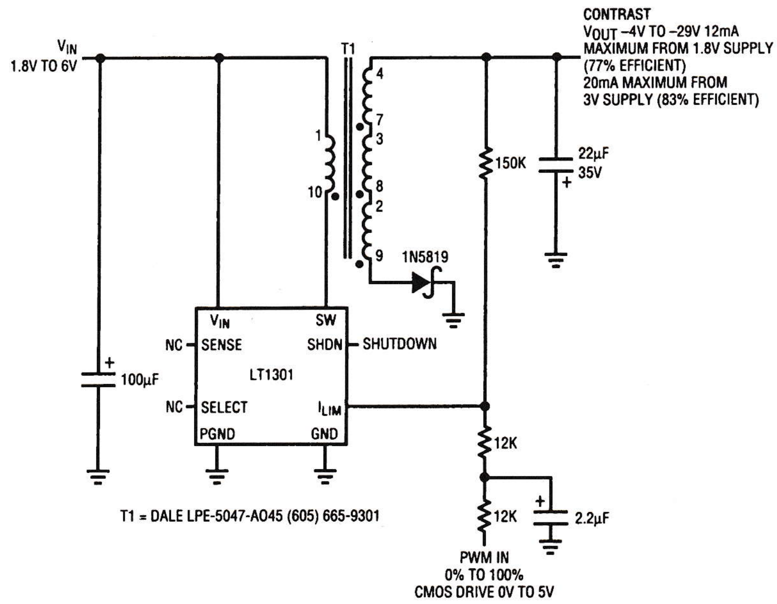
2- TO 6-V CCFL POWER SUPPLY



ELECTRONIC DESIGN *Fig. 85-9*

The power supply shown operates from 2 to 6 V. It can drive a small (75-mm) CCFL over a 100-µA to 2-mA range. An LT1301 micropower dc-to-dc converter is used in conjunction with a current-driven Royer-class converter, consisting of T1, Q1, and Q2. When power is applied along with intensity-adjust voltage V_a, the LT1301's I_{lim} pin is driven slightly positive, causing maximum switching current through the IC's internal switch pin (SW). L1 conducts current that flows from transformer T1's center tap, through the transistors, into L1. L1's current is taken in switched fashion to ground by the regulator's action. The Royer converter oscillates at a frequency primarily set by T1's characteristics (including its load) and the 0.068-µF capacitor. LT1301 drives L1, which sets the magnitude of the Q1-Q2 tail current, and thus creates T1's drive level. The 1N5817 diode maintains L1's current flow when the LT1301's switch is off. The 0.068-µF capacitor combines with L1's characteristics to produce sine-wave voltage drive at the Q1 and Q2 collectors. T1 provides voltage step-up and about 1400 V p-p appears at the transformer's secondary.

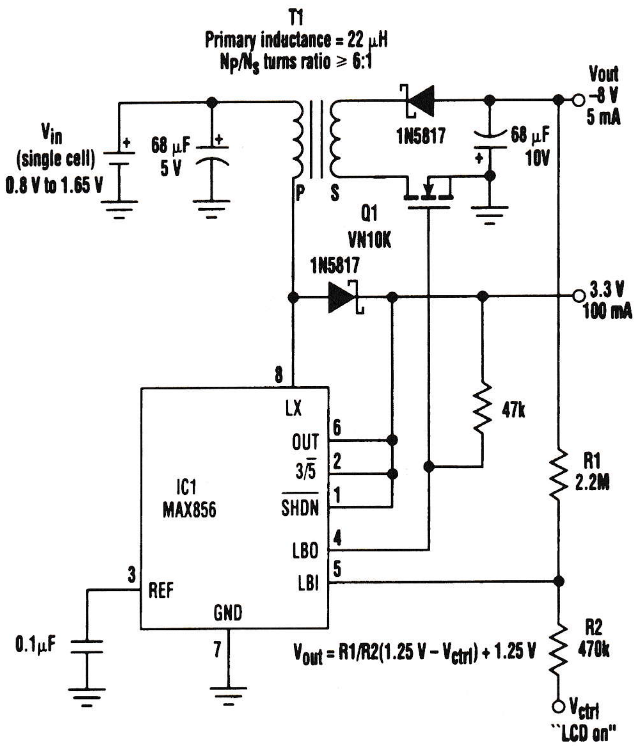
LCD CONTRAST SUPPLY



LINEAR TECHNOLOGY *Fig. 85-10*

The LT1301 circuit shown generates a negative contrast voltage that may be varied from −4 to −29 V based on a PWM control signal generated by the system microprocessor. The LT1301 is a micropower switching regulator that needs only 120 µA quiescent current and can be shut down to draw just 10 µA. The input supply can range from 1.8 to 6 V, making it ideal for operation from a portable battery supply. Transformer T1 is a standard four-winding transformer with independent terminal connections for each winding. Three windings are connected in series to create a 1:3 turns ratio flyback transformer. Voltage feedback is applied to the current limit input I_{LIM} to control operation of the oscillator. A logic-level input, such as PWM generated at a microprocessor output pin or PWM circuit, sets the output voltage. As indicated, the efficiency is very good, even at low input voltages.

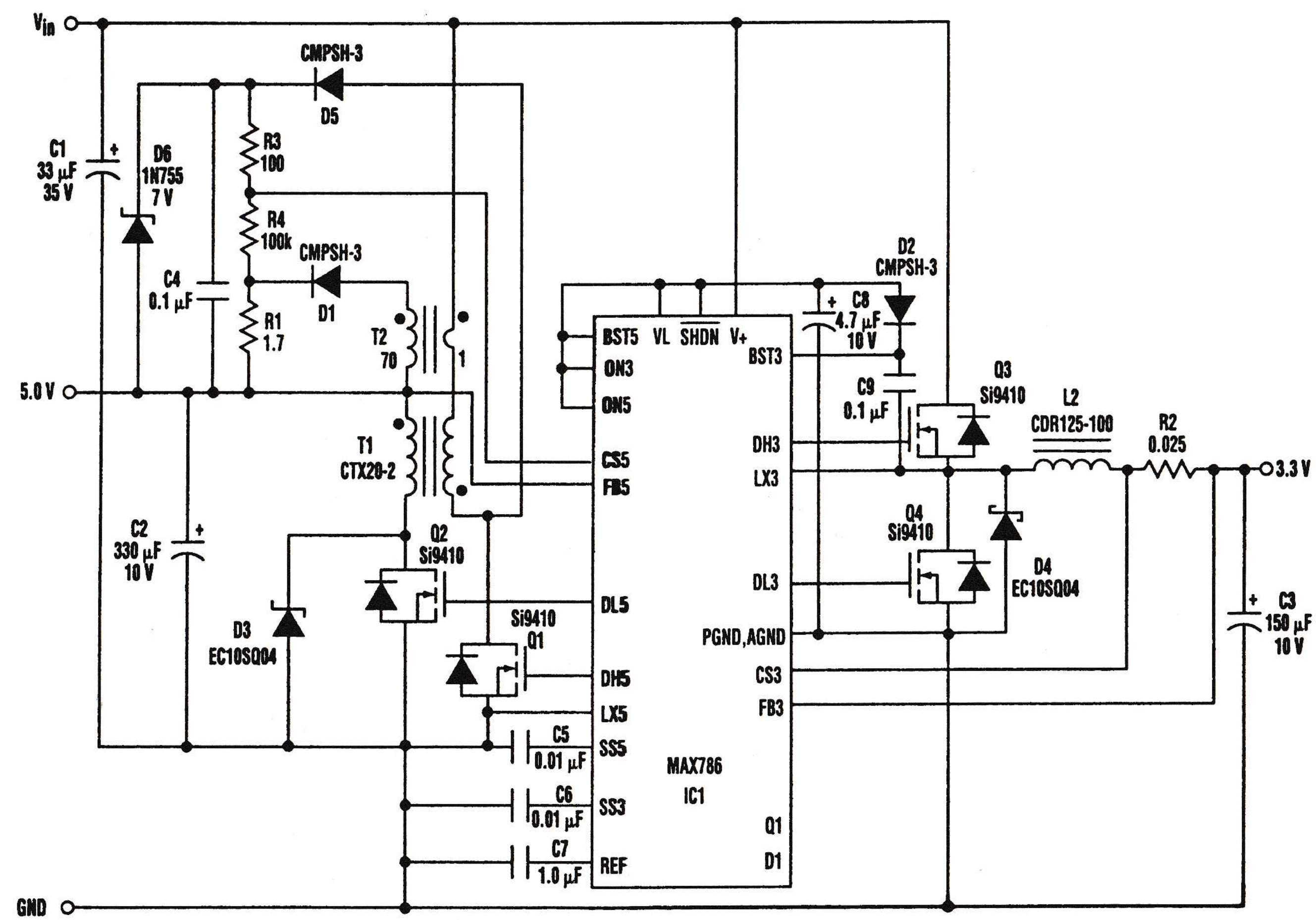
LCD AUXILIARY BIAS CIRCUIT



ELECTRONIC DESIGN *Fig. 85-11*

This single-cell boost converter can generate the low supply voltages commonly needed in pagers and other portable instruments with small, graphic LCDs. The first is a regulated 3.3 V at 100 mA, and the other is a regulated negative output, suitable for use as an LCD bias voltage. The overall efficiency is about 80 percent. The main 3.3-V supply is provided by a boost converter (IC1). The auxiliary bias voltage is provided by an extra flyback winding (the T1 secondary), and is regulated via Q1 and the low-battery detector internal to IC1. As the battery discharges, its declining terminal voltage causes a decline in the voltage in the flyback winding. At minimum battery voltage (0.8 V), the T1 primary "sees" 3.3 V−0.8 V=2.5 V, so the 6:1 turns ratio produces 6(2.5)=15 V in the secondary. At maximum battery voltage (1.65 V), the primary sees only 1.5 V, producing 9.9 V in the secondary. MOSFET Q1 stabilizes this output by interrupting the secondary current, introducing the regulation necessary to generate a constant negative output. The regulator uses IC1's low-battery detector (a comparator/reference combination) as an on/off controller for Q1. In this circuit, the R1/R2 divider holds LBI between V_{ctrl} (normally 3.3 V) and the LCD bias output (normally −8 V). R_1 and R_2 are chosen so that LBO turns off when the LCD bias becomes too negative (and pulls the LBI voltage below 1.25 V). Load current then causes the LCD bias to drift upward (toward 0 V) until LBI exceeds 1.25 V, which causes Q1 to turn on again. A logic signal at the "LCD ON" terminal provides a means to enable and disable the negative output.

5- AND 3.3-V SUPPLY



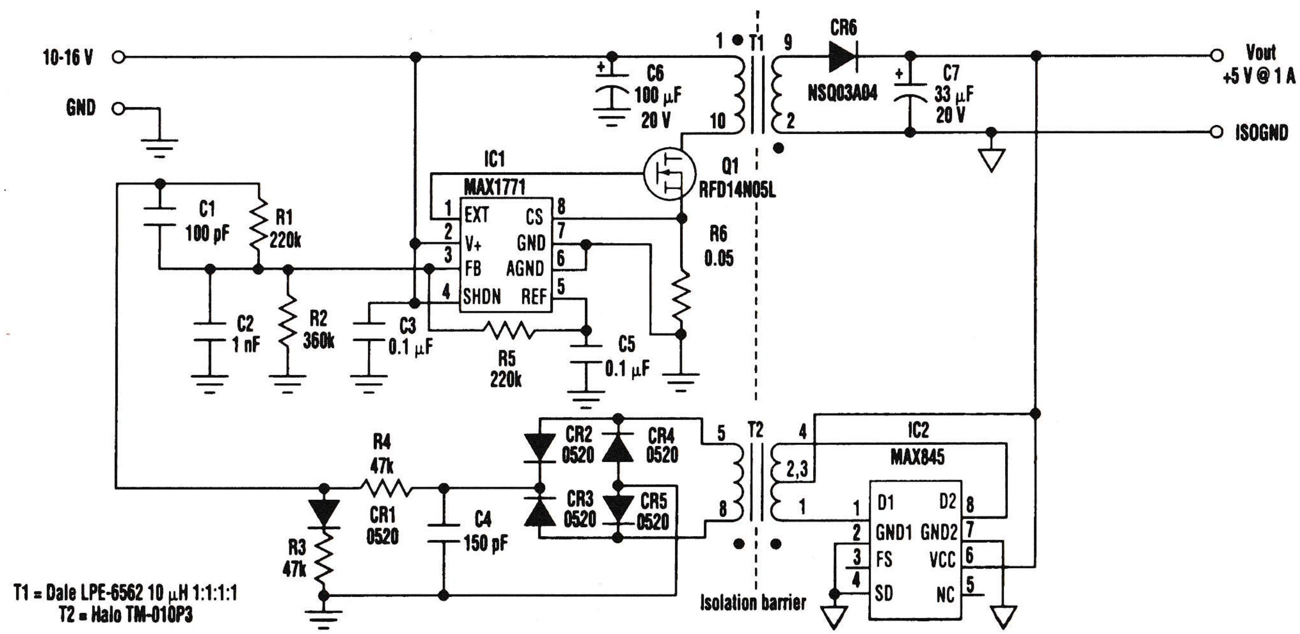
ELECTRONIC DESIGN

Fig. 85-12

5- AND 3.3-V SUPPLY *(Cont.)*

The IC shown is popular for generating 5 and 3.3 V because it includes two controllers that are highly efficient (typically >90 percent). However, the IC has a step-down (buck) topology that usually can't generate voltages equal to or higher than V_{in}. A four-cell NiCd or NiMH battery, for example, presents a problem because its terminal voltage can be above or below 5 V, depending on the state of its charge. This problem can be solved by designing in a flyback transformer, which allows V_{in} to range from 4 to 7 V. To ensure a proper gate drive to the external switching MOSFET (Q1), LX5 should be connected to ground and BST5 to the internal 5-V supply (V_L) as shown. When Q1 turns on, the T1 primary current increases and stores energy in the T1 core. When Q1 turns off, the synchronous-rectifier MOSFET Q2 turns on and enables current flow to the 5-V output. For flyback circuits, I_{out} flows only when the rectifier conducts. Yet, IC1 is a current-mode buck regulator for which I_{out} must be sensed while Q1 is on. The current-sense transformer (T2), therefore, measures the T1 primary current when Q1 is on, steps down the result with a 70:1 turns ratio, and develops a voltage across resistor R1. To ensure that synchronous rectifier Q2 remains on while Q1 is off, a simple charge pump (C4 and D5) and voltage divider (R3 and R4) provide a slight offset to the current-sense signal. Thus, Q2 remains on because the IC does not detect zero output current. V_{out} is regulated to 5 V, ±5 percent, and the maximum I_{out} is 1 A over the entire V_{in} range.

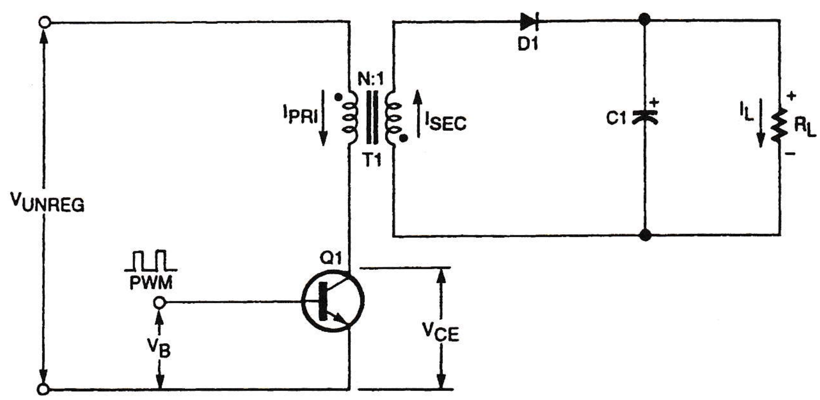
SWITCHING REGULATOR WITH TRANSFORMER-ISOLATED FEEDBACK



ELECTRONIC DESIGN *Fig. 85-13*

The zero (nonexistent) line regulation of a push-pull, surface-mount transformer and driver (T2 and IC2) produces an isolated feedback signal (to pin 3 of IC1) proportional to the regulator's nominal 5-V output. What results is a fully isolated dc-to-dc converter without the bandwidth constraints and aging characteristics associated with an optoisolator. By alternately grounding each end of T2's center-tapped primary, the transformer driver (IC2) generates an ac signal proportional to the desired 5-V feedback voltage. A diode bridge (CR2 to CR5) and a capacitor (C4) convert this transformer's output to dc, and a diode-resistor network (CR1, R3, and R4) compensates for the temperature coefficient of the diode bridge. The result is a zero-T_C voltage slightly less than $\frac{1}{2} V_{out}$. In response to a 5.00-V output, the feedback network produces an isolated 2.404 V (at IC1, pin 3) and introduces about 250 ns of delay at 100 kHz—the equivalent of 9° of phase shift. This bandwidth is sufficient for the control loop in most switching converters. Supply current for IC2 and the temperature-compensation network together is about 6 mA. Starting with a 5-V, nonisolated, transformer flyback converter in which V_{out} connects directly to the top of C1 and R1, you can insert the isolated-feedback circuit (bottom of the figure) between V_{out} and C_1/R_1. The only modification needed to accommodate this extra isolated-feedback circuit is to reduce the value of R_1, which ensures that the R1/R2 divider voltage is comparable to IC1's internal feedback reference (1.5 V). Performance of the isolated converter is virtually identical to that of the nonisolated converter, except for the power consumed by the isolated-feedback circuit. T2 provides an isolation of 500 V rms (transformers with 1500 V rms also can be obtained).

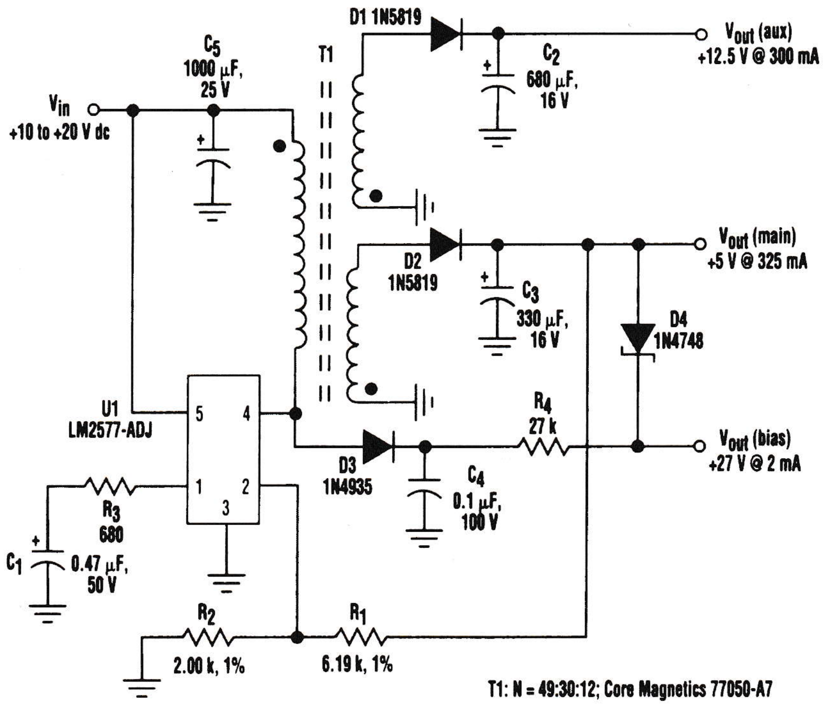
BASIC FLYBACK CONVERTER CIRCUIT



ELECTRONICS NOW *Fig. 85-14*

The figure shows a flyback converter, a variation on the boost regulator with a single switching transistor Q1 that eliminates the input inductor L1. This kind of off-line flyback switcher typically includes a bridge rectifier that converts the 120-Vac line voltage to 150 Vdc for the switching section. Current increases at a linear rate through the primary winding of transformer T1, which behaves like an inductor by storing energy in its core. As soon as Q1 cuts off, the magnetic field begins to collapse, and the winding polarities reverse. During the second half (flyback period), when Q1 is off, the energy is transferred to the secondary of transformer T1, charging capacitor C1 and feeding the output load. A PWM loop controls Q1's conduction by comparing output voltage to a set reference. If the load demands more current, the ON time is increased; if it demands less current, the ON time is decreased.

SNUBBER NETWORK ENERGY SAVER



ELECTRONIC DESIGN *Fig. 85-15*

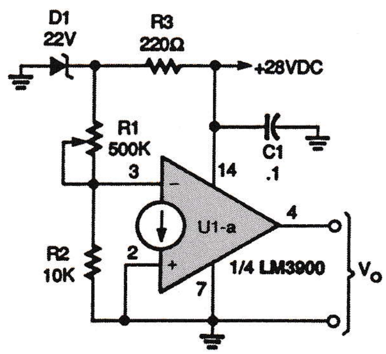
A flyback regulator offers the advantage of providing multiple output voltages with a single magnetic structure. Therefore, it is very compact and cost-effective. This particular circuit has a main +5-V output and a +12.5-V auxiliary output. The device being driven also requited a "bias" voltage of +27 V with a few milliamperes of current. The heart of the regulator is a National Semiconductor LM2577-ADJ "simple switcher" controller IC, with resistors R1 and R2 providing the feedback for the main +5-V output. The auxiliary +12.5-V output is regulated by the intrinsic tight coupling of a discontinuous-mode flyback topology. R3 and C1 are compensation devices. Although another winding could have been used in the transformer to provide the +27-V bias output, a "free" output can be realized from the transfer of the voltage spikes in the primary winding to the reservoir capacitor (C4) via diode D3. The charge in the capacitor is drawn by the current of both the bias load and the shunt zener regulator (D4). Enough charge is depleted from the capacitor to allow the next voltage spike to almost fully dump its energy in the next cycle. In a sense, this is a modified snubber network in which the energy is being put to good use, instead of being wasted as heat on a resistor.

86

Power-Supply Circuits—Variable Output

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.

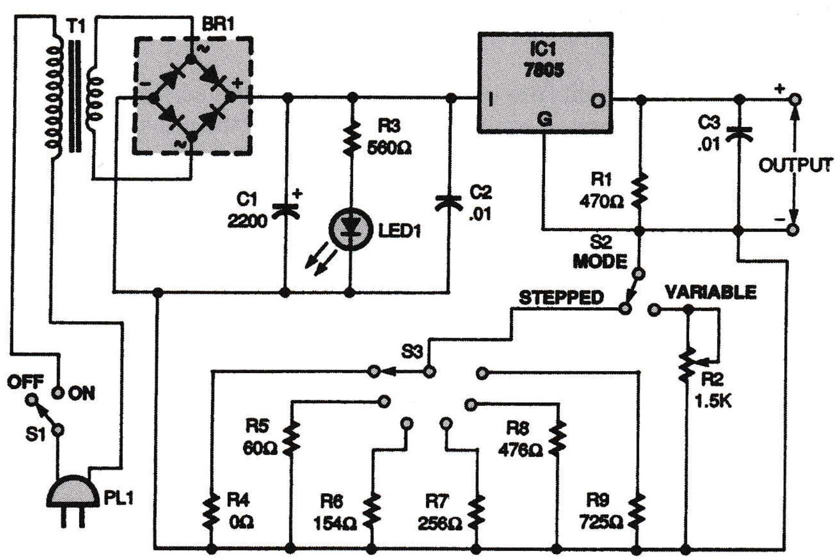
VARIABLE-VOLTAGE SOURCE



POPULAR ELECTRONICS *Fig. 86-1*

This variable-voltage source can provide between 0.6 and 20 V, depending on the setting of R1.

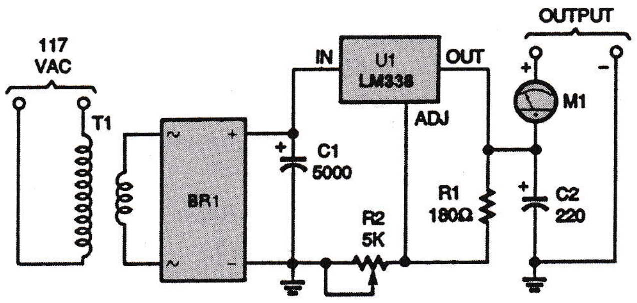
EXPERIMENTER'S POWER SUPPLY



POPULAR ELECTRONICS *Fig. 86-2*

The power-supply circuit has an output that can be varied linearly by potentiometer R2 or switched to specific levels by rotary switch S3.

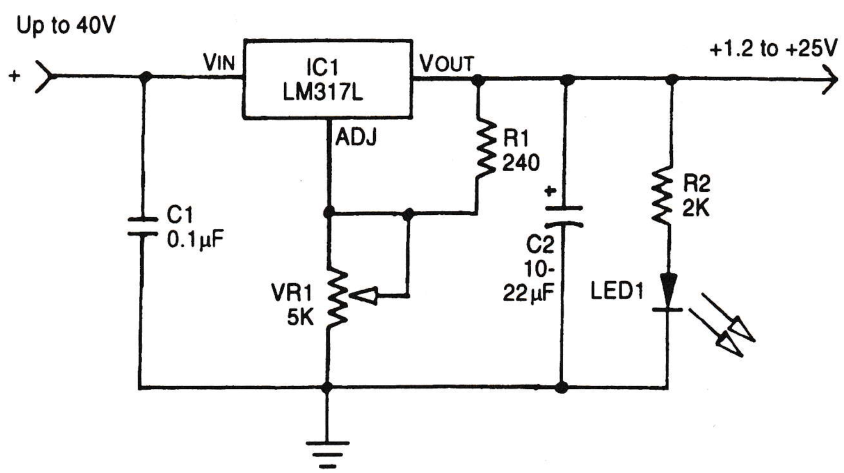
DC POWER SUPPLY



POPULAR ELECTRONICS *Fig. 86-3*

Here's the schematic for The Crusher dc power supply. The outputs are front-panel-mounted banana jacks. T1 is a 24- to 26-V transformer with 1- to 5-A capacity. C1 should be a minimum of 1000 μF per ampere of dc. C2 should be at least 100 μF (or larger). C2 helps maintain good transient response for transients that are too fast for the regulator, and 220 to 470 μF is recommended. BR1 is a 50-V bridge rectifier. U1 must be heatsinked. M1 is an ammeter of 0–5 A or 0–10 A full scale. The output voltage can be adjusted from about 1.2 to 30 V via R2. $V_{out} = 1.26\ (R_2 / R_1 + 1)$ volts.

SIMPLE ADJUSTABLE DC SUPPLY



NUTS AND VOLTS *Fig. 86-4*

Using an LM317L IC, this regulator will find broad application where a simple adjustable supply is needed. The IC is a surface-mount type, but a different package style can be used.

7.5-A 12- TO 16-VDC REGULATED POWER SUPPLY

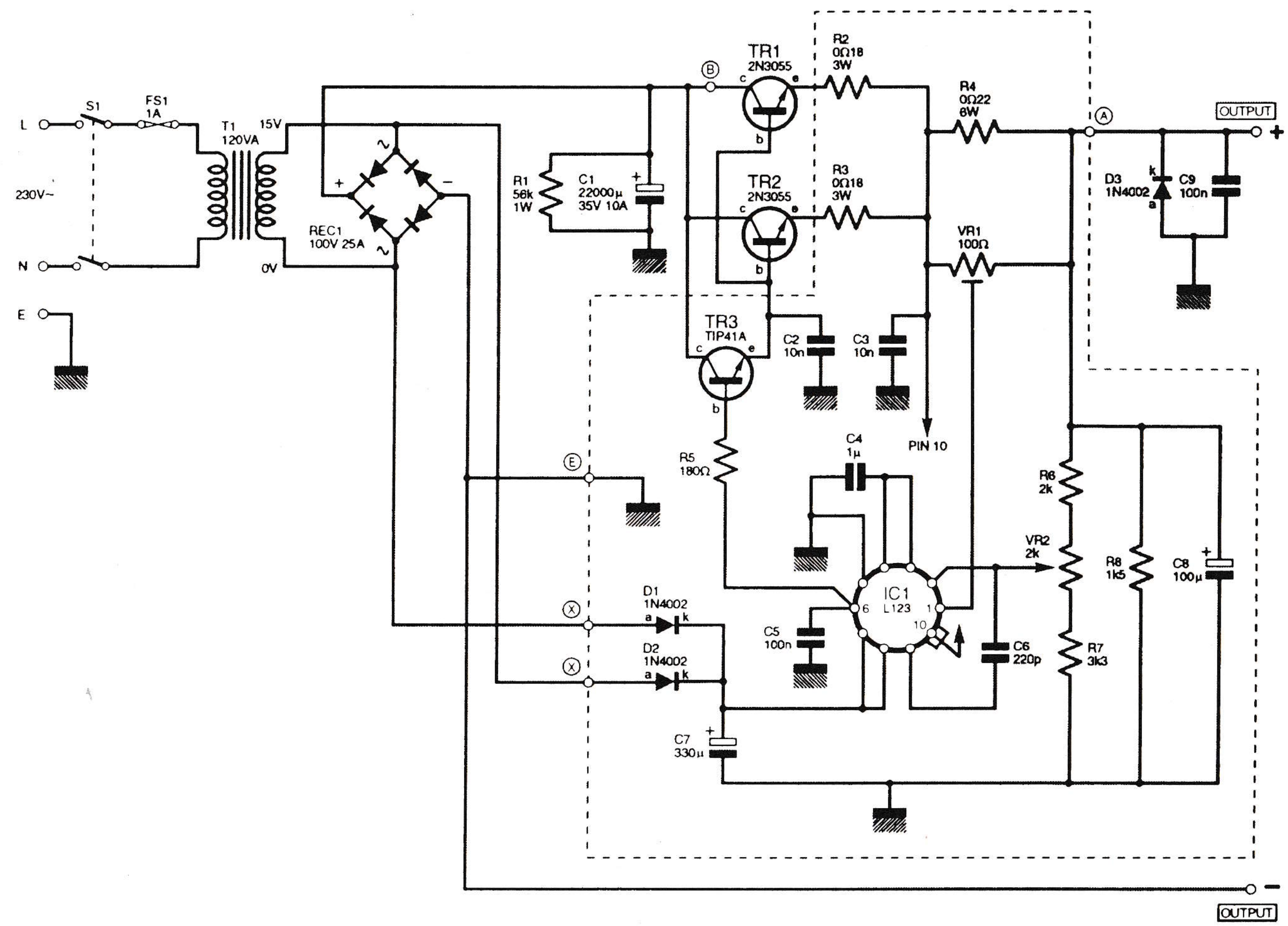


Fig. 86-5

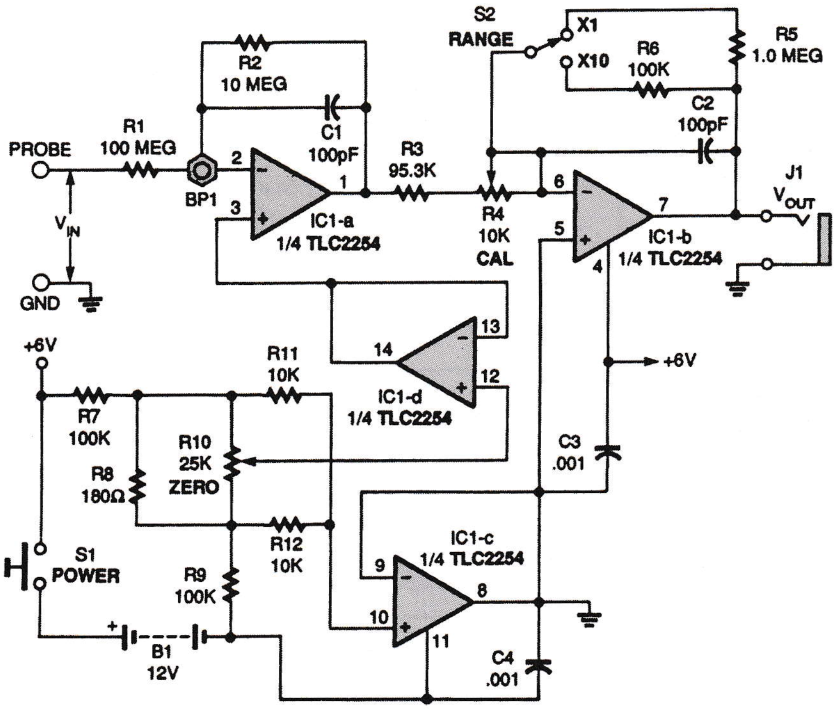
This supply uses an L123 regulator IC and a pair of 2N3055 power transistors as series-pass regulators. VR1 is the current limit, and VR2 is the voltage control. The 2N3055 transistors and the TIP41A should be heatsinked because up to 50 W of dissipation can occur.

87

Probe 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.

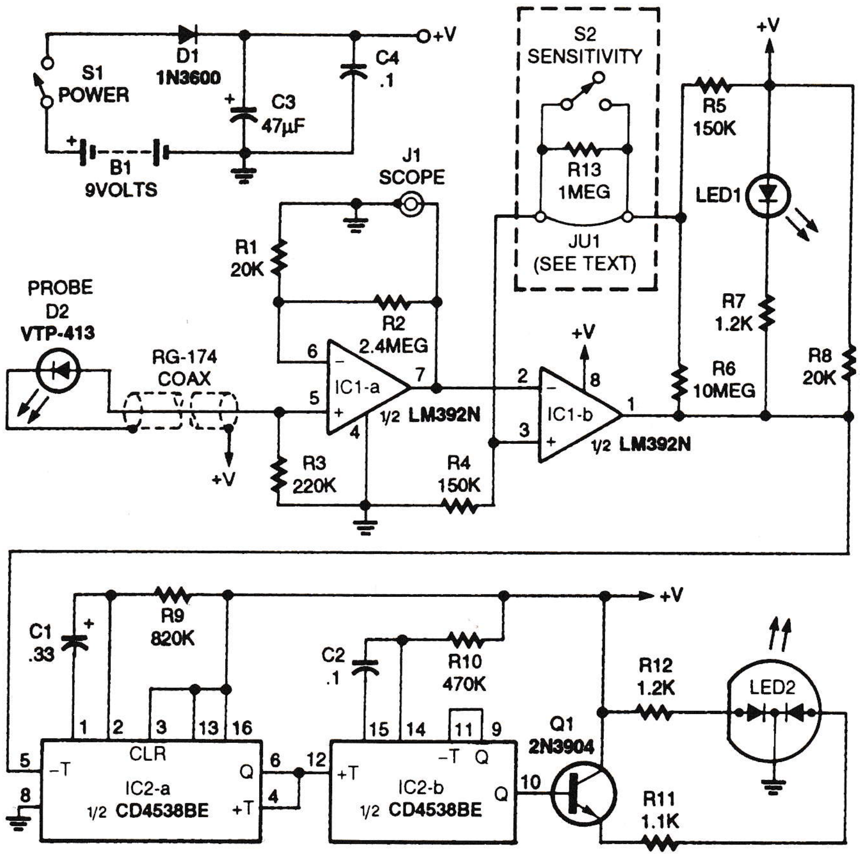
ACTIVE HIGH-Z PROBE



POPULAR ELECTRONICS *Fig. 87-1*

This probe has a 100-mΩ input impedance and uses a TI TLC2254 quad op amp operating from a 12-V battery. It can be used with a DVM or an analog multimeter for measurements in the high-impedance circuits. BP1 is a Teflon standoff to ensure low leakage at the terminal.

INFRARED LOGIC PROBE

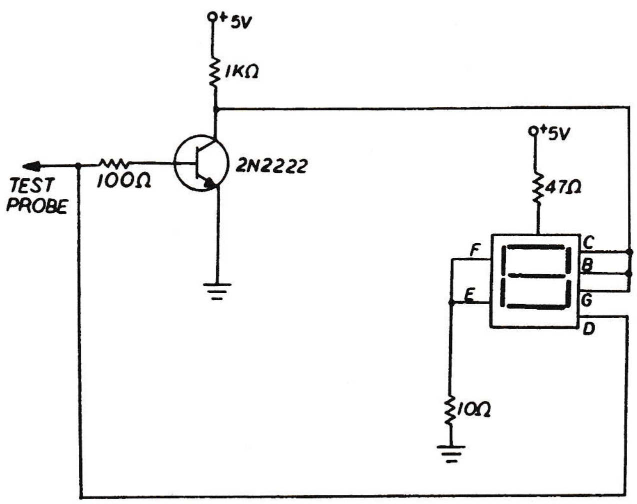


ELECTRONICS NOW

Fig. 87-2

Infrared light detected by photodiode D2 is amplified by IC1-a. The value of R2 can be changed to decrease the sensitivity of the circuit, if your application demands it. Connector J1 provides an output to an oscilloscope for the display of the amplified photodiode signal. This is handy when checking the pulsed emitters in most remote controls. Voltage comparator IC1-b squares up signals from IC1-a to digital logic levels for IC2-a. LED1 and current-limiting resistor R7 indicate the presence of steady-state infrared and also function with pulsed emitters if the duty cycle is appropriate. Monostable multivibrator IC2 conditions pulse trains with any period shorter than the time constant of R9 and C1 into a low-frequency waveform with a very high duty cycle. This provides pulses for LED2 that are constant in frequency and duty cycle, regardless of the high input frequency to IC2-a. Any frequency input to IC2-a with a period longer than the time constant of R9 and C1 creates IC2-b output pulses with the same width as before at the input frequency. Tricolor LED2 (a dual red/green device) functions as a pilot lamp and indicator for pulsed infrared sources. LED2 will always glow red and pulse amber (red+green) when infrared pulses are detected. The power source for the circuit is a 9-V battery. Alkaline batteries will provide many hours of operation because the circuit has low-power integrated circuits in place of S2 for most emitters. For certain devices, such as slotted optical switches, CD laser diodes, and reflective sensors, more sensitivity might be desirable. If you plan to use the probe for LEDs that operate below 0.5 mW, install S2 and R13—if not, you can install a wire jumper on the board instead of the switch.

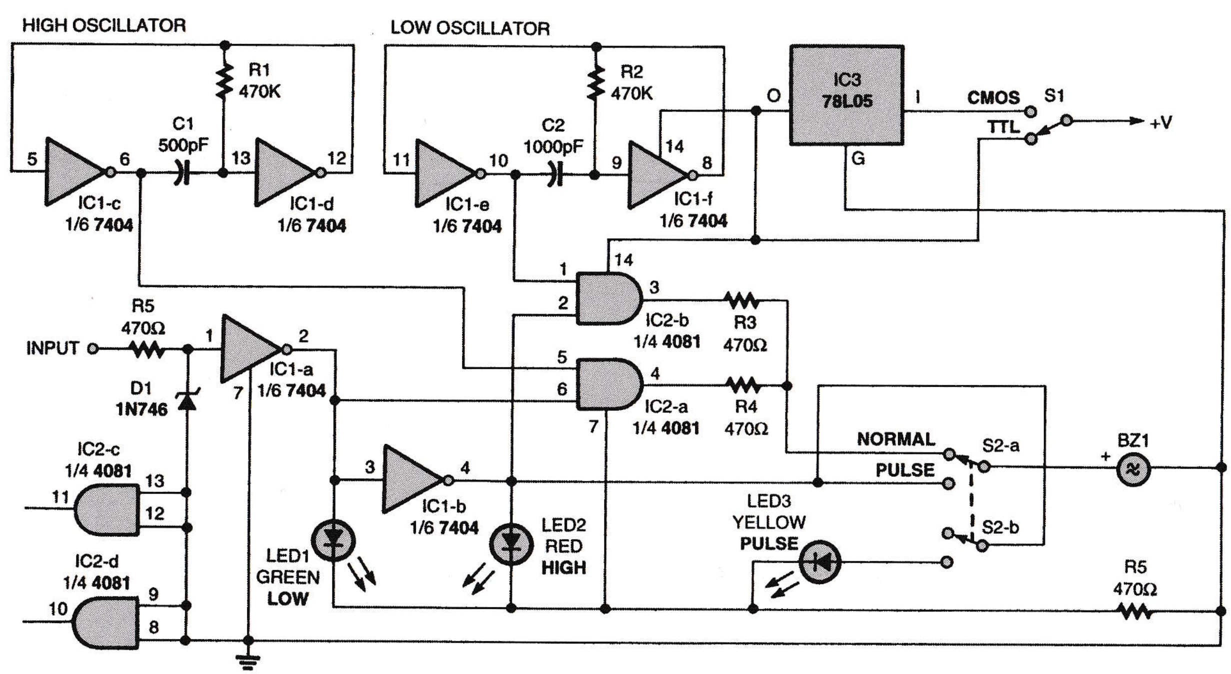
SEVEN-SEGMENT LOGIC PROBE



NUTS AND VOLTS ***Fig. 87-3***

This circuit is capable of indicating the "HI" or "LO" status of a digital circuit. The circuit in the figure will display the letter *H* for HI or +5 V and *L* for LO or 0 V. The 2N2222 NPN transistor serves as a driver for turning on the appropriate segments of the display, thereby producing the letter *H*. This condition will occur with a +5-V signal applied to the base of the transistor. If a 0-V signal is detected at the base of the transistor, the letter *L* will be displayed, indicating that the transistor driver is turned off.

LOGIC PROBE

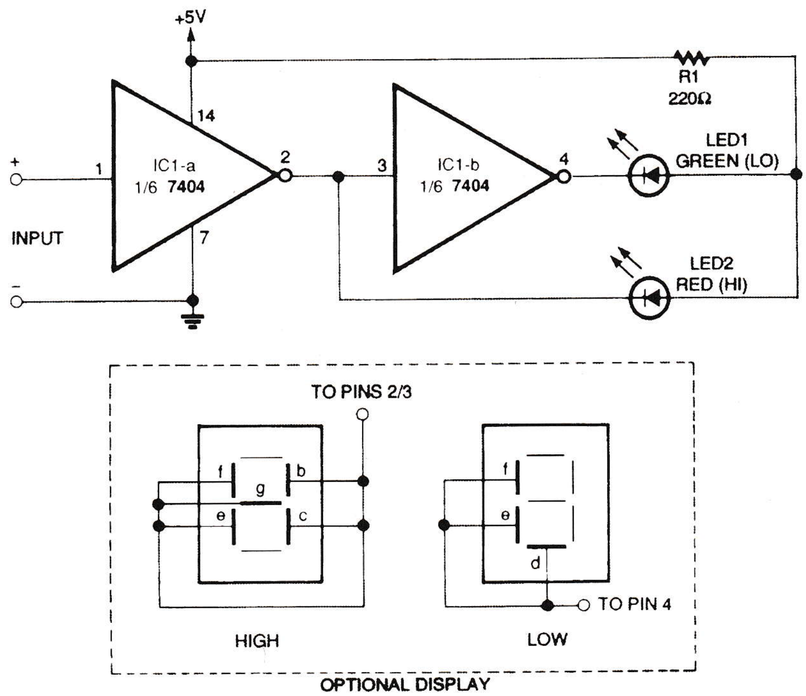


POPULAR ELECTRONICS

Fig. 87-4

The figure shows the schematic for a versatile logic probe. The zener diode clamps the input signal just above the TTL inverter's 2.2-V trigger voltage. Zener diode D1 can be left out if the probe is going to be used only on TTL circuits. The logic probe is based mainly on inverters IC1-a and IC1-b, which are sections of a 7404 integrated circuit. Depending on whether the input is high or low, the inverters enable AND gate IC2-a or IC2-b, each of which is a section of a 4081. Each AND gate is connected to an oscillator, one low-frequency, the other high. When an AND gate is made high, it passes the frequency of its oscillator to the piezo buzzer (BZ1). Whenever a high is at the input, the buzzer will produce the high tone; whenever a low is at the input, the buzzer will sound the low tone. With switch S2 in the PULSE position, if pulses are present at the input, a yellow LED will light and the buzzer will sound at the frequency of the pulses. The CMOS/TTL switch selects the voltage from the circuit under test or the voltage from the 78L05 regulator. Note that when this switch is in the TTL position, it can work only with 5-Vdc, but when the switch is in the CMOS position, it can work with from 7.5 to 35 Vdc.

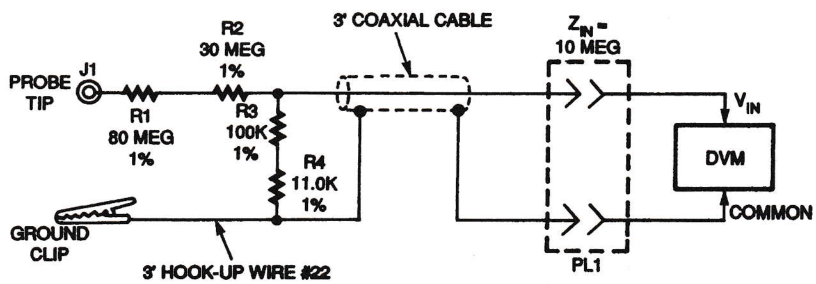
LOGIC PROBE CIRCUIT



ELECTRONIC EXPERIMENTERS HANDBOOK ***Fig. 87-5***

In this logic probe circuit, the red LED indicates logic high and the green indicates logic low. The optional use of an LED seven-segment readout is also shown.

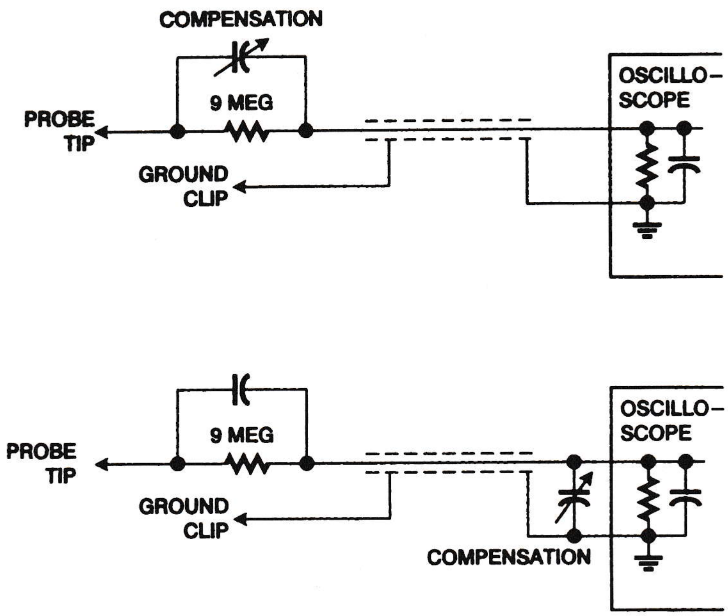
MINI HIGH-VOLTAGE PROBE



ELECTRONICS NOW ***Fig. 87-6***

The schematic diagram of the probe reveals its simple circuit. It is a standard voltage divider made up of resistors with a 1-percent tolerance. Resistors R1 and R2 are the key elements here. They are rated at 15,000 V and 10,000 V, respectively. The 7500-Vdc peak specification for the assembled probe must not be exceeded under any circumstances! The values for series resistors R3 and R4 are in parallel with the 10-MΩ resistance of the DVM, thus providing a 1000-to-1 voltage divider. Voltage measurements made by the probe should be multiplied by a factor of 1000. If your DVM uses an input impedance different from the standard 10 MΩ, you can adjust the R3/R4 series combination, as needed.

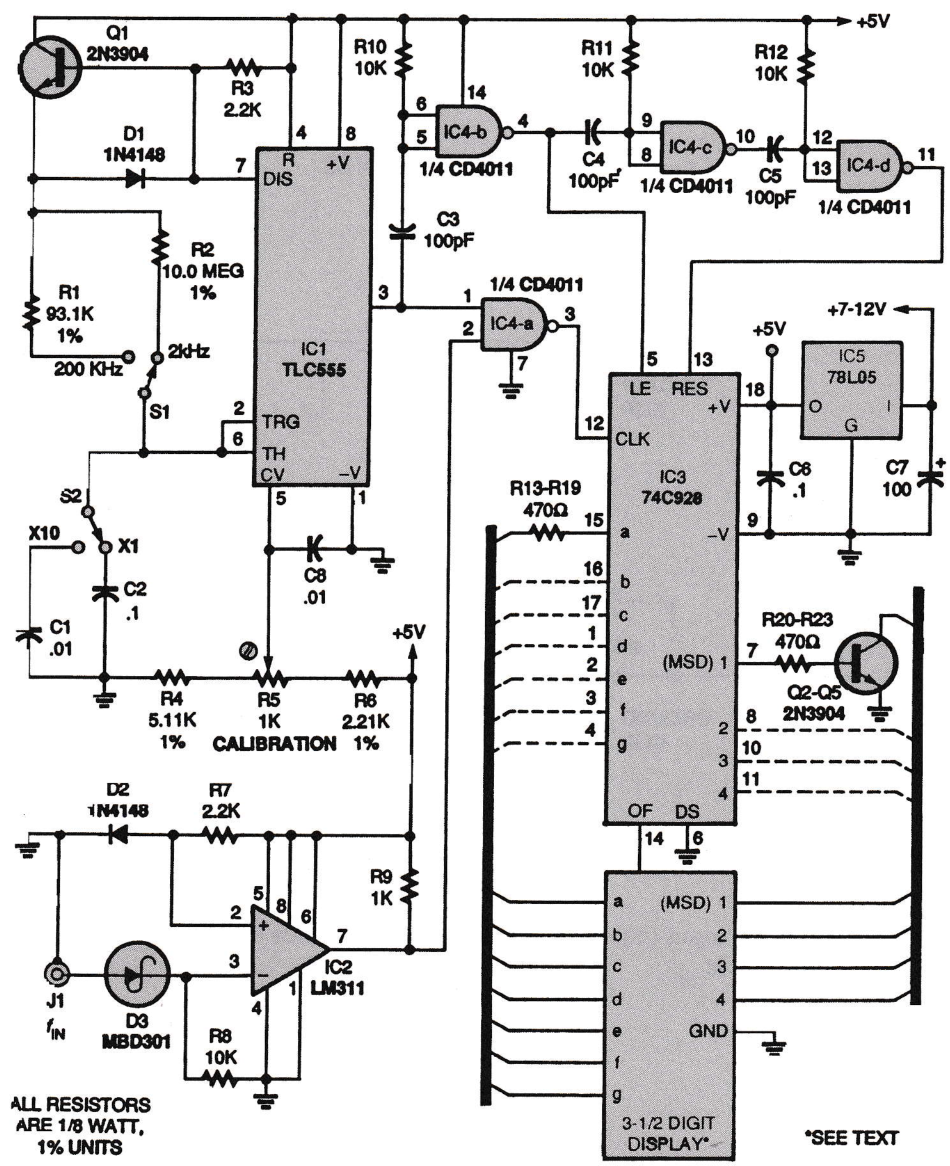
SCOPE PROBE CIRCUITS



ELECTRONICS NOW *Fig. 87-7*

Assuming a 1-MΩ scope input impedance and input capacitance C_{in}, $C_{compensation} = (R_{probe} / 1\ M\Omega)\ C_{probe}$ or $C_{probe} / C_{input} = R_{input} / R_{probe}$.

FREQUENCY PROBE

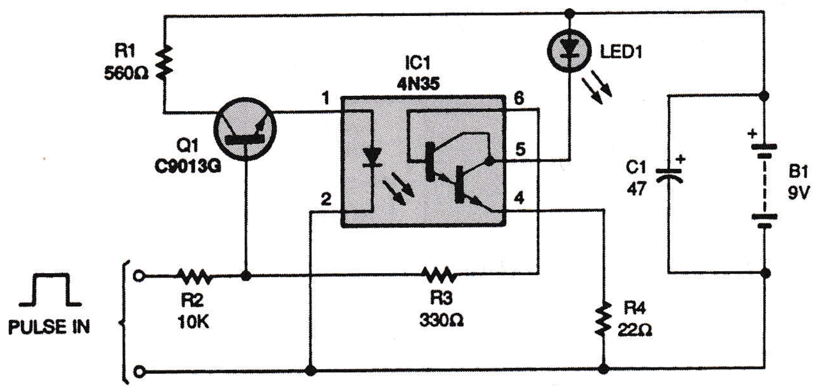


POPULAR ELECTRONICS

Fig. 87-8

This design is a simplified 3½-digit frequency counter with four ranges: 2000 Hz, 20.00 kHz, 200.0 kHz, and 2.000 MHz. An effort was made to miniaturize the circuit so that it would fit in a standard logic-probe-type case; the complete circuit was assembled on a perforated board cut down to 1×4¾ inches. The normal crystal time base with all its dividers was eliminated in favor of one eight-pin DIP: IC1, a TLC555 CMOS oscillator. It provides gate timings of 1000 ms, 100 ms, 10 ms, and 1 ms using R1, R2, C1, and C2 as the crucial timing components. Select C1 to be exactly 1/10 the value of C_2. Calibration is done with trimmer potentiometer R5. Integrated circuit IC2 (an LM311) provides input conditioning for any waveform of ±0.9 to ±30 V, whether triangle, sine, or square wave. Integrated circuit IC4 (a CD4011 or 74C00) provides proper pulse delays to IC3, a 74C928 3½-digit counter chip that directly drives a miniature 3½- or 4-digit, common-cathode LED display. The digit drivers shown, Q2 to Q5 and R20 to R23, can be replaced with a single DIP package (such as a 7549, 75492, etc.). A 78 regulator, IC5, provides the +5 V for the circuit, and is mounted on the board with the other components. It can be driven externally via a standard ac wall adapter of 7 to 12 V at 30 mA, or from a 9-V battery. Be sure to bypass the supply pins on each IC with a 0.1-μF monolithic capacitor for noise-free performance. When accuracy is important, a crystal-controlled time base should be used.

LOGIC PROBE

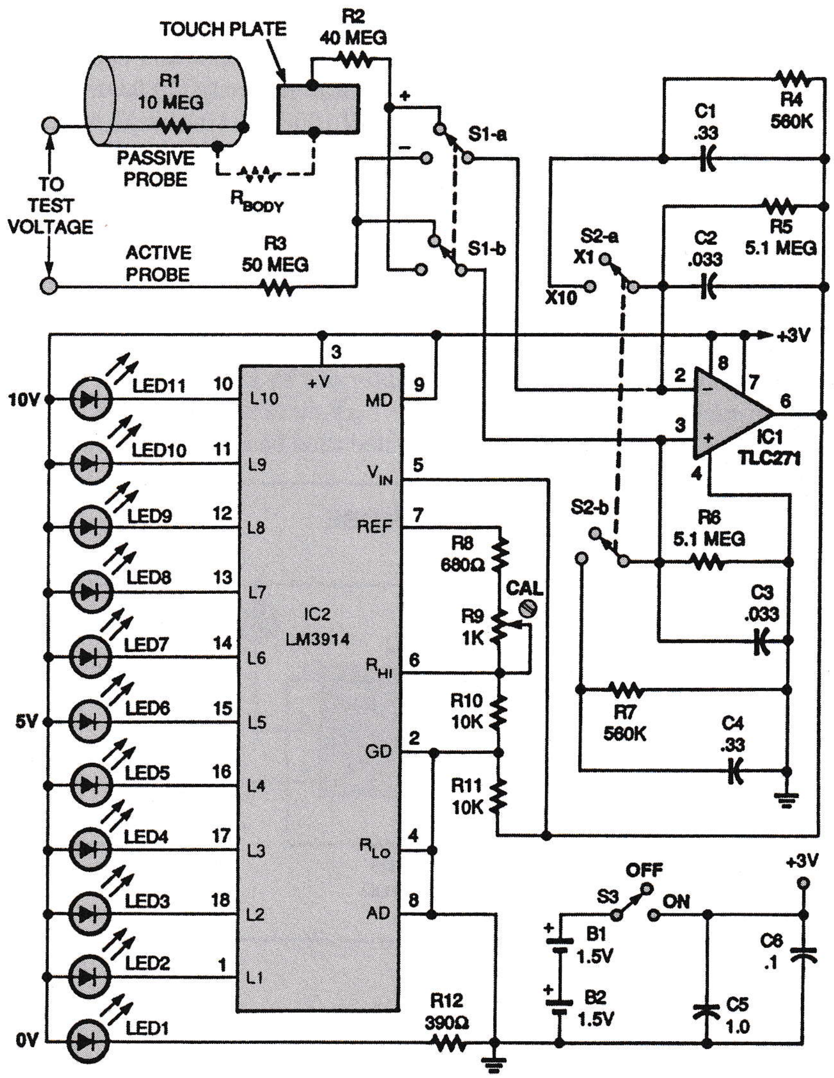


POPULAR ELECTRONICS

Fig. 87-9

The circuit uses a 4N35 optocoupler (IC1) and a C9013G transistor (Q1). A positive pulse at the base of Q1 turns on the transistor. The 10,000-Ω resistor (R2) limits the incoming pulse so as not to feed too much current to the base of Q1, preventing the transistor from being damaged. With the base of Q1 at a positive potential, electron current flows from the emitter to the collector junction. The incoming pulse also pulls pin 6 high, lighting up LED1 by allowing current to flow between pins 4 and 5. The 330-Ω resistor (R3) provides current limiting for pin 6, although R4 is the current limiter for pin 4. While testing a digital circuit, if the LED lights, that portion of the circuit is in a high state; if the LED remains off, a low is present. The circuit can be placed inside a small enclosure if its connections are made as short as possible.

WIRELESS DC PROBE

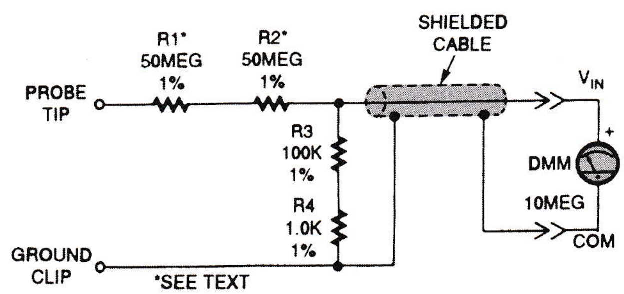


POPULAR ELECTRONICS

Fig. 87-10

This probe for low voltages only (<100 V) uses the body to complete the dc circuit in a novel way. The schematic for the dc voltmeter is shown. Power for the circuit is provided by two 1.5-V N-type cells, B1 and B2, which are wired in series. For the circuit to work, it must be completed or closed. That is accomplished when the passive probe is held in one hand and the active probe is held in the other and the points of the two probes are placed across two points in a circuit under test. The resistor labeled R_{body} is simply the resistance of the user's body. For R_{body} to be "swamped out," or kept from interfering with the reading, extremely high input-circuit impedances are used in the circuit. All of the people tested by the author for this project indicated a body resistance from hand to hand in the range of 200,000 to 500,000 Ω. Therefore, an input impedance of 50 MΩ, resistor R3, was added. That also provided an adequate safety isolation feature. The reduction of RFI and 60-Hz pickup is accomplished by the use of a symmetrical difference amplifier (IC1) at the input; the inherent common-mode rejection takes care of most the ac-related problems. The amplifier used for IC1 is a TLC271 CMOS op amp. Switch S1 is used to select polarity. Note that 50 MΩ of resistance are present at both of IC1's differential inputs (R3 at one input and the combined series resistance of R1 and R2 at the other). The user is placed in series with the 100-MΩ loop containing a 10-MΩ resistor (R1) as the protective device in the passive-probe section. Capacitors C1 to C4 provide additional filtering of residual ac noise and allow IC2, an LM3914 bar-graph display driver, to step up sequentially. Switch S2 selects between two selectable input ranges: X1, where each step equals 1 V, and X10, where each step equals 10 V. The display is made up of LED1 to LED11; LED2 through LED11 indicate the individual steps. LED1, the 0-V indicator, is also the power-on indicator.

HIGH-VOLTAGE PROBE



POPULAR ELECTRONICS *Fig. 87-11*

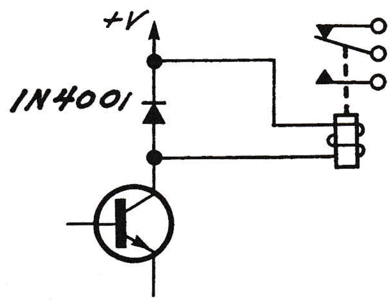
This high-voltage probe allows your DMM to take high-voltage measurements to 10,000 V peak, and acts as a high-impedance (100-MΩ) probe for high-impedance circuit testing. The probe was designed to plug into a standard 10-MΩ input DMM. If your DMM has a different input, you can change R3 and R4 to suit it. The ratio of $R_1 + R_2 + R_3 + R_4$ should be exactly 1000 to 1; thus, a 10.00-V input will read 10.00 mV on your DMM. Keep in mind that the impedance of your DMM is in parallel with R_3/R_4 when you calculate new values.

88

Protection 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.

DIODE RELAY DRIVER PROTECTION

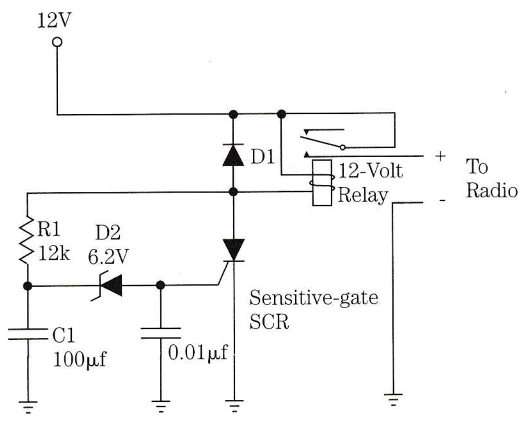


ELECTRONICS NOW

Fig. 88-1

The diode protects the switching transistor from the voltage spike caused by the relay coil.

DELAYED ACTION MOBILE RADIO-PROTECTION CIRCUIT

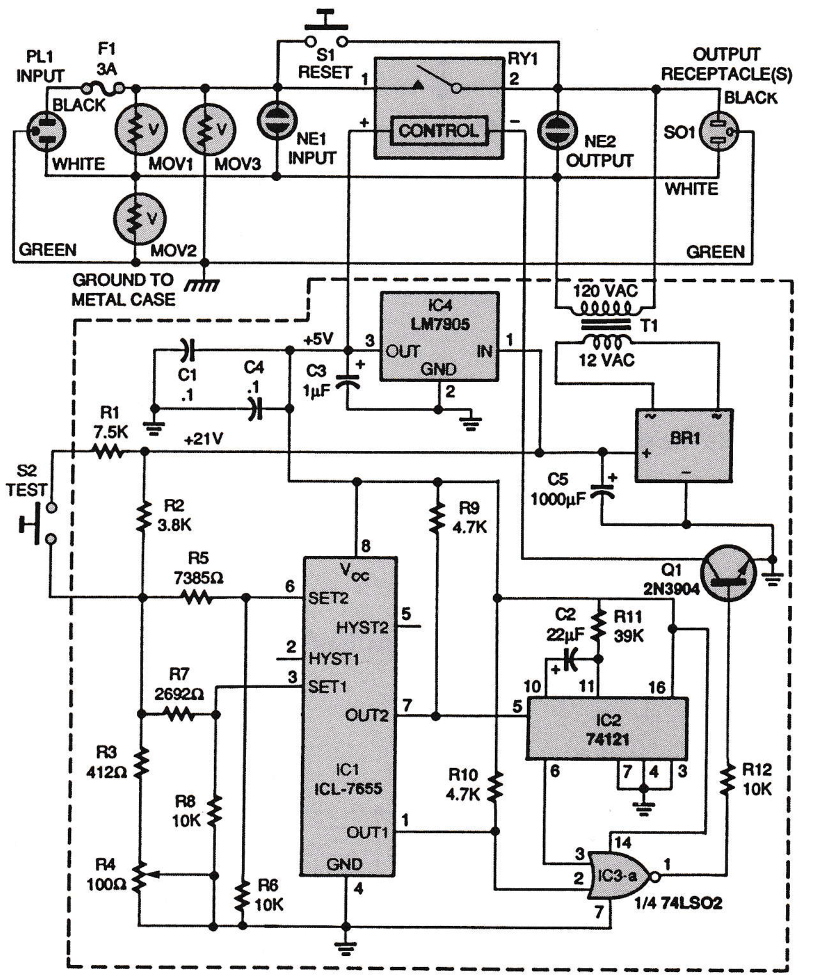


NUTS AND VOLTS

Fig. 88-2

This circuit uses an SCR and an RC circuit to delay application of power to a mobile radio or other equipment. This is to provide protection from starting motor- and alternator-induced transients.

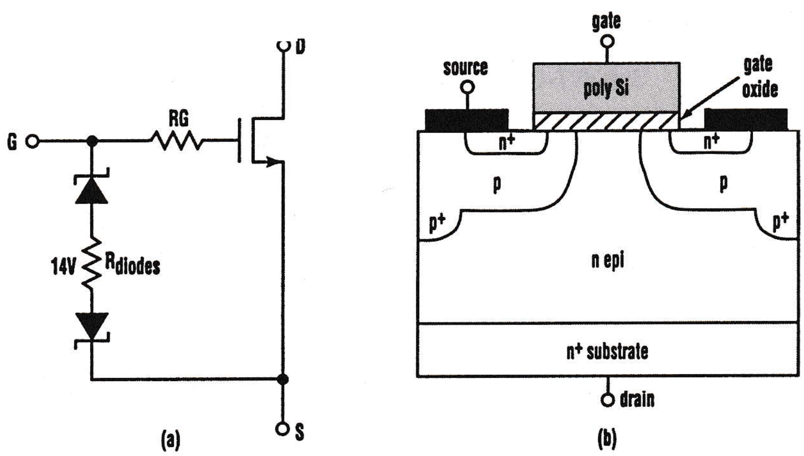
OVER/UNDERVOLTAGE PROTECTOR



ELECTRONICS NOW *Fig. 88-3*

The ICL7665 over/undervoltage detector manufactured by Maxim (IC1) monitors the line voltage and disconnects the load if the input voltage goes below 95 V or above 130 V. The over/undervoltage detector (IC1) monitors the filtered, unregulated dc voltage developed across C5, which changes with the input line voltage. The input voltage levels to IC1 are set by resistors R2 through R8. As long as the voltage at pin 3 is above 1.3 V and the voltage at pin 6 is lower than 1.3 V, both outputs (pins 1 and 7) are low and RY1 is turned on and its contacts are closed. The average line voltage varies at different locations. Trimmer potentiometer R4 provides a small adjustment range so that you can set the window's center for your particular line voltage. When IC1 detects an overvoltage at pin 3, it immediately opens the relay by sending a high output to pin 2 of NOR gate IC3-a, which, in turn, turns off Q1. When IC1 detects an overvoltage at pin 6, the output at pin 7 goes high. Monostable multivibrator IC2 provides a ½-s delay to keep RY1 turned off long enough for the voltage across C5 to return to normal. When pin 7 of IC1 goes high, it triggers IC2, and the high output at pin 6 of IC2 causes the output of NOR gate IC3-a to go low, which turns Q1 off and deenergizes RY1. Switch S2 lets you quickly check the circuit's operation at any time. Pushing S2 raises the voltage at the junction of R2 and R5 and turns RY1 off. RESET switch S1 restores normal operation. Switch S1 turns the circuit on initially. An LM7805 voltage regulator (IC4) provides a constant 5-V supply for the integrated circuits and the relay control current.

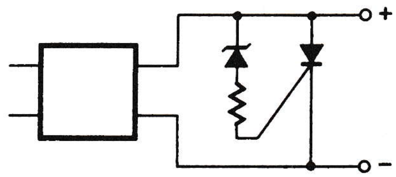
ELECTROSTATIC PROTECTOR



ELECTRONIC DESIGN ***Fig. 88-4***

A simple way to protect the gate of a power MOS device is to place back-to-back zener diodes between the device's gate and source (*a*). The breakdown voltage of the zeners is chosen to be less than the oxide-rupture voltage so that the ESD transient cannot harm the gate. The resistance of the clamp diodes must be kept to a minimum because ESD transients can have high peak currents (in amps), and the voltage appearing at the gate will be the sum of the zener breakdown voltage and the IR voltage drop across the diode resistance. The machine model (MM) is particularly stressful because there is no resistance to limit the current. Along with the diodes, the resistor (R_G) is added to improve MM performance. R_G prevents the gate of the MOSFET from charging to a dangerous voltage level during the time the ESD transient is dissipated by the diodes. A machine model here is defined as a 200-pF capacitor with no series resistance.

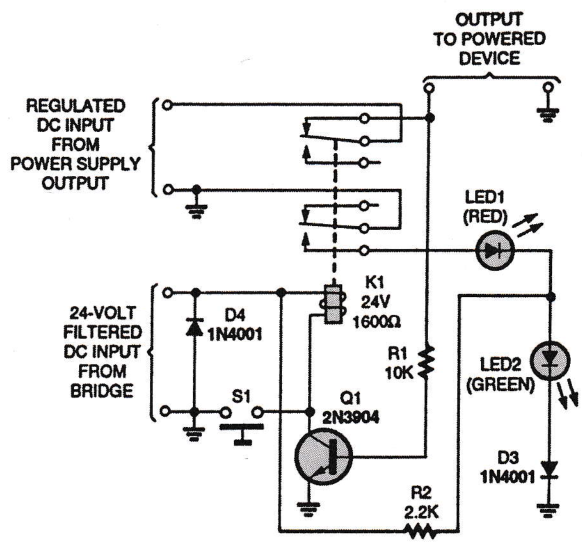
SIMPLE CROWBAR CIRCUIT



NUTS AND VOLTS *Fig. 88-5*

This circuit uses a zener diode and an SCR. When the supply voltage exceeds the zener breakdown voltage plus the gate turn-on voltage of the SCR, current flows in the gate circuit, turning on the SCR and effectively shorting the supply. A fuse is generally placed in the supply line; it is designed to blow when the SCR fires, protecting and shutting down the supply.

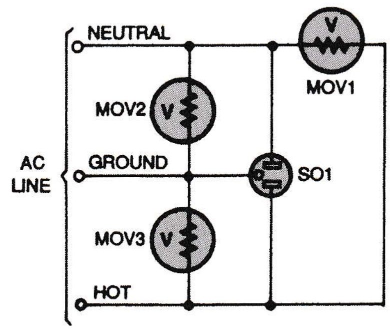
SHORT-CIRCUIT SHUTDOWN CIRCUIT



POPULAR ELECTRONICS *Fig. 88-6*

When a short or severe undervoltage develops, Q1 is cut off, deenergizing Q1, and disconnecting the load from the power supply.

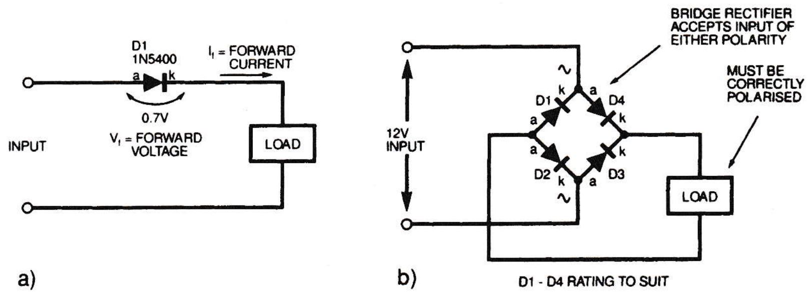
MOV SURGE-PROTECTION CIRCUIT



POPULAR ELECTRONICS *Fig. 88-7*

Three MOV devices (connected as shown) provide superior protection against line surges because all three legs are protected against excessive potential differences.

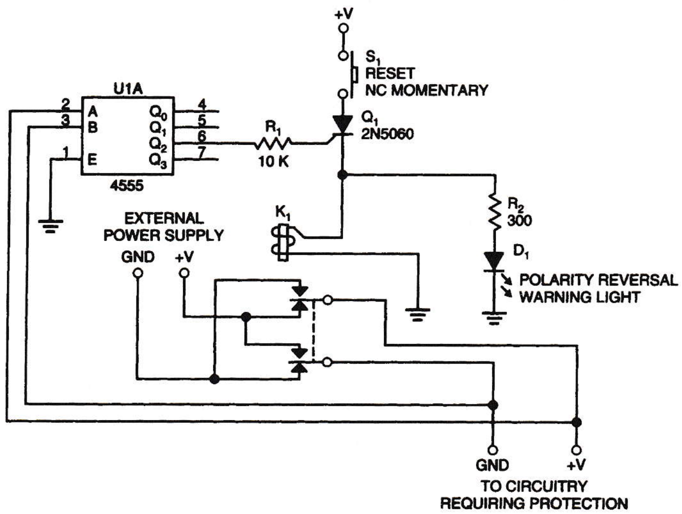
SIMPLE REVERSE-POLARITY PROTECTION CIRCUITS



EVERYDAY PRACTICAL ELECTRONICS *Fig. 88-8*

Two methods to avoid damage to circuitry from reverse voltages using diodes are shown.

REVERSED-POWER-SUPPLY PROTECTOR CIRCUIT

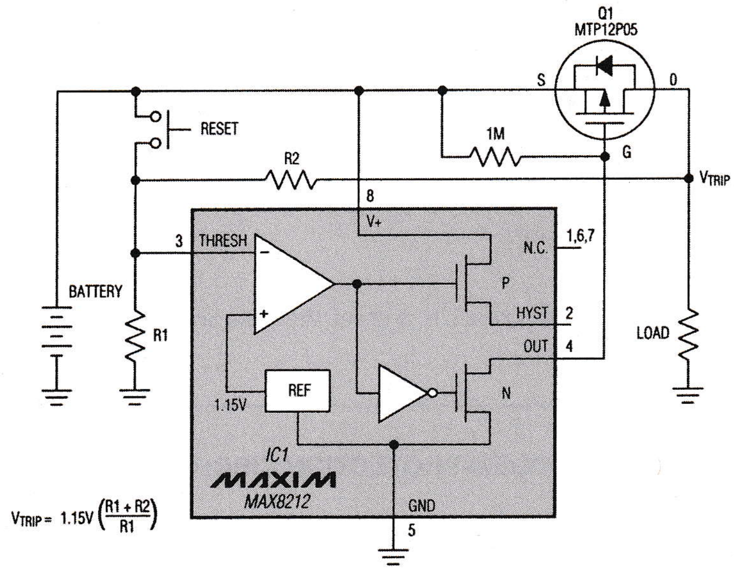


NASA TECH BRIEFS

Fig. 88-9

This circuit is designed to sense a power-supply output (to other circuitry) and detect a reversed-polarity condition. The circuit consists of a complementary metal-oxide semiconductor (CMOS) decoder (CD4555B), which monitors the output of an external power supply for proper polarity. If the power-supply polarity is incorrect, the CD4555B detects that condition and triggers a 2N5060 SCR (Q1). After triggering, the SCR supplies current to a relay (K1), which, upon activation, changes the external power-supply connections (to the external circuitry) to the correct polarity and illuminates a light-emitting diode (LED) to provide a visual warning of the polarity-reversal condition. After the reversed-polarity condition is remedied, pressing the contact switch (S1) momentarily will reset the circuit to its original state. In its present configuration, the circuit can accommodate standard positive power supplies with dc voltages of +5, +10, +12, and +15 V. The decoder was designed to operate at these different voltages. With some modifications, the circuit can monitor and correct anomalous power-supply outputs from +3 V, +28 V, or negative-polarity power supplies, or voltages that are either too high or too low.

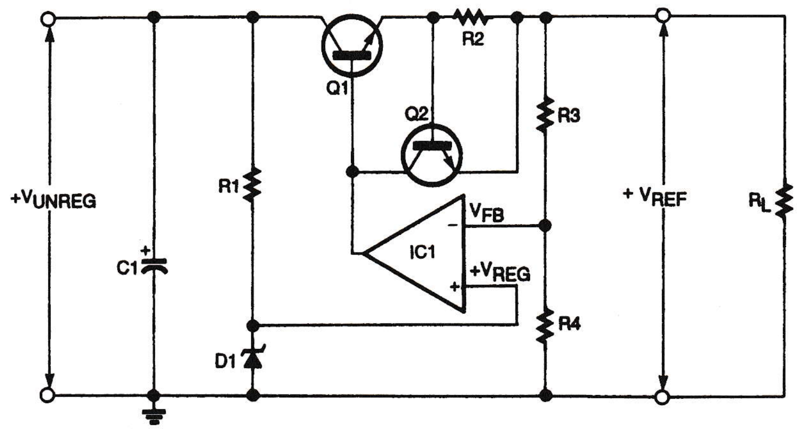
SIMPLE CIRCUIT TO DISCONNECT LOAD FROM BATTERY



MAXIM ***Fig. 88-10***

To prevent battery damage, the circuit disconnects the load at a predetermined level of load voltage. This level (V_{trip}, closely proportional to the battery voltage) is determined by R1 and R2 so that the voltage at pin 3 of IC1 equals 1.15 V: $V_{trip} = 1.15\ V(R_1 + R_2) / R_1$. The allowed range for V_{trip} is 2 V to 16.5 V. The load-battery connection remains open until the system receives a manual reset command. Pressing Reset (or pulling pin 3 above 1.15 V with a transistor) reconnects the load after the battery is recharged or replaced. Battery drain with the load disconnected is only 5 μA, so the circuit can remain in that state for an extended period without causing a deep discharge of the battery. Choose Q1 for a minimal voltage drop (source to drain) at the required load current.

POWER-SUPPLY PASS-TRANSISTOR PROTECTION CIRCUIT

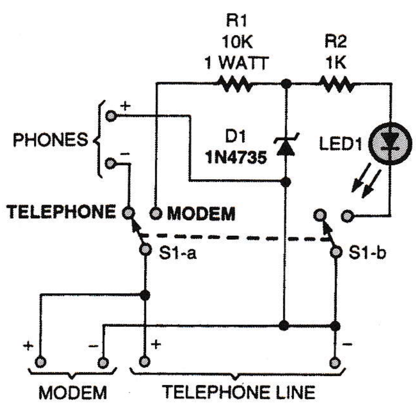


ELECTRONICS NOW

Fig. 88-11

A current-limiting transistor and resistor protect the pass transistor and rectifier bridge in this linear supply.

MODEM-PROTECTION CIRCUIT

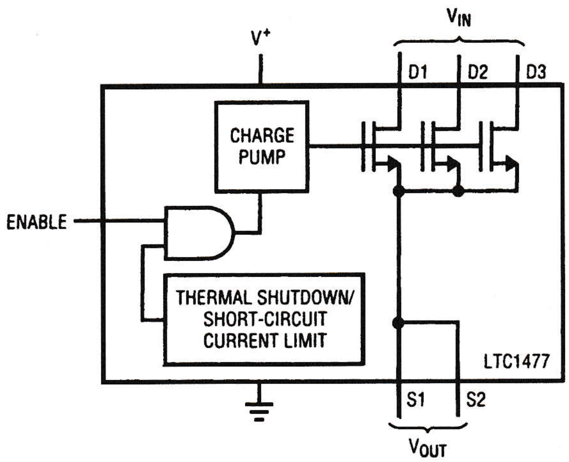


POPULAR ELECTRONICS

Fig. 88-12

A common problem in modem communications is that family members often pick up extensions during a modem call. Forget about having your downloads messed up by someone lifting a phone. This circuit completely disconnects all phones on a line when you are using a modem.

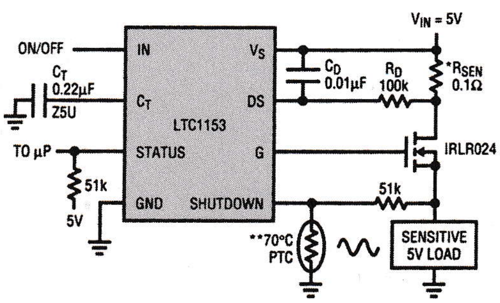
UNDERVOLTAGE DISCONNECT SWITCH

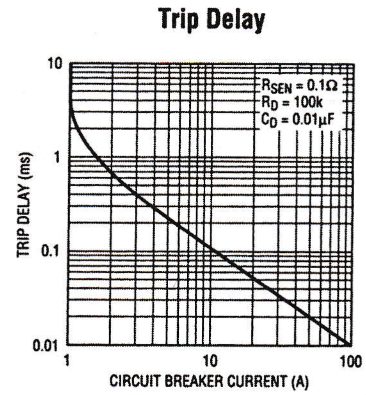


LINEAR TECHNOLOGY ***Fig. 88-13***

In an effort to conserve energy, simple shutdown schemes are incorporated into many battery-operated circuits. Not all circuits lend themselves to direct control, however. Instead, the supply must be turned off by a switch. The LTC1477 high-side switch is designed for this purpose and includes short-circuit current limiting and thermal shutdown to guard against faulty loads. The figure shows the LTC1477 and LTC699 conjoined in an undervoltage disconnect application. The LTC699 microprocessor supervisor disables the LTC1477; hence, the load is disabled whenever the input voltage falls below 4.65 V. An external logic signal applied to the gate of Q1 can also disable the LTC1477. When enabled, the LTC1477 output ramps over a period of approximately 1 ms, thereby limiting the peak current in the load capacitor to 500 mA. This prevents glitches on the 5-V source line that might otherwise affect adjacent loads.

ELECTRONIC CIRCUIT BREAKER



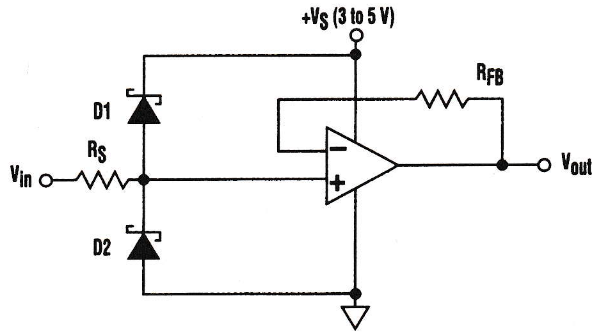


ALL COMPONENTS SHOWN ARE SURFACE MOUNT.
* IMS026 INTERNATIONAL MANUFACTURING SERVICE, INC. (401) 683-9700
** RL2006-100-70-30-PT1 KEYSTONE CARBON COMPANY (814) 781-1591

LINEAR TECHNOLOGY *Fig. 88-14*

Fault conditions can quickly put stress on power sources and also on the loads themselves. Without a protective device to interrupt power during fault conditions, the supply can be overloaded or a load can overheat. The LTC1153 is a high-side MOSFET switch controller device with built-in circuit breaker, which turns off the MOSFET switch in the event of a fault. There is a built-in automatic reset, along with an input for thermal shutdown. The trip delay and reset times are fully adjustable. Because of its low (20 μA max) standby current, the LTC1153 can also be used in battery-powered equipment to protect the battery without reducing battery life. The switch can also be controlled with logic input. A status indicator reports fault conditions to a processor.

AMPLIFIER PROTECTOR

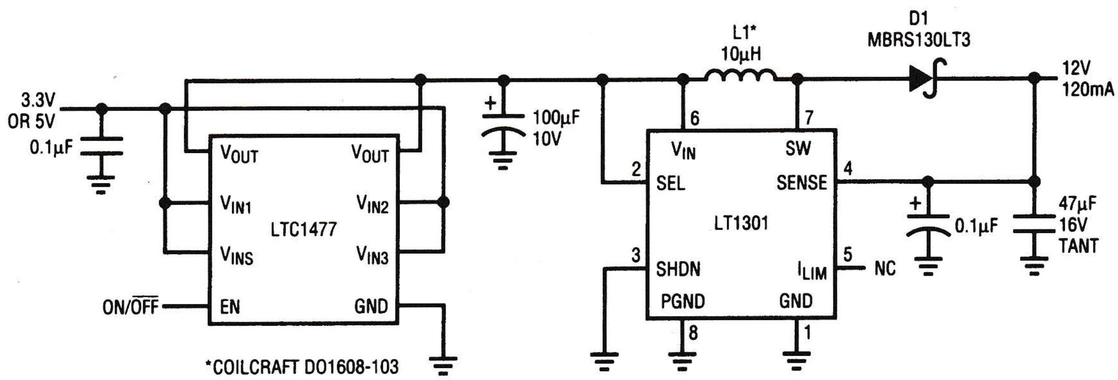


ELECTRONIC DESIGN

Fig. 88-15

Unprotected amplifiers in noninverting, single-supply, voltage-follower stages might need external protection if input signals can exceed the rail voltages. Low-threshold Schottky diode clamps D1 and D2 provide safe clamping while R_S limits the fault current.

SHORT PROTECTION AND SHUTDOWN CIRCUIT

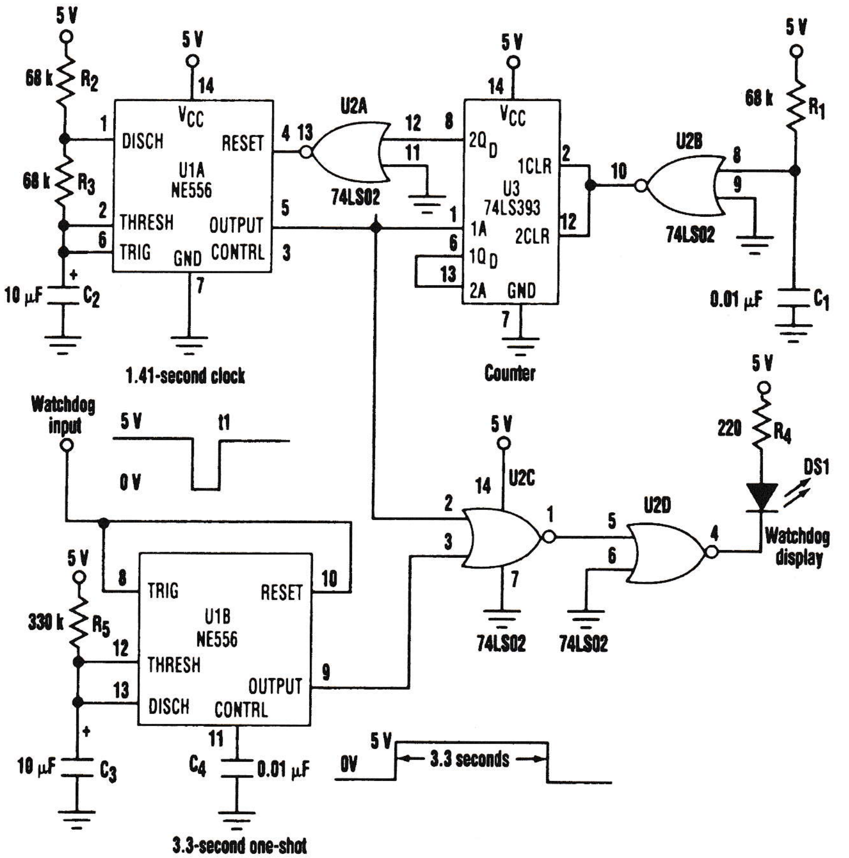


LINEAR TECHNOLOGY

Fig. 88-16

An LT1301 is used in the figure to boost a 3.3-V or 5-V input to 12 V, as for V_{PP} for flash memory. Although the LT1301 features a shutdown control, the input supply can still feed through to the output through L1 and D1. Similarly, a short circuit on the output could drag down the input supply. With the addition of the LTC1477, the circuit furnishes 100-percent load shutdown and output short-circuit protection.

FAILURE MONITOR

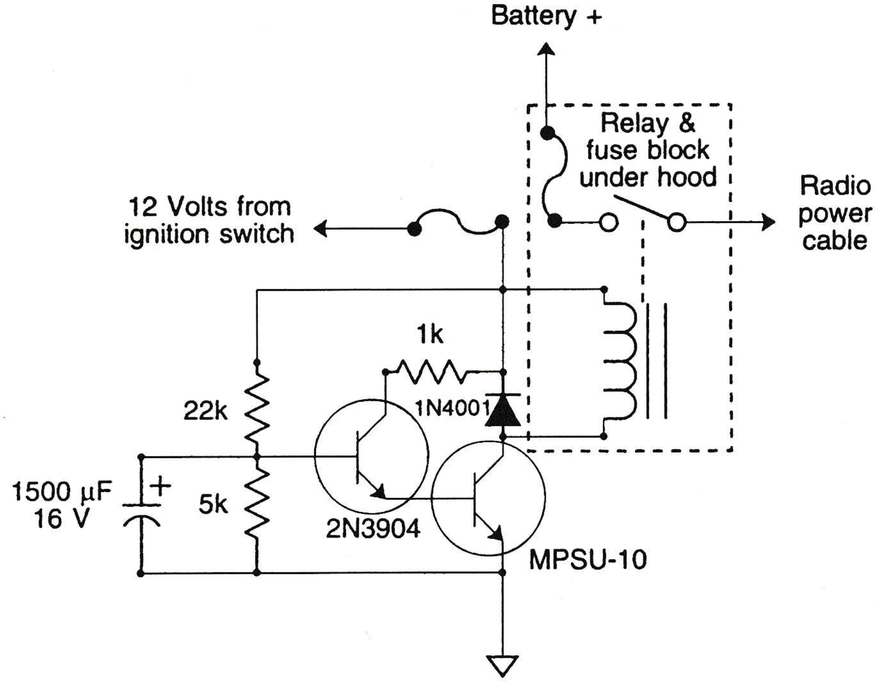


ELECTRONIC DESIGN *Fig. 88-17*

Some time ago, a situation arose in which a watchdog timer was needed to monitor an embedded computer. The computer in question required approximately 2½ minutes to boot up and run the application software, so a monitor circuit was created that could wait 3 minutes before indicating failure. U1A, U2A, U2B, and U3 form a 3-minute timer. U1A operates as a free-running oscillator with a period of 1.41 s. The square-wave pulses are counted by U3, which generates an oscillator reset via U2A that effectively stops the clock. During the 3-minute interval, U2C and U2D send the oscillator signal to DS1, causing the indicator to flash. This flashing shows that the equipment is in its power-up cycle. When the reset occurs, the output of U1A is held low. U2B is a power-up reset for the counter. After 3 minutes, the indicator will come on continuously unless the watchdog input signal is present. U1B is configured as a 3.3-s-duration one-shot. When the watchdog input is pulsed low, the output switches high and keeps the LED from turning on. If the next pulse is not received in at least 3.3 s, the output will remain low. As a result, the LED will turn on, indicating failure. Should the watchdog input begin pulsing prior to the 3-minute timer, the watchdog will take precedence and turn off the flashing LED.

What happens if the watchdog circuit fails? One of the characteristics of the NE556 timer is the inability to fully discharge the timing capacitor if the timer is retriggered prior to finishing a timing cycle. Applying a 10-Hz, 100-ms-wide pulsed input to the watchdog causes the capacitor charge to accumulate for approximately 8 s. This results in a 100-ms "heartbeat" flash of the LED every 8 s, which indicates that the circuit is still alive and that the LED hasn't burned out. The watchdog input is generated by an I/O line of the computer. Depending on the I/O board's design, the signal might need to be inverted to allow the watchdog input to remain normally high.

SIMPLE MOBILE RADIO PROTECTOR



73 AMATEUR RADIO TODAY *Fig. 88-18*

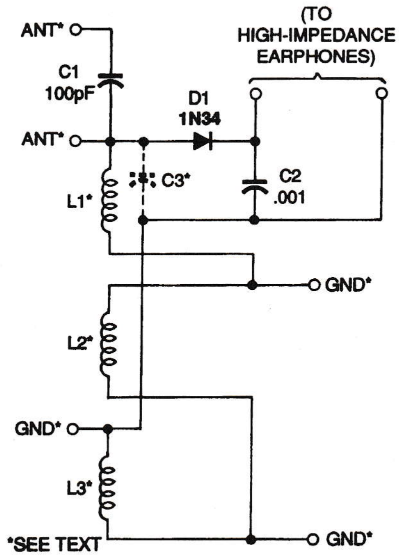
This circuit supplies power to a mobile radio only when the ignition is on and has a delay feature to prevent energizing the radio until the key has been on for several seconds, to avoid spikes and possible transients from the starter motor.

89

Receiving 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.

VARIOMETER RADIO

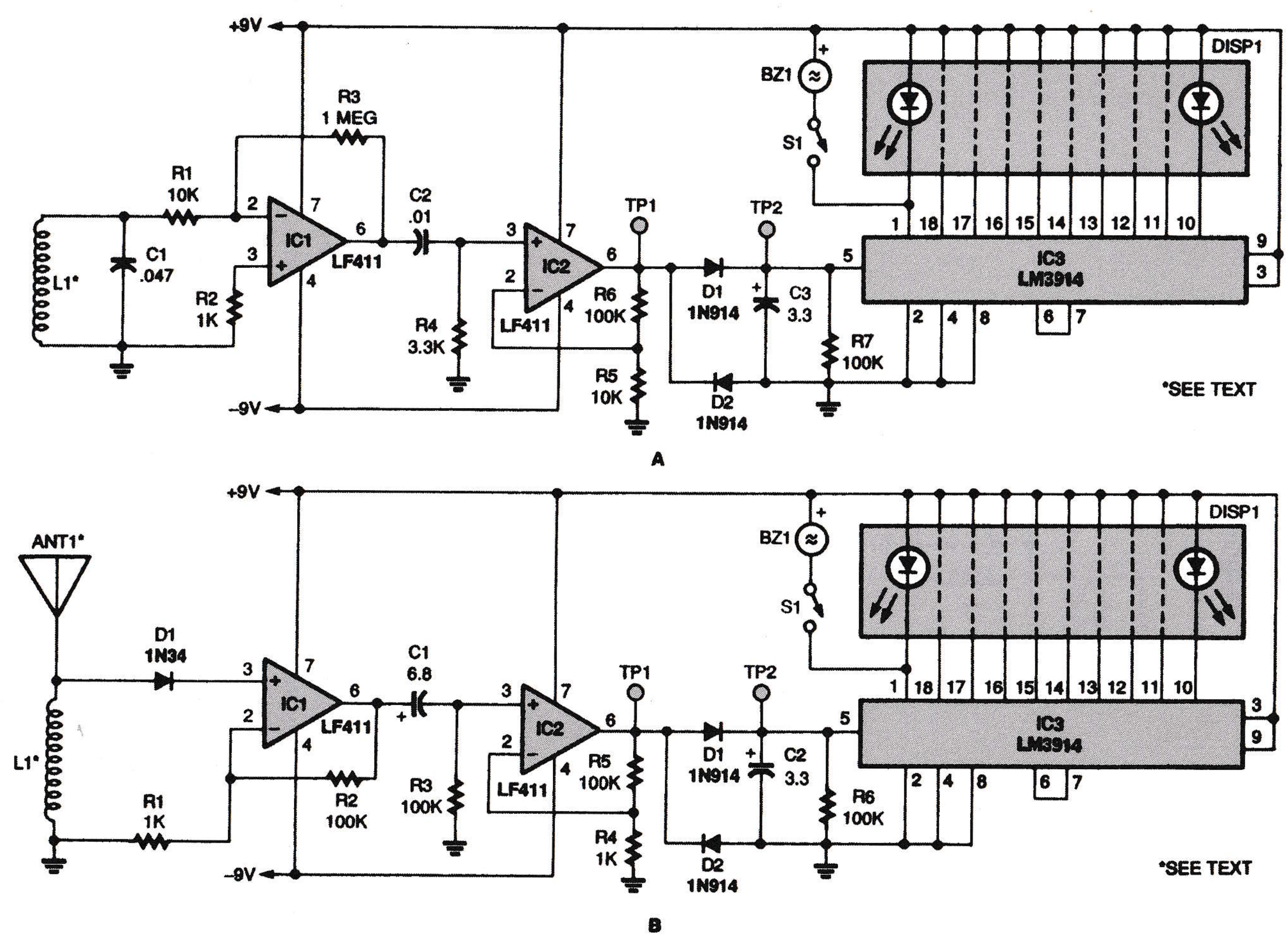


ELECTRONICS HOBBYISTS HANDBOOK

Fig. 89-1

The schematic of the complete variometer radio is shown in the figure. An antenna can be connected to the radio through either of the two points labeled *ANT*: either directly to the circuit or through a 100-pF capacitor. The ground connection can be made at any of the points marked *GND*. There is a reason for the preceding options: By varying the antenna capacitance, the ground connection, and the position of the sliding coil, the entire AM broadcast band can be tuned. Depending on the antenna and ground connections, it might be necessary to add a small capacitor, C3, at the point indicated in the schematic. If so, experiment with values between 25 and 200 pF (separately or in parallel) to find which gives the best result. If you build the variometer using Fahnestock clips (as explained later), adding the capacitor(s) after the radio is built if the need arises should be easy. When a signal is selected by adjusting the antenna, ground connection, and position of L2, the signal is passed on to the diode-detector part of the circuit, composed of D1, which demodulates the signal. The signal then goes through bypass capacitor C2 to the earphones. Only high-impedance earphones should be used with the variometer. L1 and L3 are 86 turns of #22 wire on a 1.25-inch form, and L2 is 74 turns of #22 wire on a 1.75-inch form.

VLF/HF LIGHTNING DETECTOR RECEIVER



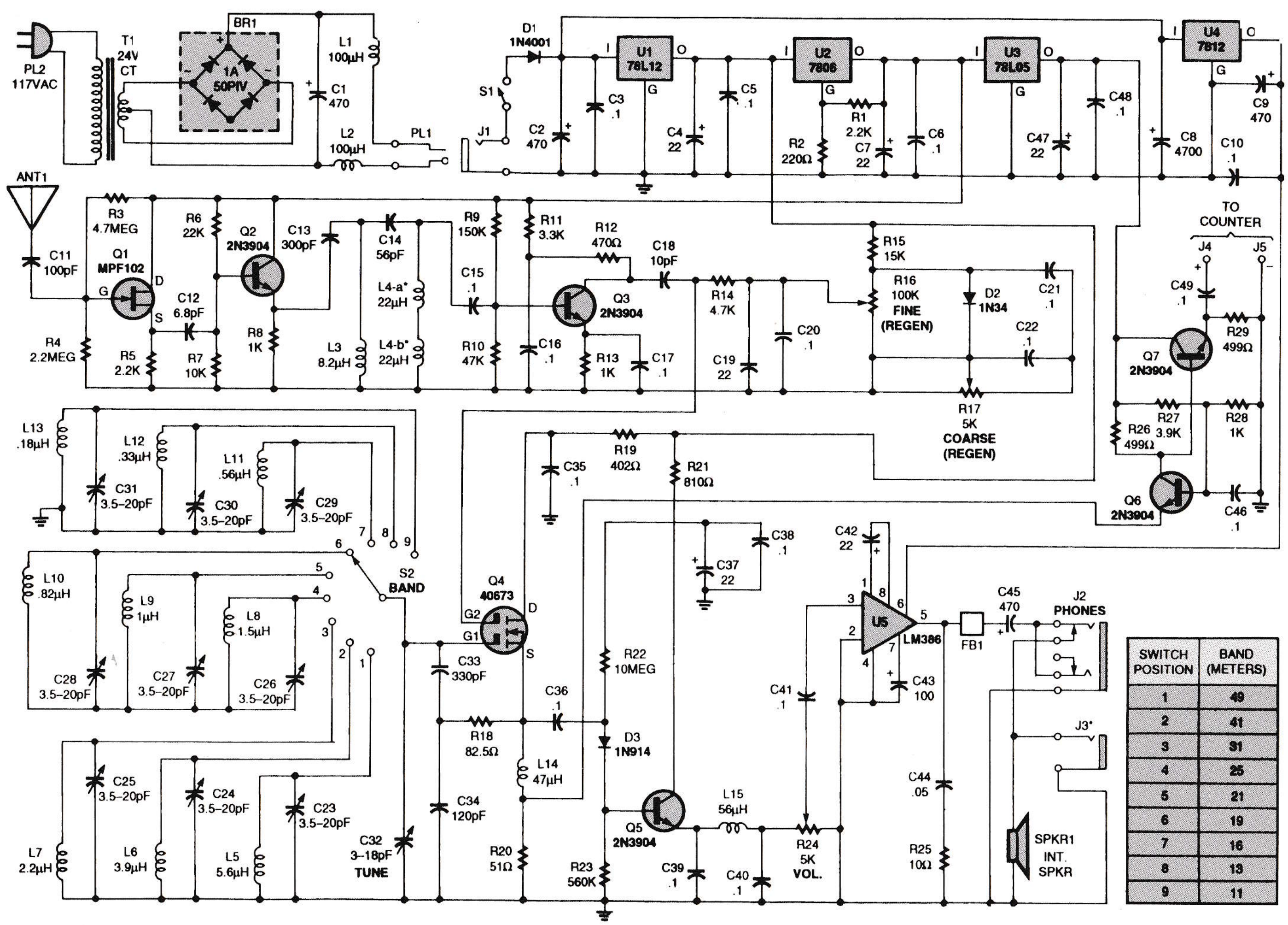
POPULAR ELECTRONICS

Fig. 89-2

VLF/HF LIGHTNING DETECTOR RECEIVER *(Cont.)*

It is known that cloud-to-ground lightning strikes produce far more VLF emissions than cloud-to-cloud strikes. By monitoring both VLF and HF, lightning can be analyzed for such things as strikes per flash, leader steps, amplitude or relative range, and the ratio of cloud-to-ground to cloud-to-cloud discharge. This pair of simple receivers separately monitor both VLF and HF. Note that they are both extremely similar, except for their respective antenna coils. The VLF-antenna coil, L1 in Fig. A, is made of 94 turns of #33 magnet wire wound on an 11-inch-diameter cardboard disk. The HF-antenna coil, L1 in Fig. B, is a common RF choke, or about 100 turns of very fine magnet wire on a ½-inch-long ferrite core (any similar junkbox choke should do). Antenna ANT1 is a 6-inch wire antenna. The first LF411 FET op amps (IC1 in both circuits) are preamps. The second LF411s (IC2 in both) add more gain. Test point 1 in either circuit can be used to connect high-impedance headphones or an oscilloscope. Test point 2 in either circuit is for a connection to chart recorders or event counters. The outputs of both circuits go to LM3914 bar-graph display drivers (IC3 in both circuits), which power both LED bar graphs (DISP1 in both) and low-voltage piezo buzzers (BZ1, again in both receivers). The negative leads of the buzzers, while shown connected to pin 1, can be connected to any of the bar-graph outputs. Both circuits are powered by split supplies.

REGENERATIVE SHORTWAVE RECEIVER



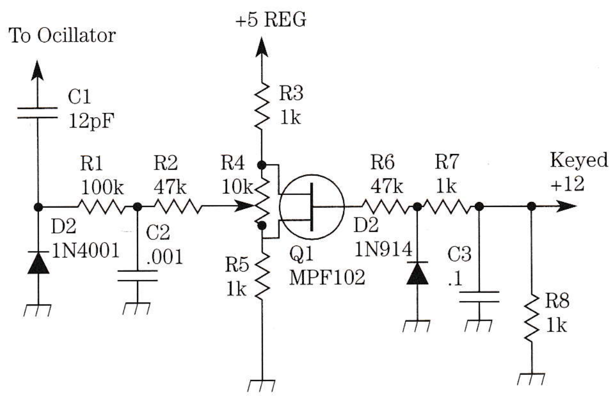
SWITCH POSITION	BAND (METERS)
1	49
2	41
3	31
4	25
5	21
6	19
7	16
8	13
9	11

POPULAR ELECTRONICS

Fig. 89-3

The receiver is composed of several subassemblies: an active antenna, an amplifier (with a regeneration control and band-switching circuitry), an AM detector, a power amplifier, and some form of output device (internal speaker, external speaker, or phones), plus a multivoltage power supply. The schematic diagram of the receiver is shown in the figure, a dual-gate MOSFET, Q4 (which is analogous to a pentode vacuum tube), is used as the regenerative amplifier. The dual-gate MOSFET is configured as a Colpitts oscillator, rather than an Armstrong type. The MOSFET's feedback from source to gate is provided via R18 and C33. The circuit contains several standard fixed-value inductors, each of which is connected in parallel with a small variable capacitor. Those LC pairs along with a SP12T rotary switch (S2) are used for band selection. Regenerative amplification and AM detection are performed by two separate transistors, Q4 and Q5. The AM detector (which is called an *infinite-impedance detector*) has the advantage of not loading the RF stage appreciably. Because D3 is operated with a slight forward bias, either a germanium or a silicon diode can be used in that position. The dc voltage across R24 (the volume control) should be about 0.1 V. Regeneration is controlled by varying the voltage applied to gate 2 of Q4. The circuit also contains fine and coarse regeneration controls that allow delicate adjustments. The receiver uses an active-antenna circuit, consisting of transistors Q1, Q2, and Q3. Under most conditions, a short whip antenna is adequate.

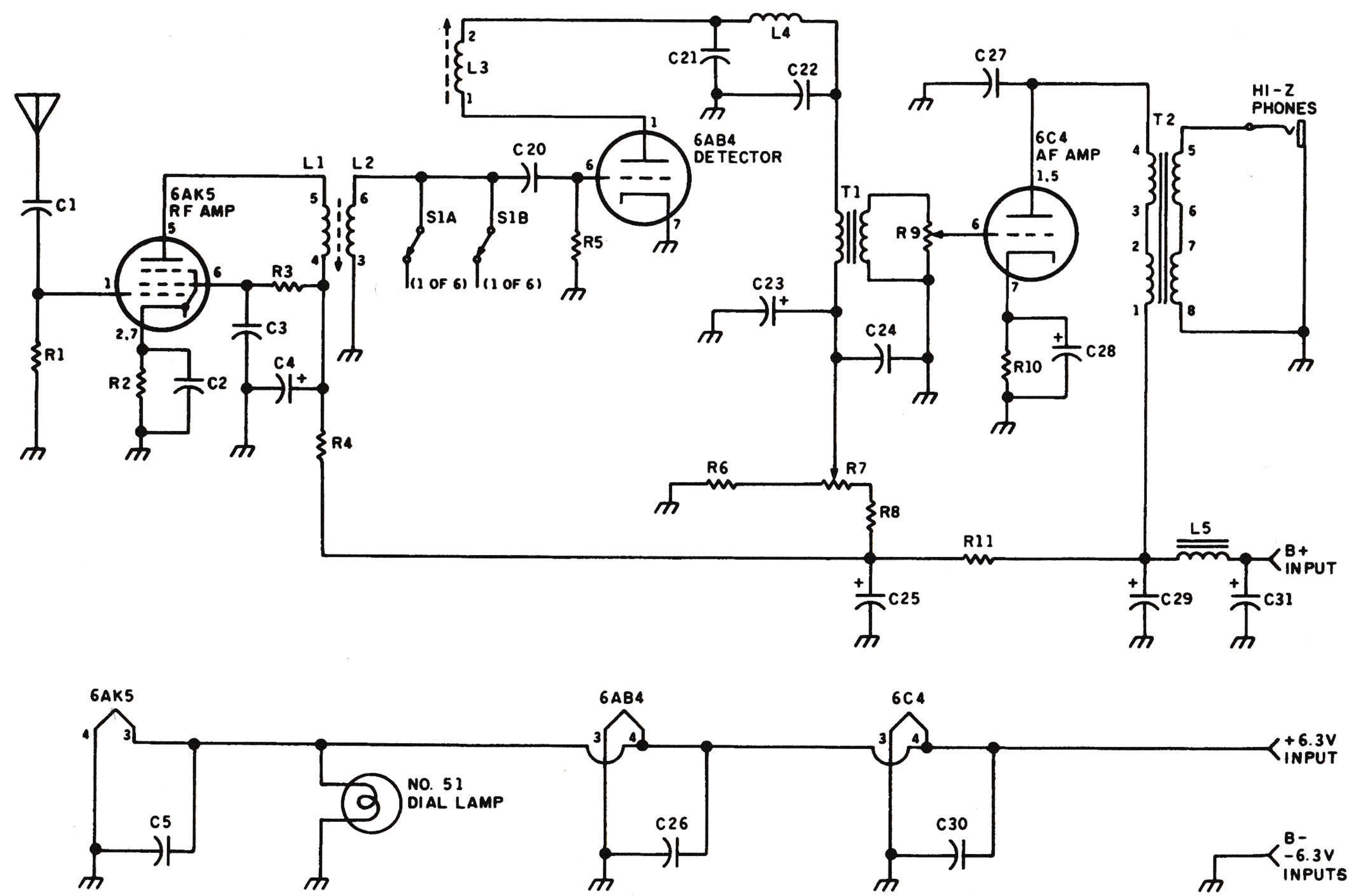
RECEIVER INCREMENTAL TUNING CIRCUIT

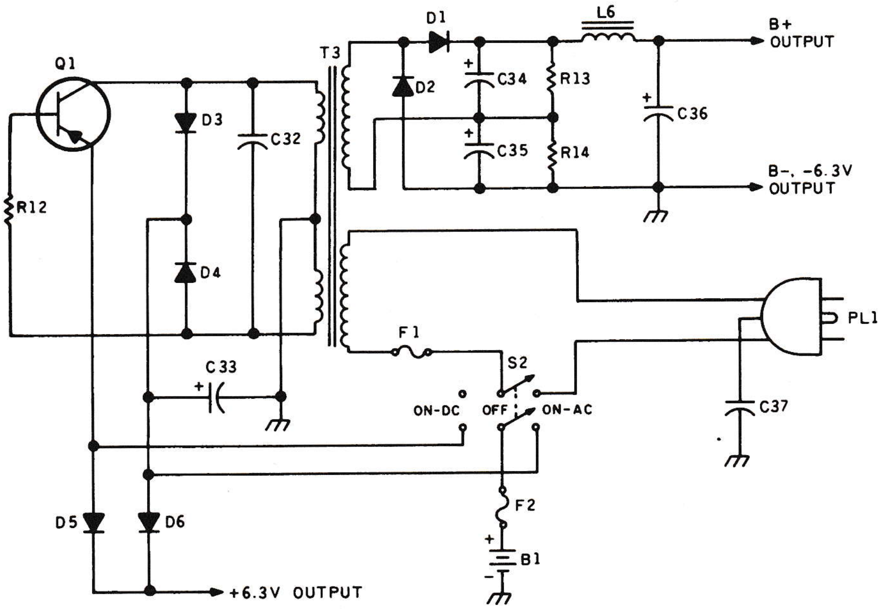


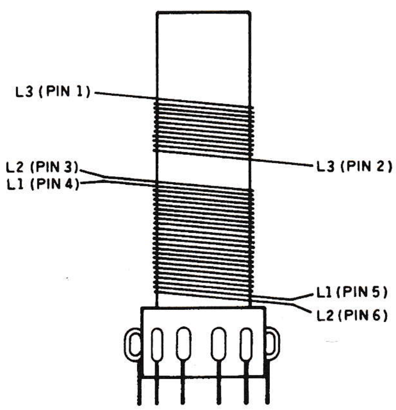
73 AMATEUR RADIO TODAY ***Fig. 89-4***

D1 acts as a varactor diode coupled to the transceiver or receiver LO tuning circuit. On receive, Q1, the MPF102, is cut off and the varactor voltage is controlled by the 10-kΩ pot. On transmit, Q1 conducts; this effectively shorts the 10-kΩ pot, placing a fixed voltage on the varactor diode.

VACUUM-TUBE SW RECEIVER







L1- 14 TURNS, CLOSEWOUND BETWEEN L2 TURNS.
L2- 15 TURNS, SPACED BY L1.
L3- 12 TURNS, CLOSEWOUND, WINDING SPACED 1/8" FROM TOP OF L1/2.

* USE NO.26 ENAMELLED WIRE FOR ALL 3 INDUCTORS.

** CORE IS 1/4" DIA. BY 1 1/8" LONG PHENOLIC, WITH 2 FERRITE SLUGS. CORE BASE SECTION IS 1/2" DIA. BY 3/8" LONG, WITH 6 SOLDER LUGS IMBEDDED.

This vacuum-tube receiver covers from 9.4 to 22 MHz and is of interest to those hobbyists who wish to experiment with vacuum-tube circuitry.

73 AMATEUR RADIO TODAY *Fig. 89-5*

IMPROVED REGENERATIVE SW RECEIVER

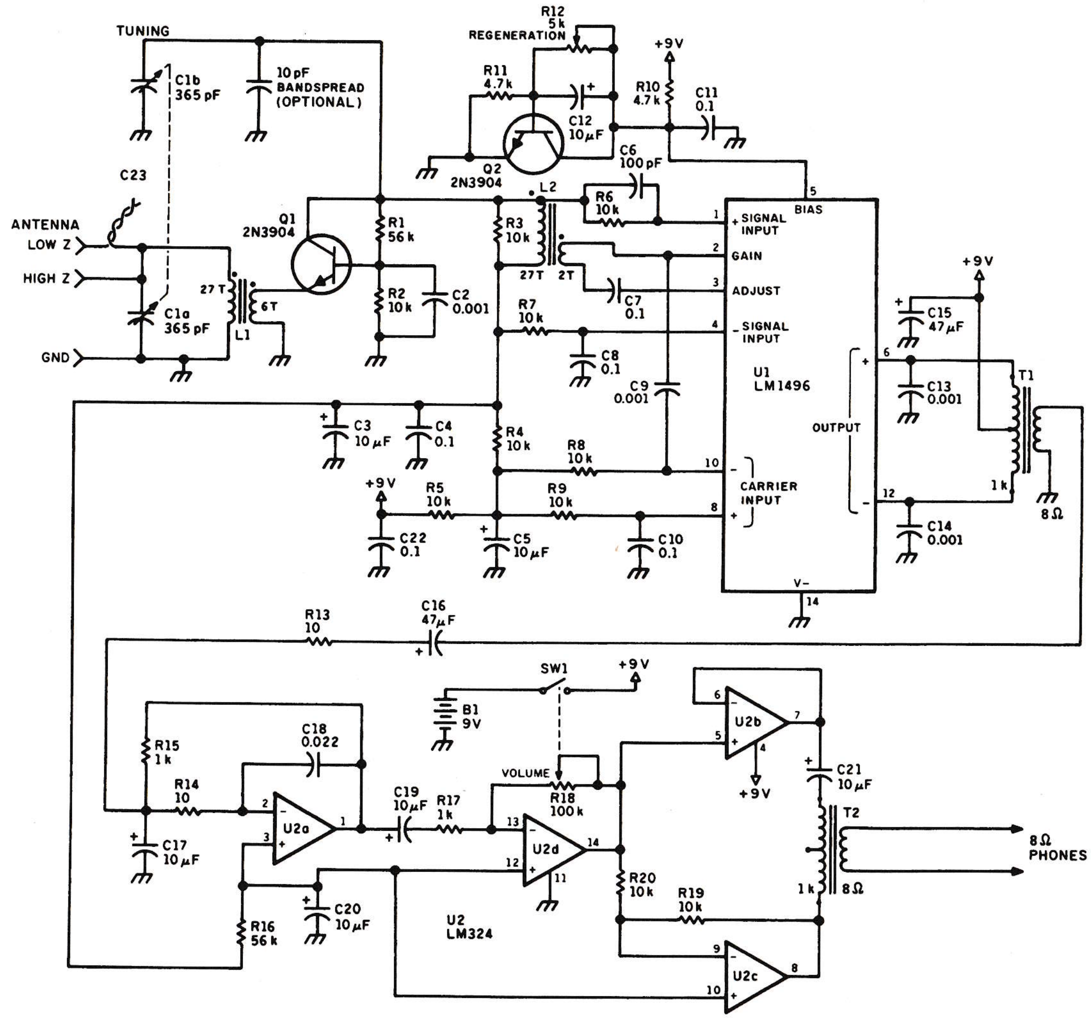
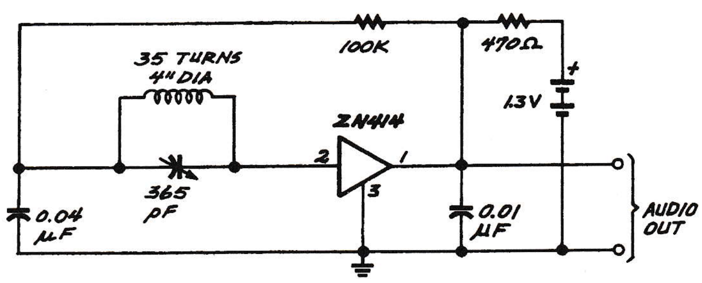


Fig. 89-6

The figure shows the schematic of the circuit. A number of unique features give this design its trouble-free performance. The tendency for regenerative receivers to radiate oscillator-frequency signals is eliminated here by placing a transistor buffer Q1 between the antenna preselector circuit L1-C1a and the regenerative oscillator-tuned circuit L2-C1b. This buffer also nearly eliminates hand-capacitance effects. This design is also unique in that it uses an IC for the regenerative detector. U1, an LM1496 double-balanced mixer, is used here in a somewhat unorthodox manner. The differential SIGNAL INPUT amplifier transistors internal to the IC are used as a Hartley oscillator in conjunction with L2 and C1b. The regenerative feedback for this oscillator is supplied by the output of the GAIN and ADJUST pins of the LM1496. Some of the oscillator output is coupled to one of the CARRIER INPUT pins via C9, which allows the mixer section of U1 to act as an asynchronous detector, greatly improving the RF detection sensitivity over that of other regenerative circuits. The regeneration level is controlled by the voltage level applied to the BIAS pin of U1. The circuit containing R12 and transistor Q2 is used as a variable-voltage source, providing the regeneration level immunity from supply-voltage ripple. This bias level controls the quiescent current level through the SIGNAL INPUT amplifier transistors, which, in turn, determines the emitter output impedance of these transistors, controlling the amount of power delivered to the feedback winding of L2. This results in very smooth and predictable regeneration control. The outputs of U1 are coupled through audio transformer T1 into the first section of U2, an LM324 op amp. Volume control is achieved though U2d and variable resistor R18. Using a push-pull audio output stage, as is done here, also reduces susceptibility to audio oscillation. Although the use of switched or plug-in coils could have allowed multiband reception, in the interest of simplicity, this was not done. However, the values of L1 and L2 allow coverage of 5 to 15 MHz, where much of the shortwave action occurs.

ONE-CHIP AM RADIO

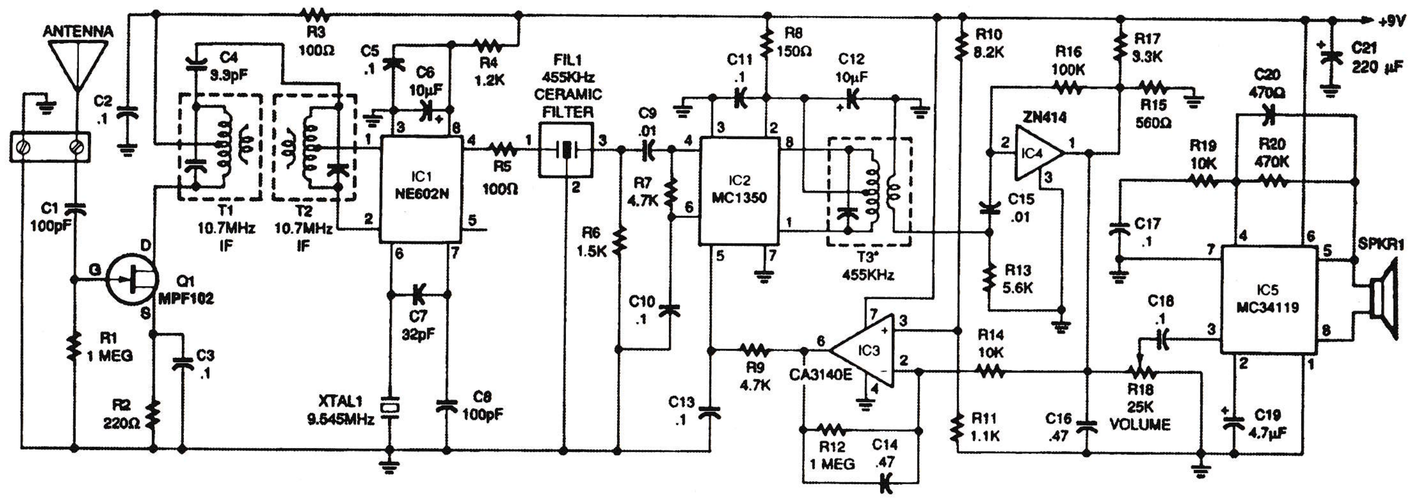


ELECTRONICS NOW

Fig. 89-7

The ZN414 IC contains a complete AM radio, with AGC, except for an audio section. Like an MMIC, it is powered through its output terminal.

WWV RECEIVER

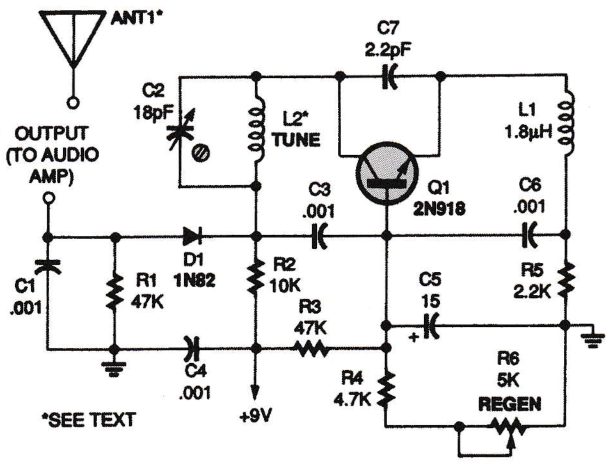


ELECTRONIC EXPERIMENTERS HANDBOOK

Fig. 89-8

This receiver is a crystal-controlled superheterodyne receiver with an MPF102 RF amplifier, NE602 mixer, ceramic IF filter, MC1350P IF amplifier, ZN414 AM detector, and MC34119 audio output. The AGC system uses a CA3140E op amp. A 9545-kHz crystal is used in the L.O.

SIMPLE 225- TO 400-MHz AIR-BAND RECEIVER



POPULAR ELECTRONICS *Fig. 89-9*

Tuning coil L2 can be wound with 2 turns of #22 wire on a 5/32" drill bit. This circuit is well behaved as long as a good component layout is used. The component leads must be kept short and neat, especially the leads of the transistor. The lengths should not exceed 3/16". Audio could be tapped off the tuning coil with a 5-µF (or so) electrolytic capacitor, but the 1N82 diode circuit seems to produce less signal loss. The RF signal from ANT1, an approximately 18" antenna, can be introduced through a small capacitor of 1 pF (or less) to the emitter of the 2N918. Other high-frequency transistors can be used, but might require different resistance in the regeneration circuit. The output of this circuit must go to an audio amplifier.

DIRECT-CONVERSION WWV RECEIVER

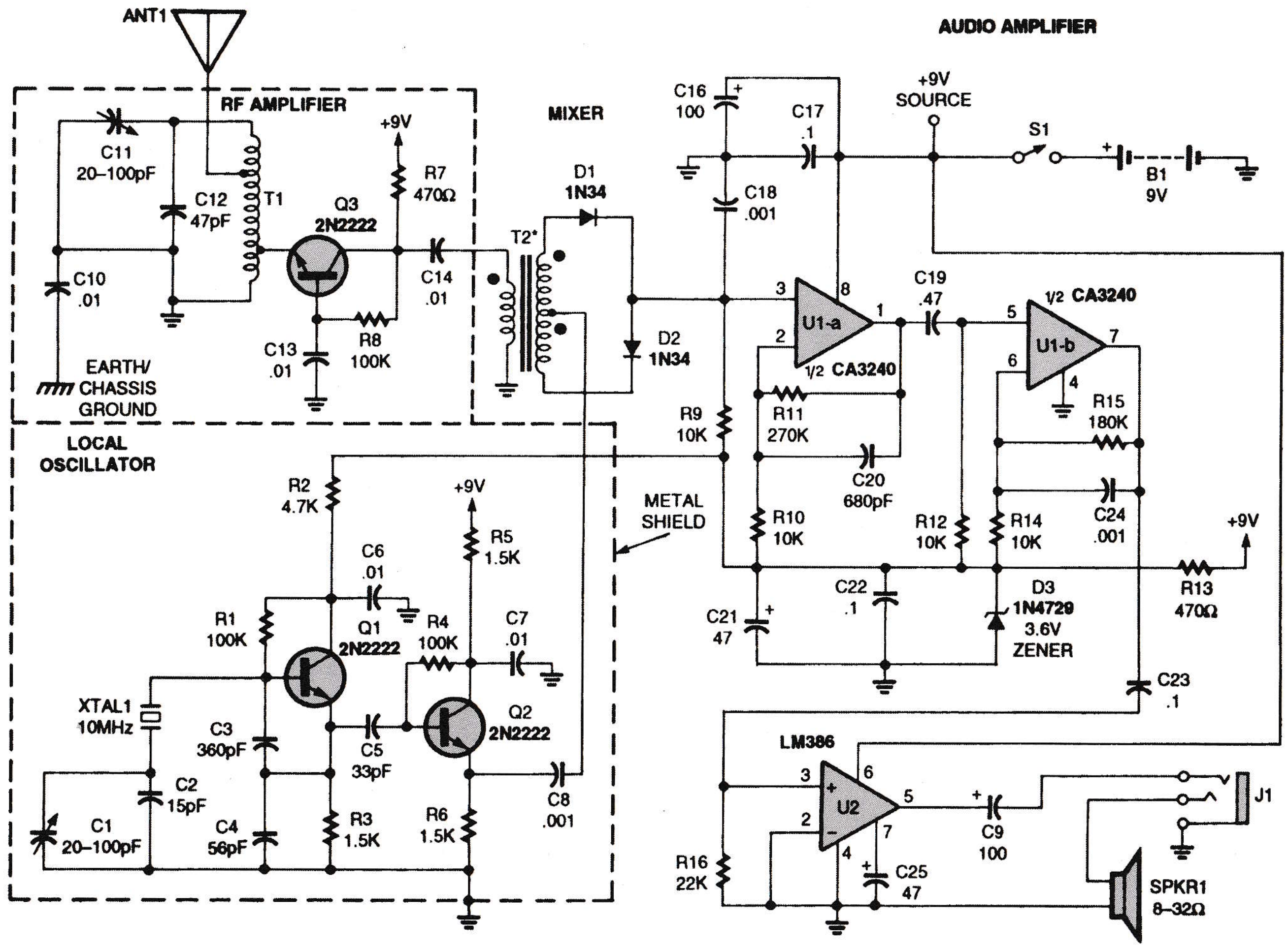
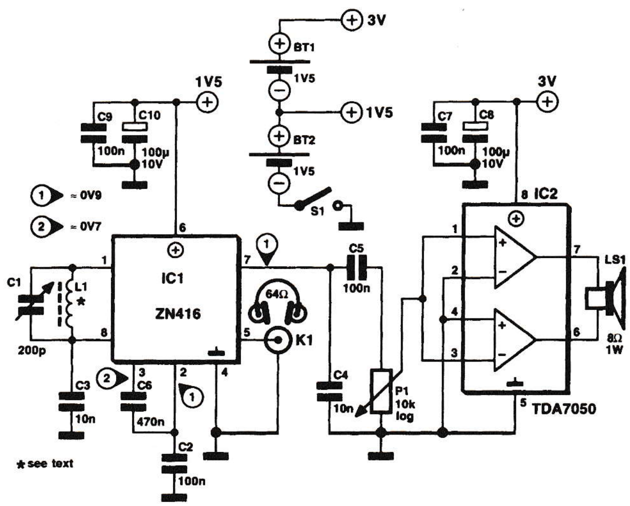


Fig. 89-10

Incoming RF is picked by the antenna (ANT1) and is coupled via an autotransformer to a grounded-base amplifier (Q3) before being applied to a diode-mixer network that comprises T2, D1, and D2. The best mixer performance is obtained when both secondary windings of T2 are identical, and D1 and D2 are matched. The output of the local oscillator (LO)—a grounded-collector Colpitts oscillator (built around Q1)—is applied to emitter-follower/buffer Q2, which provides a low-impedance drive signal for the mixer. The demodulated signal is coupled to a pair of high-gain op-amp stages (U1-a and U1-b). The op amps provide a 50-dB gain. Amplifier U2 provides a 20-dB gain, thereby producing sufficient output drive for an 8-Ω speaker or 32-Ω headphones. The volume is controlled merely by adjusting the length of the whip antenna. When driving 32-Ω headphones, the circuit consumes less than 25 mA; however, the current drain increases to 40 mA when driving an 8-Ω speaker.

TWO-IC MEDIUM-WAVE RECEIVER

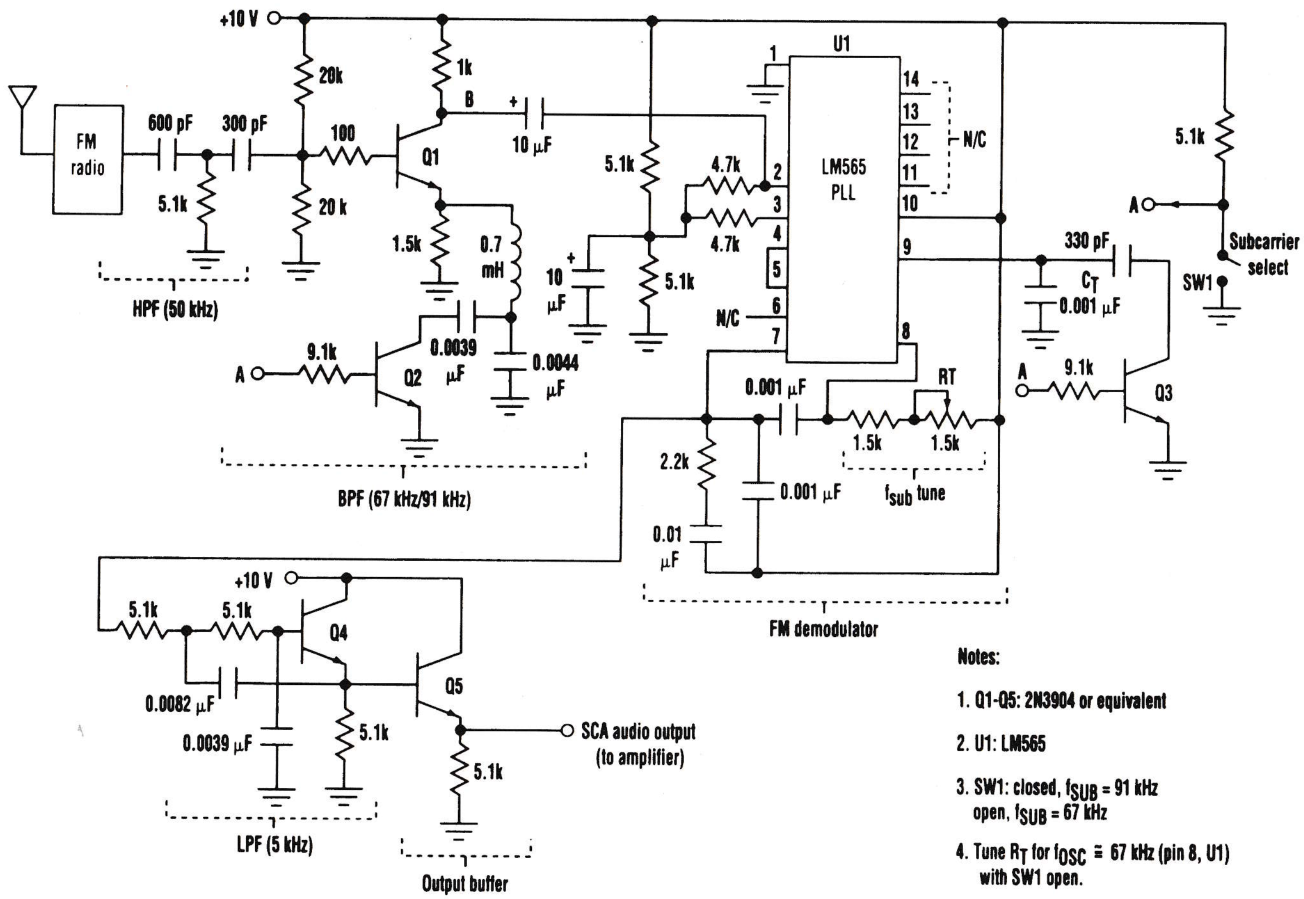


ELEKTOR ELECTRONICS

Fig. 89-11

The antenna is an inductor, L1, consisting of about 60 turns of 0.2-mm (SWG36) enameled copper wire on a ferrite rod with a diameter of 12 mm and a length of about 12 cm. The inductor is tuned with a 500-pF foil-dielectric variable capacitor, C1. The audio power amplifier, a TDA7050, is required only if you want to use a small loudspeaker instead of, or in addition to, the headphones. The AF power amplifier also adds the luxury of a volume control to the receiver. The receiver IC operates at 1.54 V from only one of two series-connected AA (penlight) batteries, which supply 3 V to the TDA7050. Current consumption is of the order of 8 mA.

SCA RECEIVER



Notes:

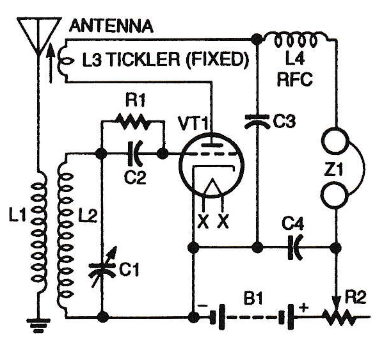
1. Q1-Q5: 2N3904 or equivalent
2. U1: LM565
3. SW1: closed, f_{SUB} = 91 kHz
   open, f_{SUB} = 67 kHz
4. Tune R_T for f_{OSC} ≡ 67 kHz (pin 8, U1) with SW1 open.

Fig. 89-12

SCA RECEIVER *(Cont.)*

A simple PLL-based FM demodulator can be made to demodulate two subcarriers and provide a source of background music. The input to this receiver is fed from the wideband audio output from an FM radio's first FM detector. This is the point that feeds the FM stereo demodulator in an FM receiver. Care should be taken to ensure that the signal is tapped off at a point which hasn't yet been filtered [the subcarrier(s) are still present]. This FM input signal is then passed through a second-order high-pass filter and peaker stage (Q1), which serves to bandpass and provide additional gain within the input spectrum prior to the FM demodulator input. The FM detection is accomplished by a simple LM565 PLL IC (U1) operating as an FM demodulator. The PLL's VCO is tuned to 91 kHz via R_T/C_T. The demodulated output signal is available at pin 7, which is followed by a second-order LPF/buffer combination (Q4). The characteristics of this filter can be modified to suit the user. The design shown has an audio corner frequency of about 5 kHz. The filtered output is the recovered audio output and is the input to an audio amplifier. To choose the second subcarrier (67 kHz), the peaker and VCO are gang-tuned by the Q2 and Q3 saturating switch transistors. These devices switch in appropriate-valued parallel capacitors to retune the peaker and VCO to the proper frequency for reception of the second subcarrier signal. Circuit values shown are for an FM level of about 50 to 300 mV rms at the input to the peaker stage. In addition, the PLL dynamic characteristics can be altered as desired by modifying the loop filter. The typical recovered audio level at pin 7 of U1 is 200 mV rms. To receive SCA signals, the FM receiver can simply be tuned to normal FM stations, and then the presence of either or both subcarriers can be checked.

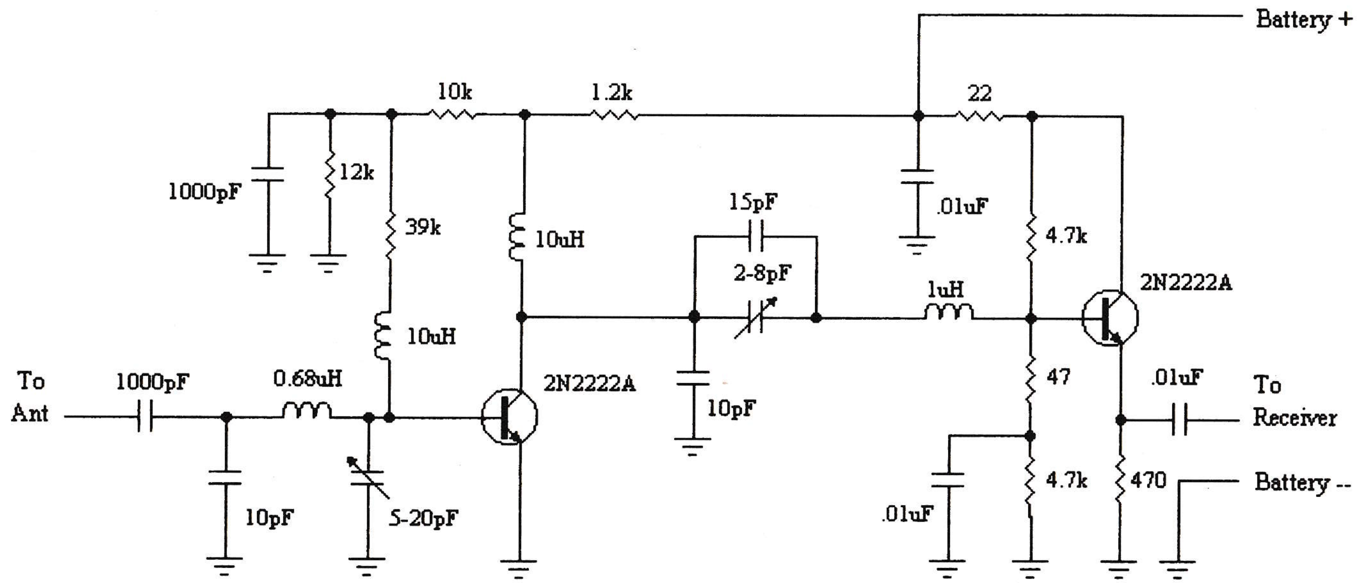
VARIABLE-RESISTOR-CONTROLLED REGENERATIVE RECEIVER



ELECTRONICS NOW

Fig. 89-13

R/C RECEIVER PREAMPLIFIER



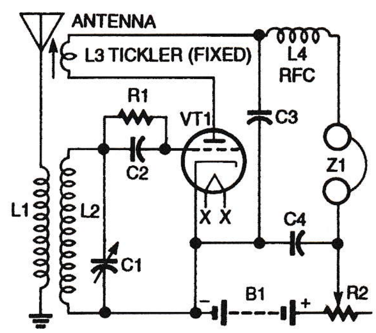
NUTS AND VOLTS

Fig. 89-14

The circuit shown is small, draws little current, and is easily fabricated on a perfboard—just keep the wires short and the bypass capacitors close to their position on the schematic. To install, make a break in the wire from the antenna and insert the preamplifier. With proper trimming, this circuit yields about 20 dB of gain.

A simple PLL-based FM demodulator can be made to demodulate two subcarriers and provide a source of background music. The input to this receiver is fed from the wideband audio output from an FM radio's first FM detector. This is the point that feeds the FM stereo demodulator in an FM receiver. Care should be taken to ensure that the signal is tapped off at a point which hasn't yet been filtered [the subcarrier(s) are still present]. This FM input signal is then passed through a second-order high-pass filter and peaker stage (Q1), which serves to bandpass and provide additional gain within the input spectrum prior to the FM demodulator input. The FM detection is accomplished by a simple LM565 PLL IC (U1) operating as an FM demodulator. The PLL's VCO is tuned to 91 kHz via R_T/C_T. The demodulated output signal is available at pin 7, which is followed by a second-order LPF/buffer combination (Q4). The characteristics of this filter can be modified to suit the user. The design shown has an audio corner frequency of about 5 kHz. The filtered output is the recovered audio output and is the input to an audio amplifier. To choose the second subcarrier (67 kHz), the peaker and VCO are gang-tuned by the Q2 and Q3 saturating switch transistors. These devices switch in appropriate-valued parallel capacitors to retune the peaker and VCO to the proper frequency for reception of the second subcarrier signal. Circuit values shown are for an FM level of about 50 to 300 mV rms at the input to the peaker stage. In addition, the PLL dynamic characteristics can be altered as desired by modifying the loop filter. The typical recovered audio level at pin 7 of U1 is 200 mV rms. To receive SCA signals, the FM receiver can simply be tuned to normal FM stations, and then the presence of either or both subcarriers can be checked.

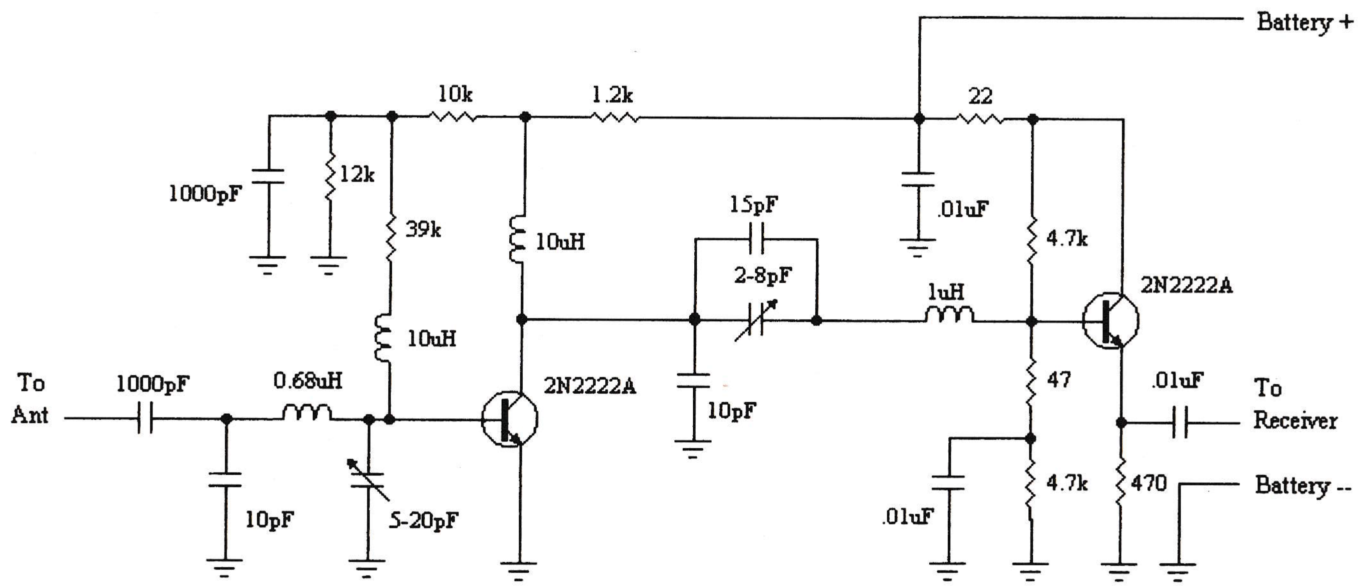
VARIABLE-RESISTOR-CONTROLLED REGENERATIVE RECEIVER



ELECTRONICS NOW

Fig. 89-13

R/C RECEIVER PREAMPLIFIER

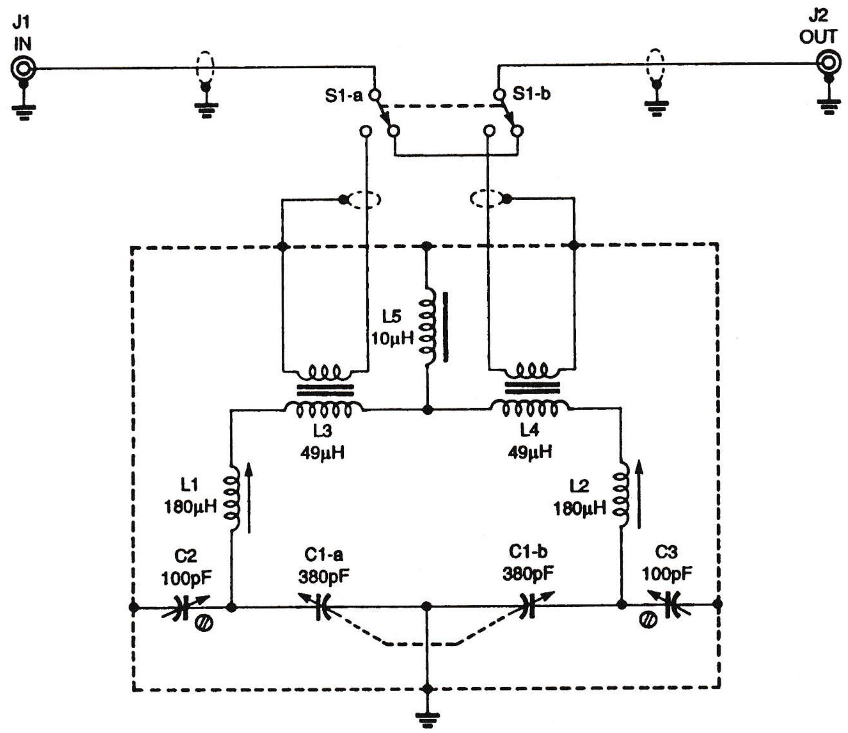


NUTS AND VOLTS

Fig. 89-14

The circuit shown is small, draws little current, and is easily fabricated on a perfboard—just keep the wires short and the bypass capacitors close to their position on the schematic. To install, make a break in the wire from the antenna and insert the preamplifier. With proper trimming, this circuit yields about 20 dB of gain.

AM BROADCAST-BAND PRESELECTOR

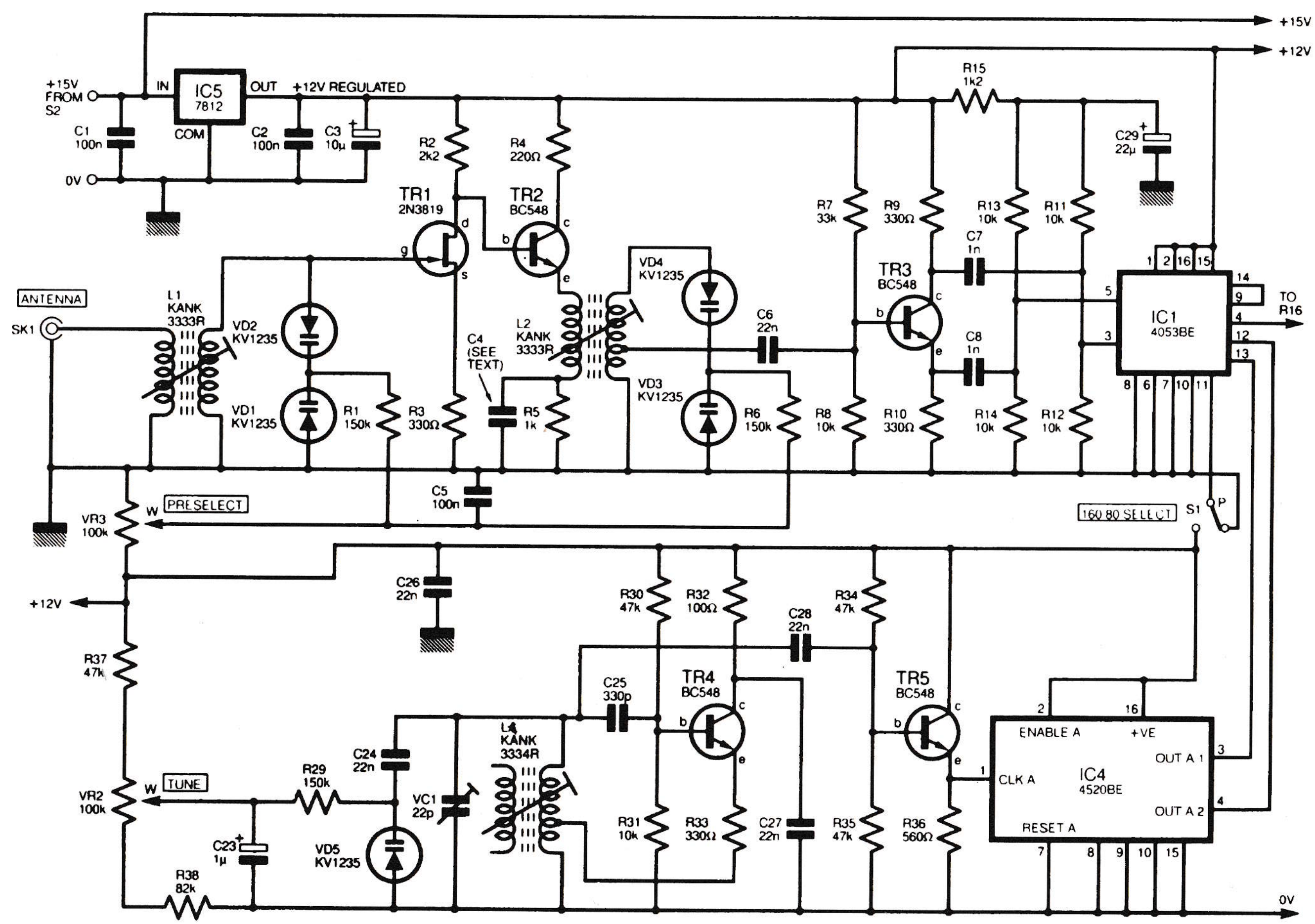


POPULAR ELECTRONICS

Fig. 89-15

The circuit for the AM-BCB preselector is completely bilateral; for that reason, J2 could just as easily be the input jack. That makes connecting the unit to your receiver a breeze. Note that switch S1 can be set so that the unit is bypassed.

80- AND 160-m DIRECT-CONVERSION RECEIVER



80- AND 160-m DIRECT-CONVERSION RECEIVER *(Cont.)*

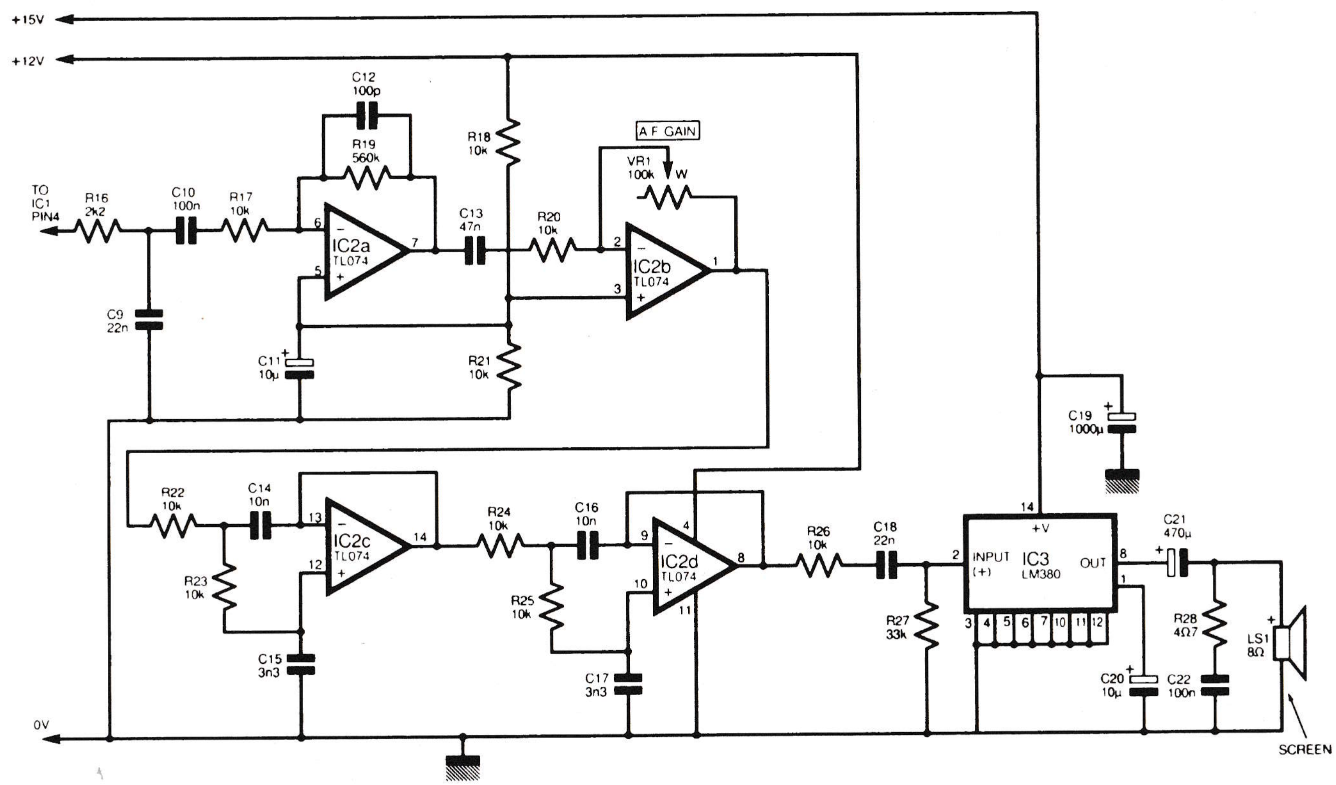
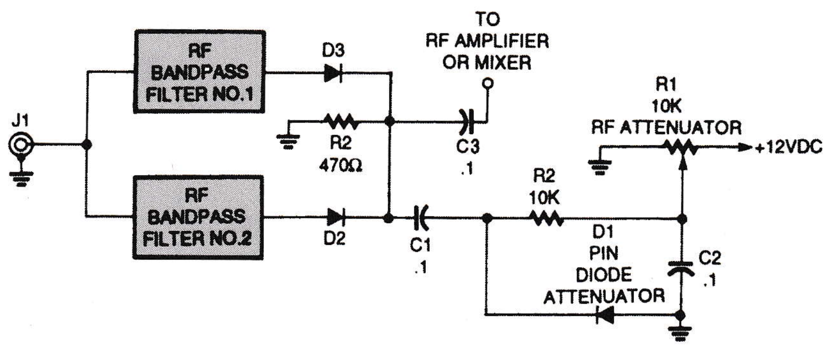


Fig. 89-16

The full circuit diagram, except for power supply, for the direct-conversion top-band and 80-m receiver is shown. Incoming RF from the antenna is fed to the primary side of coil L1. This transformer/coil is bought to resonance at the required frequency by a pair of back-to-back varicap diodes (VD1 and VD2). TR1, an RF, is coupled to the base (b) of transistor TR2, an emitter-follower. The output of TR2 feeds L2, the secondary being brought to resonance by varicaps VD3 and VD4. The variable-frequency oscillator (VFO) comprises a tuned circuit consisting of transformer L3, variable trimmer capacitor VC1, and varicap diode VD5. Variable bias to VD5 is provided by tuning control VR2. Transistor TR4 maintains oscillations at the desired frequency, and TR5 is an emitter-follower. The output of TR5 is sufficient to drive the CMOS divider chain formed by IC4. The VFO covers the frequency range 6.9 to 8.1 MHz, and this is divided by IC4 to produce 3450 to 4050 kHz for 80 m and 1725 to 2025 kHz for 160 m. The output of IC4 is fed to IC1, part of the product detector. The RF signal from the secondary tap on L2 is fed to a "phase splitter" formed around transistor TR3. Analog switch C1 operates at the selected VFO frequency and thus produces sum and difference frequencies of the VFO and the incoming RF. The output of IC1 at pin 4 is filtered to give resolved audio at this point. A high-gain inverting amplifier, with −3-dB points of approximately 300 Hz and 3 kHz, is formed by IC2a. This audio is now fed to IC3 with a maximum power output of 2 W. An LM380 is used in a standard configuration, and a fixed gain of around 30 dB is obtained.

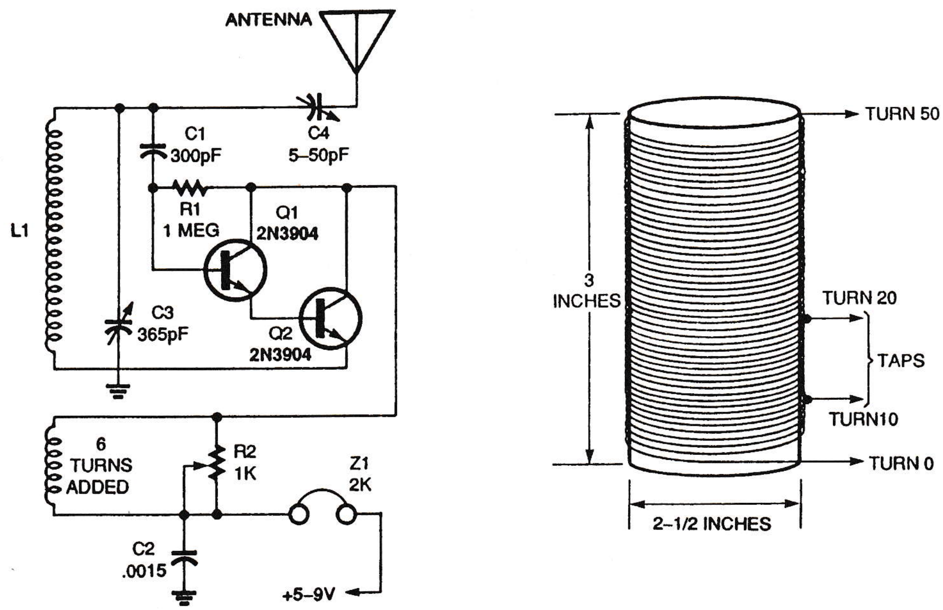
RECEIVER FRONT-END RF ATTENUATOR



POPULAR ELECTRONICS *Fig. 89-17*

This PIN-diode front-end RF attenuator circuit contains a simple shunt circuit. The dc voltage from the potentiometer sets the attenuation level. The PIN diodes can be MV3404 or similar types.

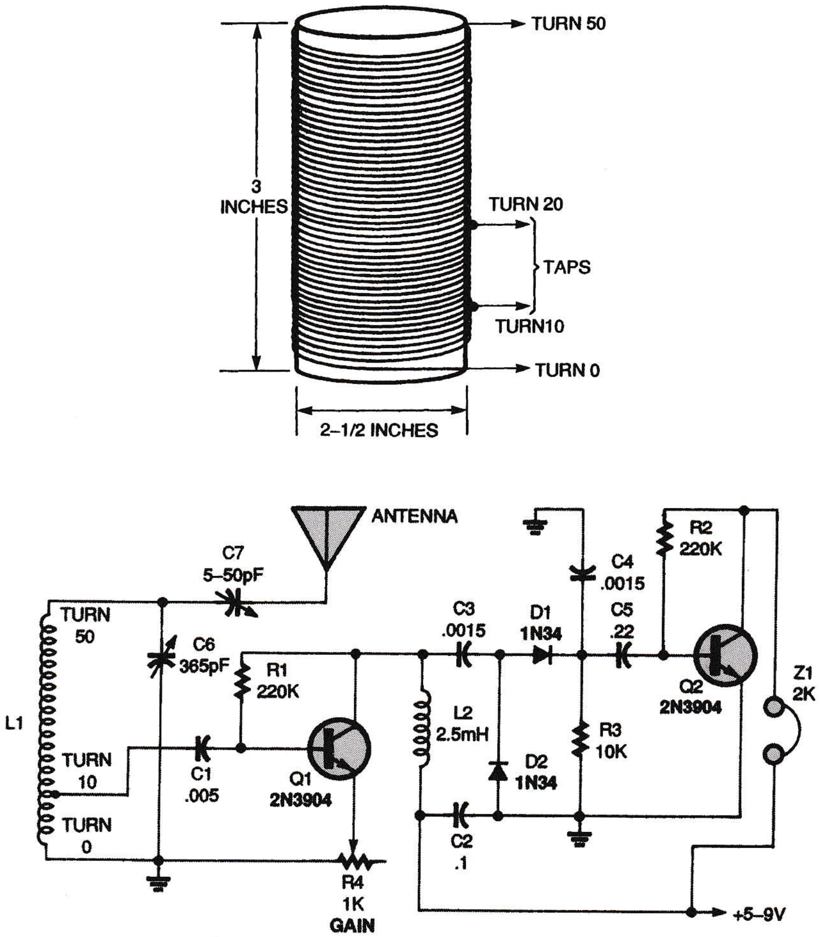
SOLID-STATE REGENERATIVE RECEIVER



POPULAR ELECTRONICS *Fig. 89-18*

You will need to modify the coil shown to use it with the regenerative receiver. Place a single layer of electrical tape around the bottom winding of the coil (L1); wind 6 turns of 19- or 20-gauge wire over the taped winding, leaving 4" pigtails. Tape the winding in place. Then connect the modified coil to the receiver circuit as shown in the figure. The two 2N3904 transistors are connected in a Darlington high-input-impedance circuit configuration to reduce loading of the tuned circuit. Potentiometer R2 controls the positive RF feedback. If the receiver seems dead or if only weak signals are heard, try reversing the leads on the six-turn feedback coil.

TWO-TRANSISTOR TRF RADIO RECEIVER WITH AUDIO AMPLIFIER

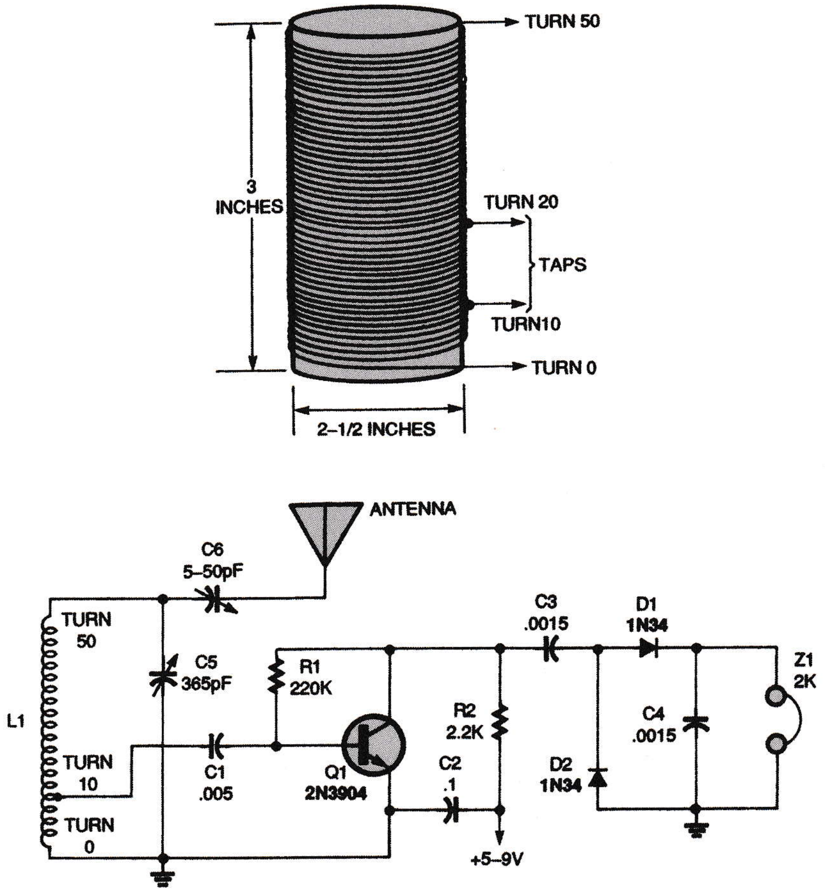


POPULAR ELECTRONICS

Fig. 89-19

This receiver allows you to select the gain of its RF amplifier by adjusting R4.

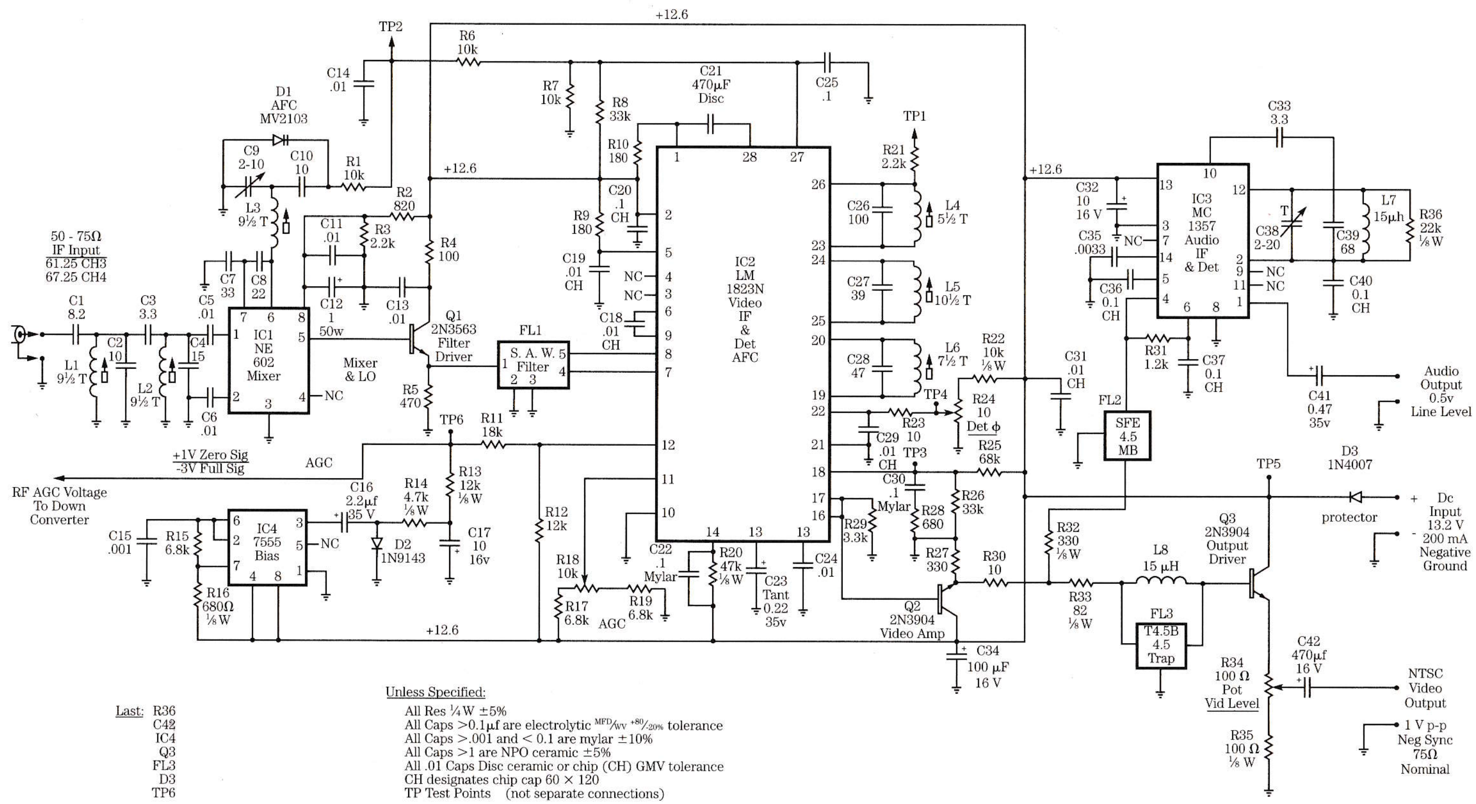
SIMPLE TRF RECEIVER



POPULAR ELECTRONICS *Fig. 89-20*

Here is a receiver that contains an RF amplifier. The desired radio-frequency signal can be selected by tuning C5.

60- TO 72-MHz VIDEO AND SOUND RECEIVER AND IF SYSTEM



Unless Specified:
All Res ¼ W ±5%
All Caps >0.1µf are electrolytic MFD/WV +80/-20% tolerance
All Caps >.001 and < 0.1 are mylar ±10%
All Caps >1 are NPO ceramic ±5%
All .01 Caps Disc ceramic or chip (CH) GMV tolerance
CH designates chip cap 60 × 120
TP Test Points (not separate connections)

Last: R36
C42
IC4
Q3
FL3
D3
TP6

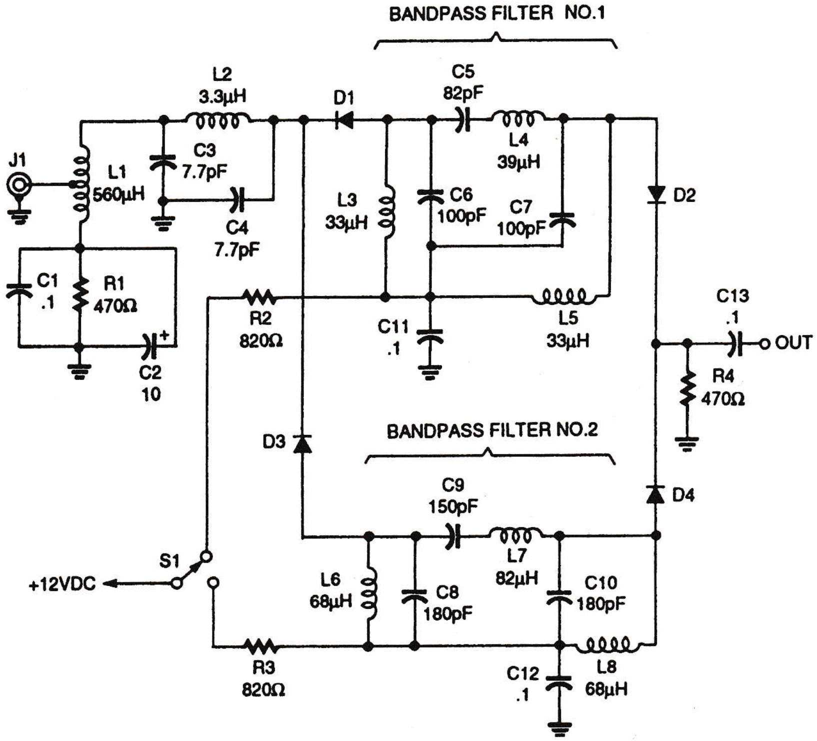
WILLIAM SHEETS

Fig. 89-21

This IF system uses a NE602 oscillator/mixer to convert VHF TV signals of 60 to 72 MHz (channel 3 or channel 4 under the U.S. NTSC) to 45 MHz. An SAW filter is used to provide bandpass filtering, followed by an LM1823 video IF/AGC/AFC/detector IC. Recovered video is fed to a sound trap and 4.5-MHz sound takeoff filter. Video is fed to the output emitter follower and is up to 1.5 V p-p into 75 Ω. An MC1357P FM IF/limiter/quadrature detector recovers audio information and provides 0.5 V p-p line-level audio. An LM555 oscillator and 1N914 diode act as a dc-to-dc converter system to derive a negative 3-V supply for the LM1823 AGC system. Both AFC and AGC voltages are available for interfacing with external downconverters used for 440, 915, and 1280 MHz amateur TV reception. Operation is from a 12-V supply at about 200 mA.

A complete kit of parts, including PC board, is available from North Country Radio, P.O. Box 53, Wykagyl Station, New Rochelle, NY 10804-0053A.

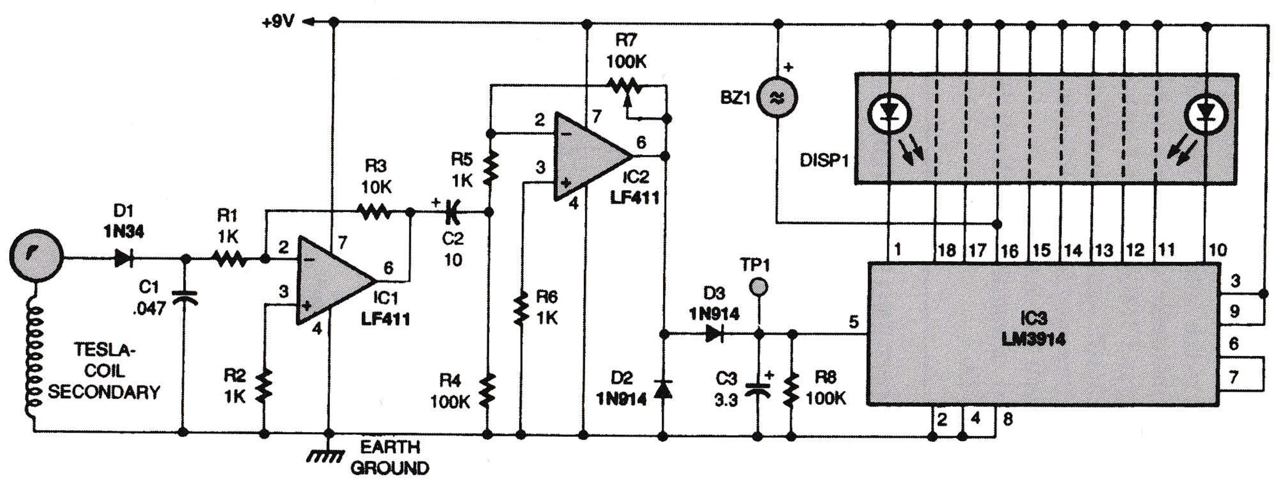
RECEIVER FRONT-END SELECTOR



POPULAR ELECTRONICS *Fig. 89-22*

Receiver front-end selection can be accomplished by using PIN-diode switches (as shown). The PIN diodes can be MV3404 or similar types.

TESLA COIL SECONDARY RECEIVER

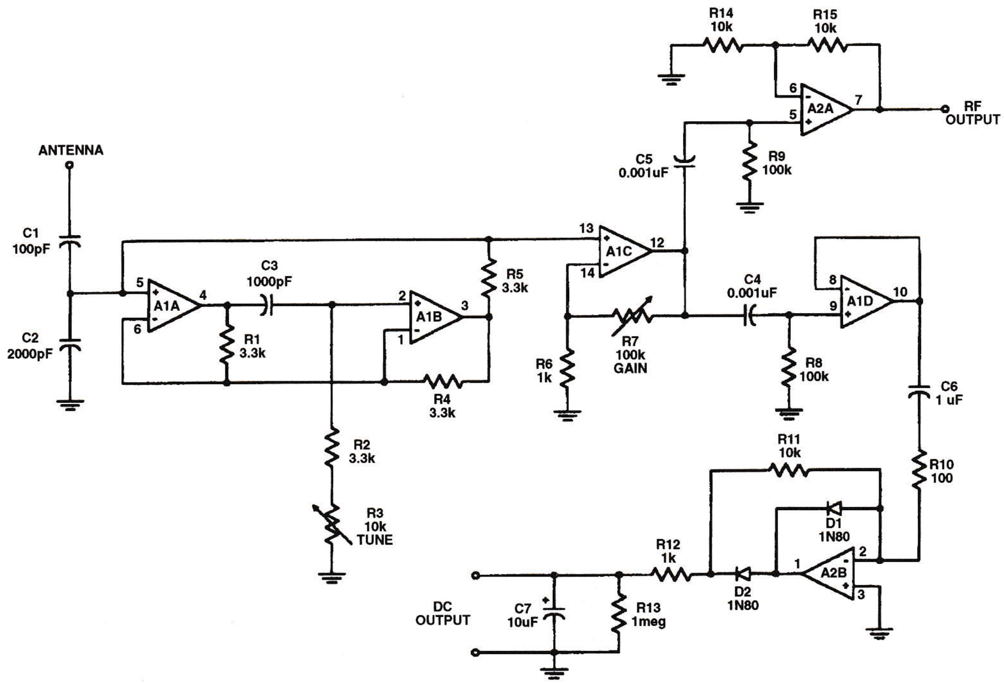


POPULAR ELECTRONICS

Fig. 89-23

Here's a Tesla-coil secondary to try: Wind 750 turns of 24-gauge enameled magnet wire onto an 18" long piece of 1.9" outer-diameter PVC pipe. The large coil has an inductance of about 2800 mH, with a self-capacitance of about 20 pF. One end of the coil should be earth grounded. Put a metal ball (a drawer pull knob or doorknob) at the other end. Now attach it to a crystal radio. The RF is detected by a 1N34 germanium diode, D1, and you will note that signal strength is high. What you should hear is one or possibly several AM radio stations, depending on the coil, the radio frequencies in your area, and distance to the transmitter(s).

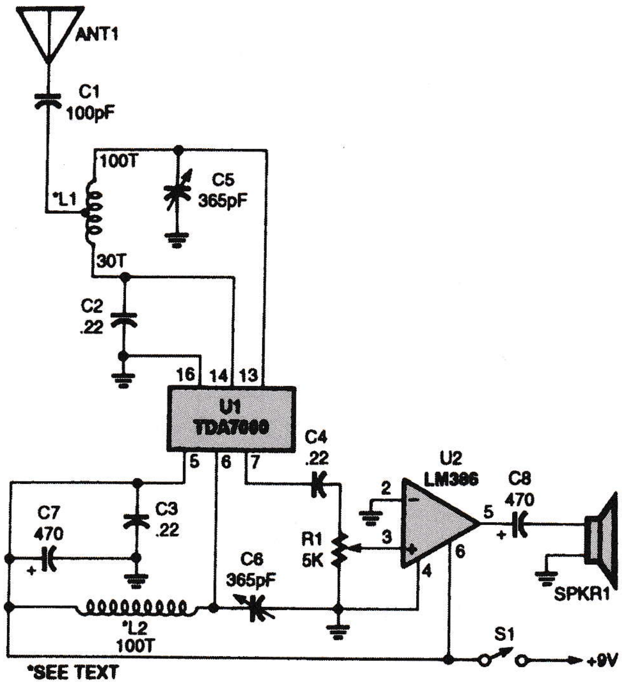
OP-AMP VLF RECEIVER



73 AMATEUR RADIO TODAY *Fig. 89-24*

The figure shows the circuit diagram for an operational-amplifier VLF receiver. The circuit in the figure uses a virtual-inductor front end. A virtual inductor is a circuit that acts like an inductor, but isn't. Operational amplifiers A1A and A1B form a gyrator circuit. The inductance of this circuit is the product of the components shown between A1A and A1B [$C_3 \times 3300 \times (R_2 + R_3)$]. Capacitor C2 resonates with the virtual inductance produced by the gyrator circuit to tune the desired frequency. For the values of C2, C3, R2, and R3 shown, the circuit will tune from about 15 kHz to more than 30 kHz. Resistor R3 is the tuning control. It is a potentiometer, and should be either a multiturn knob via a vernier-reduction drive. The receiver front-end amplifier consists of amplifier A1C, which has a maximum gain of ×101 [i.e., $(R_7/R_6)+1$]. The output of A1C is an RF signal with a frequency equal to that tuned by the gyrator and C2. This signal is coupled to the RF output stage (A2A) through capacitor C5. The RF output stage shown here is a noninverting operational amplifier circuit with a gain of ×2. The dc output circuit consists of a precise rectifier (A2B). The precise rectifier works like a regular rectifier, but does not have the low-voltage "knee" between 0 and 0.6 V (for silicon) or 0 and 0.2 V (for germanium). The pulsating dc from the precise rectifier is filtered and smoothed to straight dc, at a value proportional to the signal strength, by an RC integrator consisting of R12 and C7. The buffer amplifier (A1D) is used to isolate the precise rectifier from the RF output amplifier.

ONE-CHIP FRONT-END AM RECEIVER



POPULAR ELECTRONICS ***Fig. 89-25***

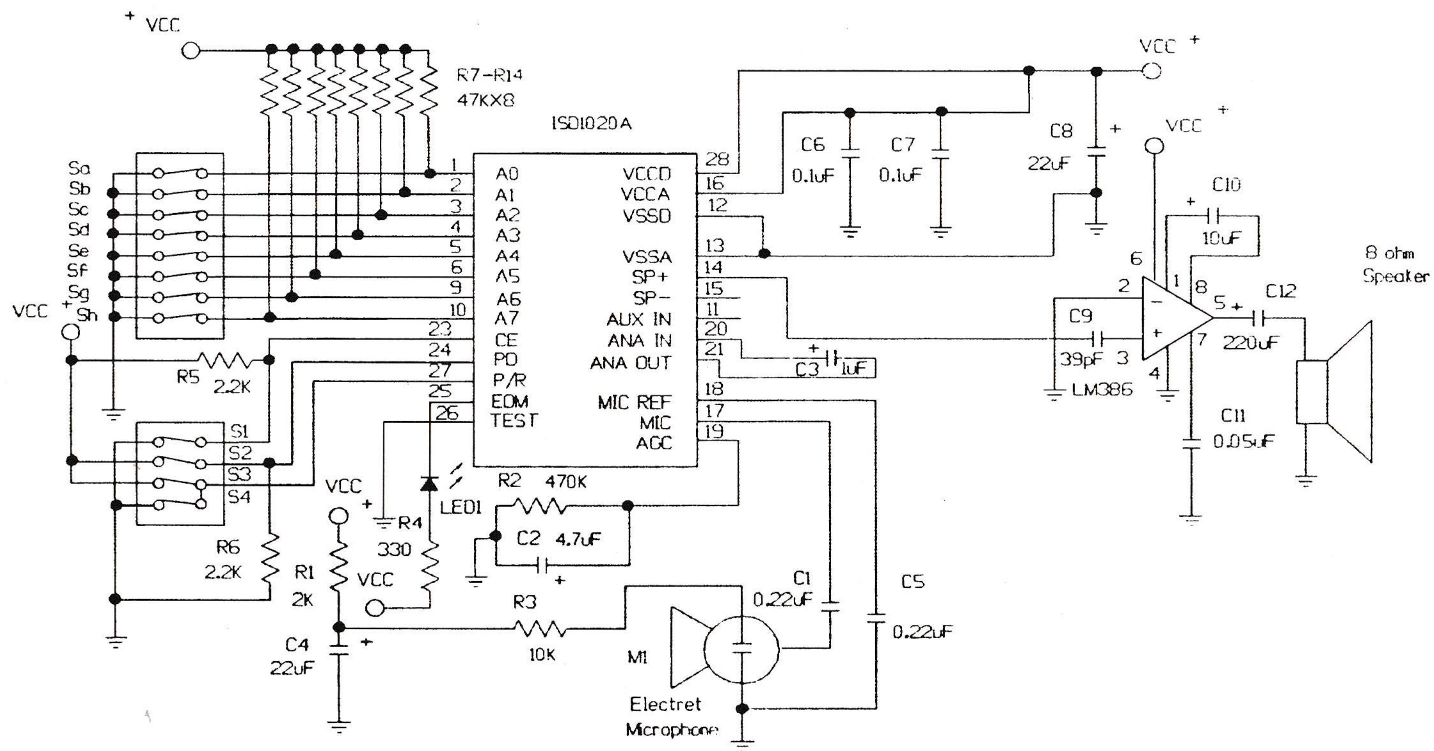
The schematic diagram of the receiver circuit is shown. About all you have to do is wind two coils, connect a few components together, and tie the input to a simple wire antenna, and a receiver is born. The two coils, L1 and L2, each comprised 100 turns of #28 enamel-covered copper magnet wire wound on T80-2 toroid cores (with a tap at the 30th turn on L1).

90

Record and Playback 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.

TAPELESS RECORD/PLAY DEVICE

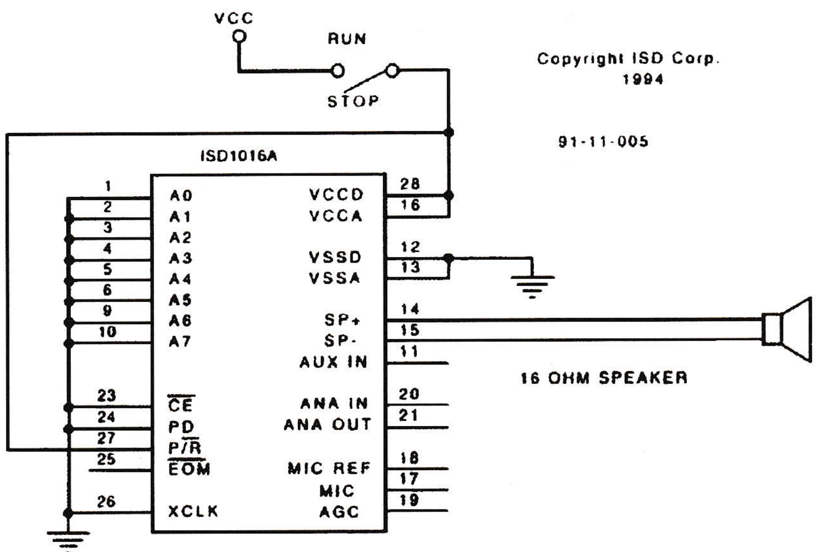


NUTS AND VOLTS *Fig. 90-1*

The schematic for a record/play device with an audio power amplifier added is shown.

- A four-section DIP switch is used to activate the Chip enable, Power down, Playback, and Record functions.
- An LED detects an end-of-message condition. It remains off during Record or Play and turns on when a message ends.
- A three-terminal electret microphone is used for recording.
- The only off-board components are the microphone, speaker, and power supply. For optimum sound, the speaker should be baffled (placed in an enclosure). Four 1.5-V AA cells can be used as a power source.

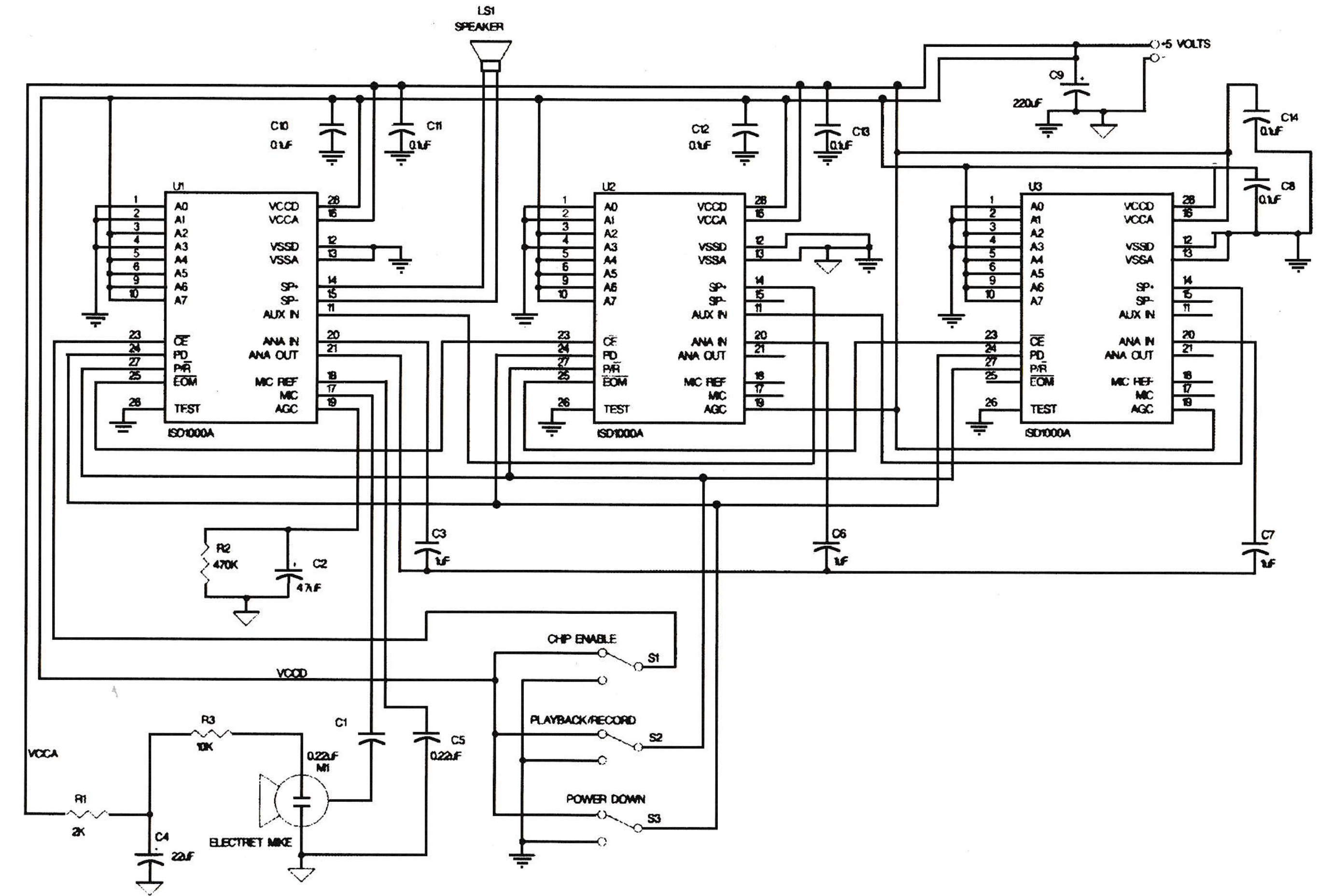
TAPELESS PLAY-ONLY DEVICE



NUTS AND VOLTS *Fig. 90-2*

This requires a prerecorded message to be preprogrammed in the ISD1020A. To play a message, set the switch to the +5-V position. The ISD1020A plays the entire contents one time, then stops. Because CE is tied low, the set end-of-message bits are ignored. Momentarily changing the switch to open, then back to +5 V makes the ISD1020A play again.

1-min RECORD/PLAYBACK CIRCUIT

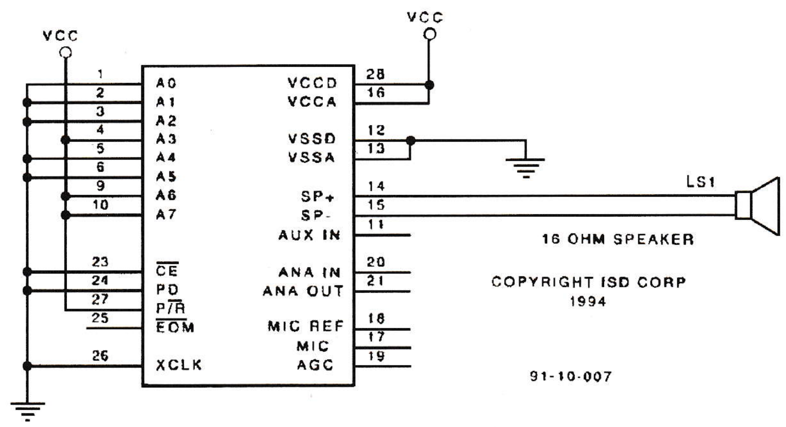


NUTS AND VOLTS

Fig. 90-3

You can cascade several ISD1020As to increase a system's capacity. A circuit to create a 1-minute message is shown. With this configuration, a message is stored across chip boundaries in a manner transparent to the user. Changing from Record to Play resets the MSP to the beginning of the first message in the series. The next Play proceeds under control of CE. The circuit operates exactly like that for a single device.

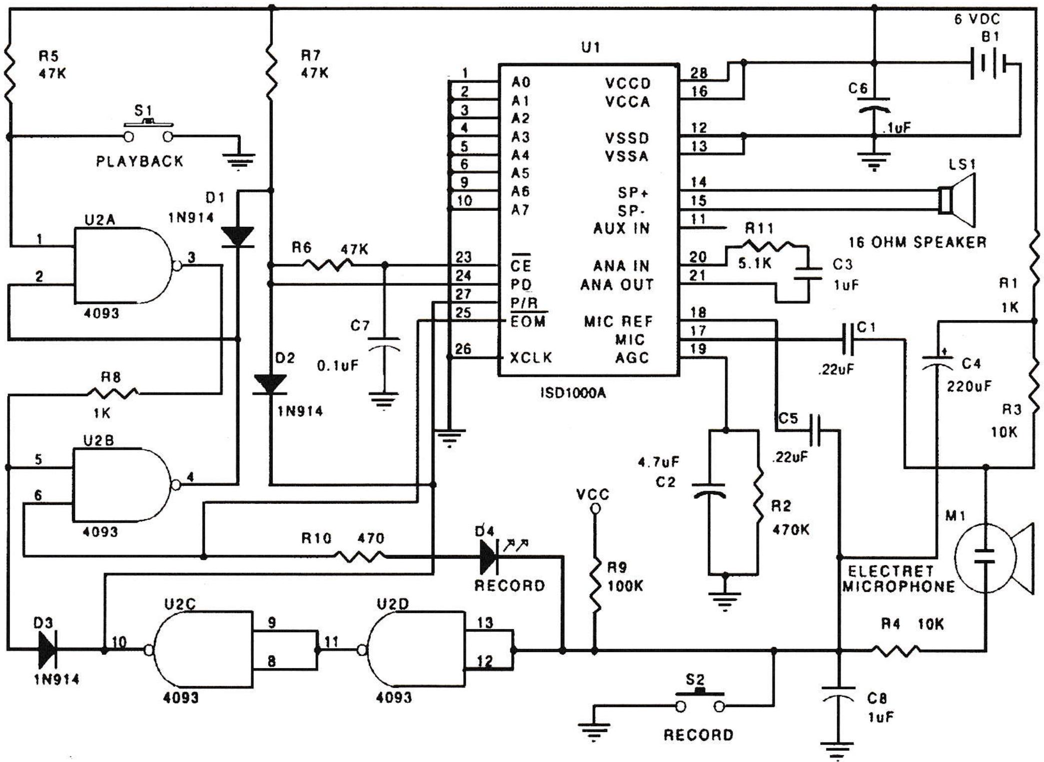
CONTINUOUS-LOOP PLAYBACK DEVICE



NUTS AND VOLTS ***Fig. 90-4***

This requires a prerecorded message to be preprogrammed in the ISD1020A. If you want a message to repeat over and over again, automatically, the circuit in the figure will do the trick. It uses the Operation mode to accomplish playback looping as long as the message starts at address 0 (the beginning of the memory) and does not require the full 20 seconds of analog storage. A message is first recorded into an ISD1020A using the Yack/Yack project, with all address bits tied low. Next, connect the circuit in the figure. Note that address bits A6 and A7 are tied high to enable the Operation mode. Bit A3 is also tied high to enable continuous repeat. With PD low, P/R high, and CE held low, the beginning message in the ISD1020A will repeat.

RECORD/PLAYBACK CIRCUIT WITH AUTOMATIC POWER DOWN



NUTS AND VOLTS ***Fig. 90-5***

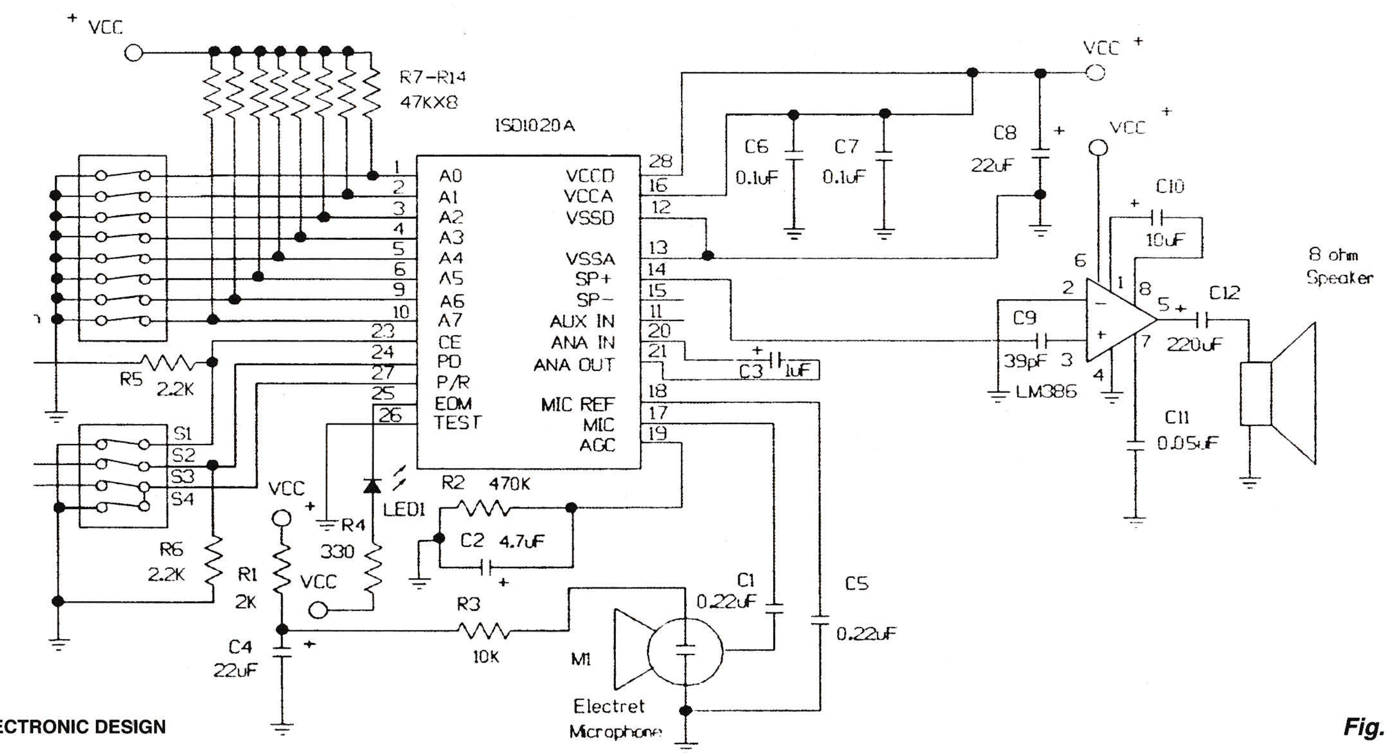
Many applications for sound recording and reproduction, where battery power is necessary, require minimum power consumption. A circuit that achieves automatic power down in a record-and-play application is shown. The cross-coupled latch, consisting of a 4093 Schmitt trigger quad two-input NAND package (U2A and U2B), works to control the PD and CE pins for the Play mode. Circuitry for the Record mode consists of U2C and U2D plus several support components. To start the Record cycle, S2 supplies the ground to the microphone circuit and takes the input to U2D low. The Schmitt Trigger action of U2 debounces the logic input to the ISD1020A.

91

Relay 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.

50-μA SOLID-STATE RELAY

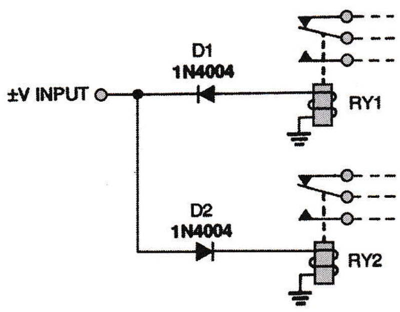


ELECTRONIC DESIGN

Fig. 91-1

The relay circuit described here reduces the control current to 50 μA, but can switch up to 600 W of 120-Vac power. The circuit uses a conventional 10-A, 400-V triac. The triac gate current is routed through a small bridge rectifier, a 15-V zener diode, a sensitive SCR (Q2), and a 180-Ω resistor (R2). The circuit allows a small SCR to control ac current through the triac's gate terminal. The voltage needed to control the SCR's gate terminal is developed by rectifying and filtering the ac voltage across the triac. Capacitors C2, C4, and C5, resistor R3, bridge rectifier BR2, and zener diode D2 form the rectifier circuit. C5 and D2 filter and limit the supply voltage to about 8 V, while the 470-Ω resistor R3 limits the charging current. To develop a slightly higher voltage (up to 30 V p-p), a 15-V zener diode (D1) is inserted in series with the SCR. D1 delays the triac's conduction trigger point each half cycle and produces only a slight reduction in rms power to the load. The dc control voltage, produced by the rectifier circuit, is switched to the SCR's gate using a sensitive Darlington-type optoisolator (A1). Only about 50 µA of LED current in the isolator is needed to fully turn on the SCR.

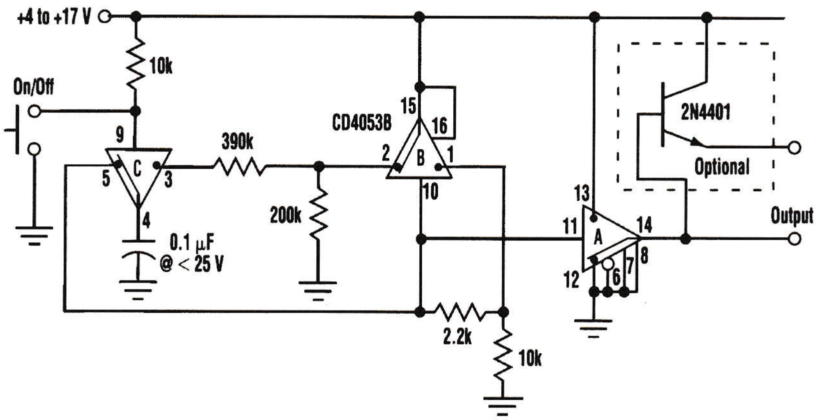
POLARITY-SENSITIVE RELAY CIRCUIT



POPULAR ELECTRONICS *Fig. 91-2*

When a positive voltage is input to the circuit, relay RY1 is activated; when a negative voltage is input, RY2 is activated.

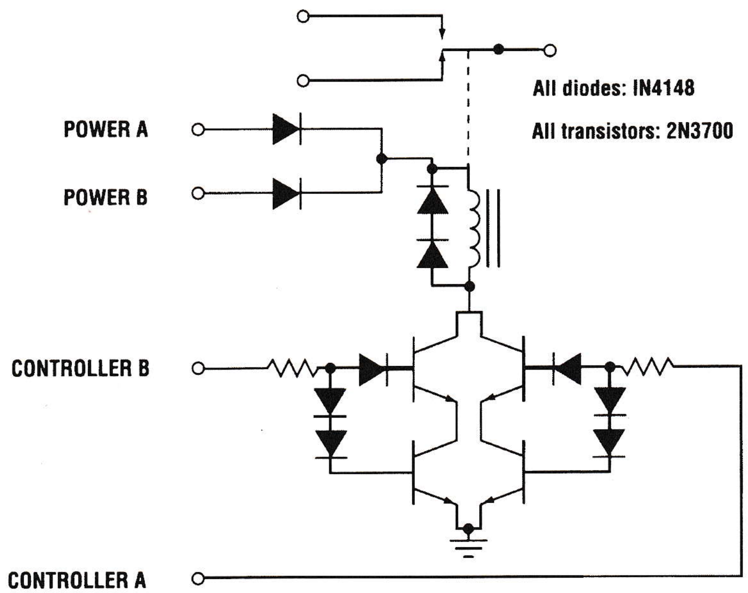
SOLID-STATE "LATCHING-RELAY" CIRCUIT



ELECTRONIC DESIGN *Fig. 91-3*

A multitude of simple circuits perform switch debouncing because there are many ways to implement a toggling latch. The circuit illustrated here merges these functions into one topology, is extremely tolerant of power-supply variation (it works fine over more than a 3:1 range of supply voltage), and, most importantly, is unusual. The IC used in this case is the 4053B triple CMOS SPDT switch. Section B acts as a bistable latch and stores the current ON/OFF state of the relay. The 2.2-kΩ resistor between pins 1 (the ON terminal of the switch) and 10 (the control input) provides positive feedback that sustains the switch in whichever state it finds itself. Thus, if the latch is ON, pin 1 will be switched to pin 15 and, thereby, the positive rail. This will reinforce the positive state of pin 10 and the ON state of the switch. If, on the other hand, the latch is OFF, then the connection of pin 1 to pin 15 will be broken and the 10-kΩ pull-down resistor will drag pin 1 to ground. This will pull pin 10 low, in turn, holding the latch in the OFF state. Meanwhile, pin 2 will output the logic inverse of the signal appearing in pin 1. This signal communicates to pin 3 and, if the control push button is open, will connect to pin 4 and charge the capacitor to a state opposite that of the latch. There matters will rest until someone presses the button. This will connect the capacitor to pin 10 and toggle the Latch state. 4053B section A serves as an output buffer and has an output impedance of about 200 Ω when run with a 5-V supply and 100 Ω when run with a 12-V supply. If this is insufficient for the application, a transistor emitter-follower, like that illustrated, will boost output capability to beyond 0.1 A.

FAULT-TOLERANT RELAY DRIVER



ELECTRONIC DESIGN

Fig. 91-4

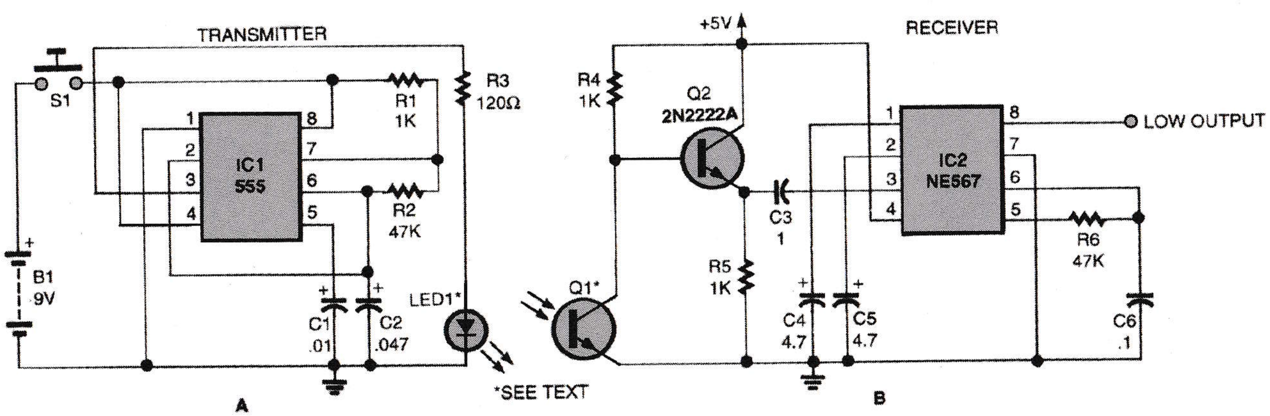
Mechanical relays are useful in remote-switching applications that require electrical isolation between control and switched circuits. The traditional approach for driving the relay coils uses a single-transistor common-emitter switch. The figure shows a circuit that can reduce the likelihood of having an unrecoverable failure in the relay driver circuit. Additional transistor switches, inserted in series with the original controlling transistors, maintain proper operation if a single transistor fails. The diodes connected to the upper transistors prevent reverse base-current flow if the collector-base junctions break down. The diodes connected to the lower transistor provide proper biasing for the circuit. The upper and lower transistors will have a similar V_{be} because they are the same type and have nearly identical currents. Therefore, the V_{ce} of the lower transistor will be about the same as one diode voltage drop, and the device will be operating in the active region. Power to the relays can be provided by one of two voltage sources connected together through diodes in a wired-OR configuration. The additional diode clamps the coil inductance voltage spike in the event that one of the suppression diodes fails shorted.

92

Remote-Control 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.

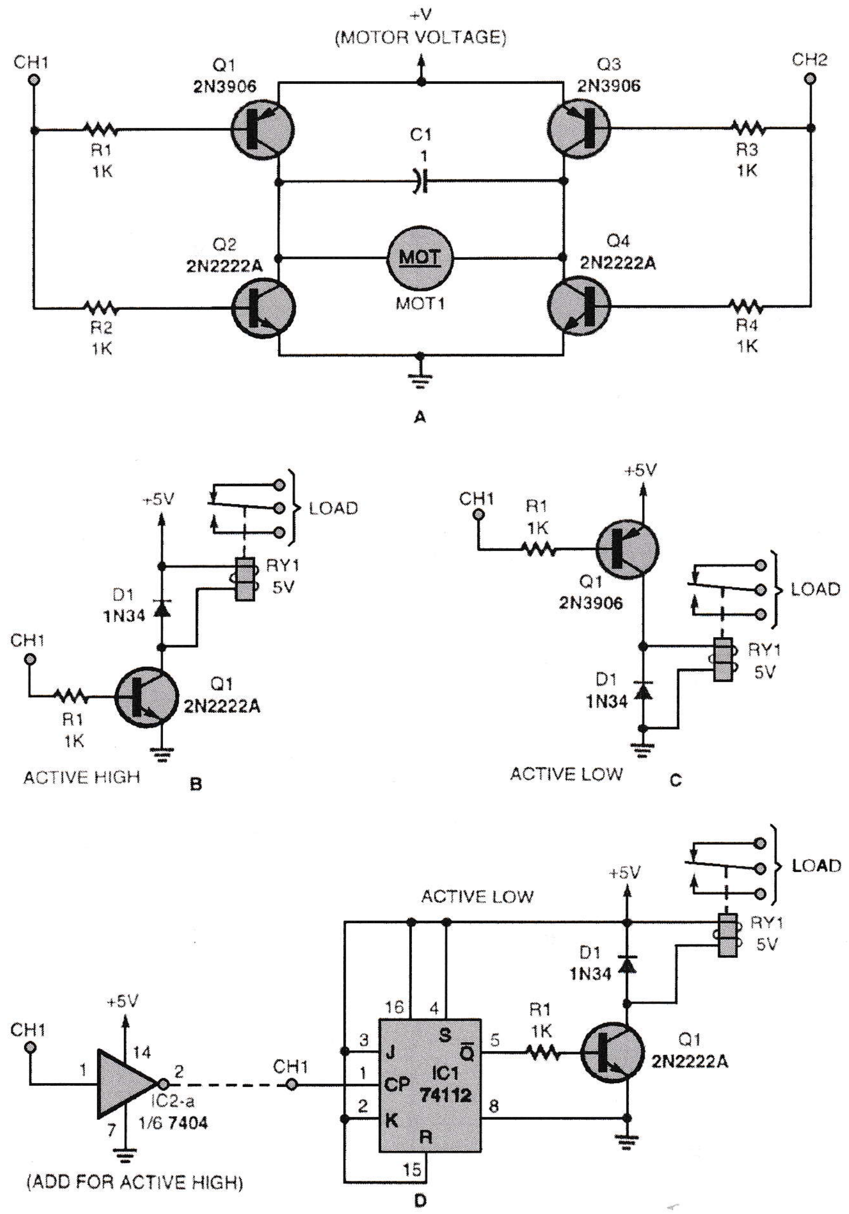
SIMPLE REMOTE CONTROL



POPULAR ELECTRONICS *Fig. 92-1*

Here is a remote-control transmitter and receiver. The theory of the circuit's operation is very simple. The transmitter (Fig. A) generates IR light pulses at a frequency of 320-Hz (set in part by R2). The pulses arrive at the collector of the phototransistor and are amplified by the 2N2222 transistor. An NE567, IC2, is tuned to 320-Hz (by R6), so if pulses of any other frequency arrive at the phototransistor, the NE567's output will remain high. When the 320 Hz signal enters the phototransistor, the NE567 recognizes this frequency and pulls its output low. If you wish to change the NE567's operating frequency, you will have to adjust R2 and R6 to the same value. Keep in mind that the NE567 will work between 100 Hz and 1 kHz. You can also add more resistors (for more frequencies) instead of R2, and more NE567s tuned at the desired frequencies in order to make a multichannel remote control system.

SIMPLE REMOTE-CONTROL INTERFACE CIRCUITS



POPULAR ELECTRONICS

Fig. 92-2

If you want to control a dc motor, a momentary load, or an on/off load, these are some useful interface circuits. Figure A shows a dc-motor controller that requires the outputs of two different channels (CH1 and CH2). Note that it doesn't matter if the channel outputs are active low or high; what matters is that CH1 must be different from CH2 for the motor to be energized. The circuits in Figs. B and C are momentary-load controllers for active high and active low channel outputs, respectively. The circuit in Fig. D is a toggled-load controller. If you have an active high channel output, you must add the inverter shown.

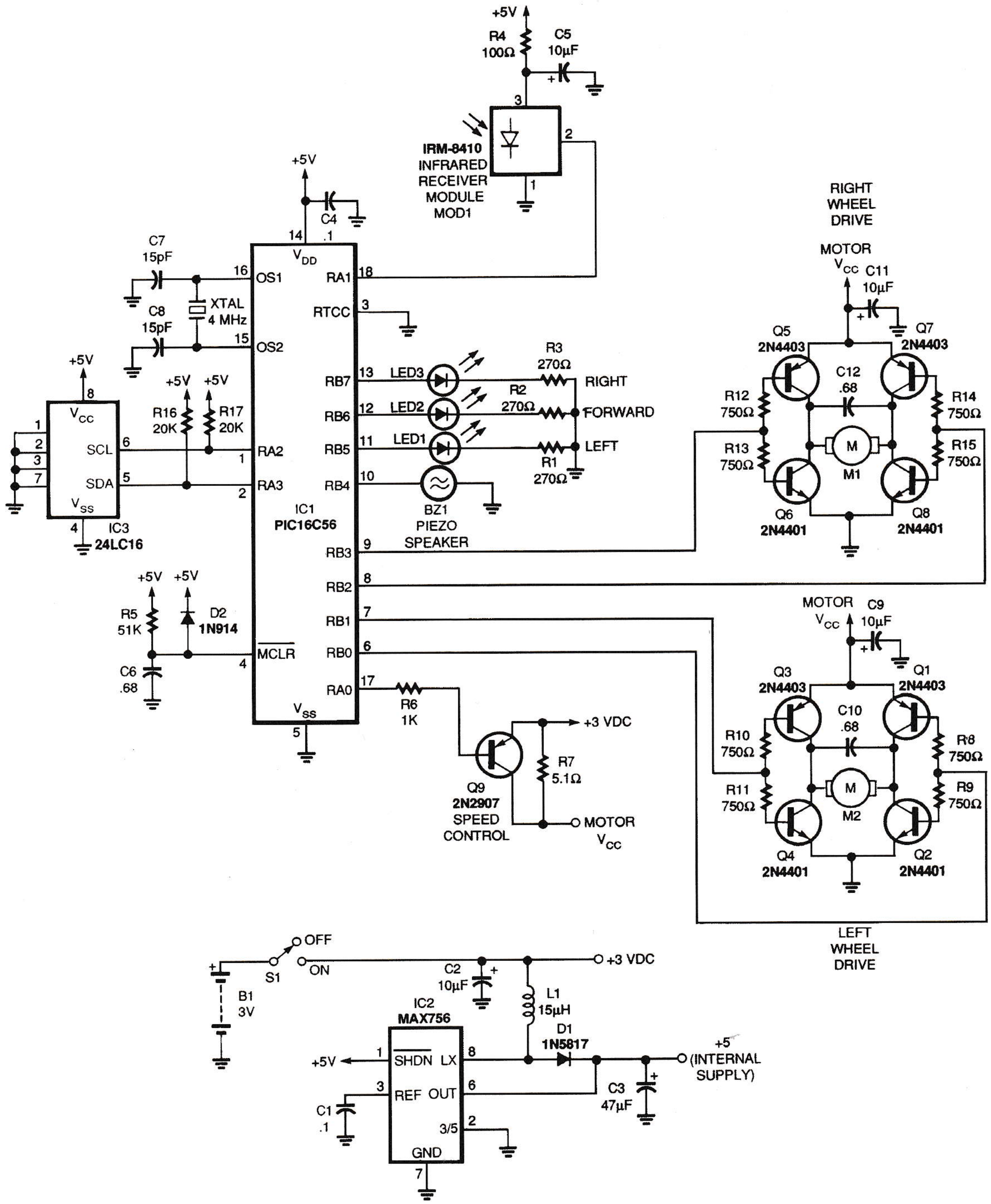
93

Robot-Control Circuit

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.

Universal Remote-Controlled Robot

UNIVERSAL REMOTE-CONTROLLED ROBOT



RUNABOUT OPERATION

Universal Remote Key	Runabout Action
Up Channel	Move Forward
Down Channel	Move Reverse
Up Volume	Turn Right
Down Volume	Turn Left
Key 1	Single LED On (Left)
Key 2	Single LED On (Middle)
Key 3	Single LED On (Right)
Key 4	"Erratic Driver" Mode
Key 5	Beep (Horn)
Key 6	Dual Tones
Key 7	Rising Tones
Key 8	Change Speed
Key 9	Falling Tones
Key 0	Shift Key (Selects Memory 1-6)
Enter Key	Enter/Exit "Program" Mode
Power Key	Run Selected Program
Mute Key	Pause (In Program Mode Only)

ELECTRONICS NOW *Fig. 93-1*

This project uses a microcontroller programmed with software that is posted on the Gernsback BBS at 516-293-2283 as part of RUNABOUT.ZIP. The robot can be controlled via a universal remote control.

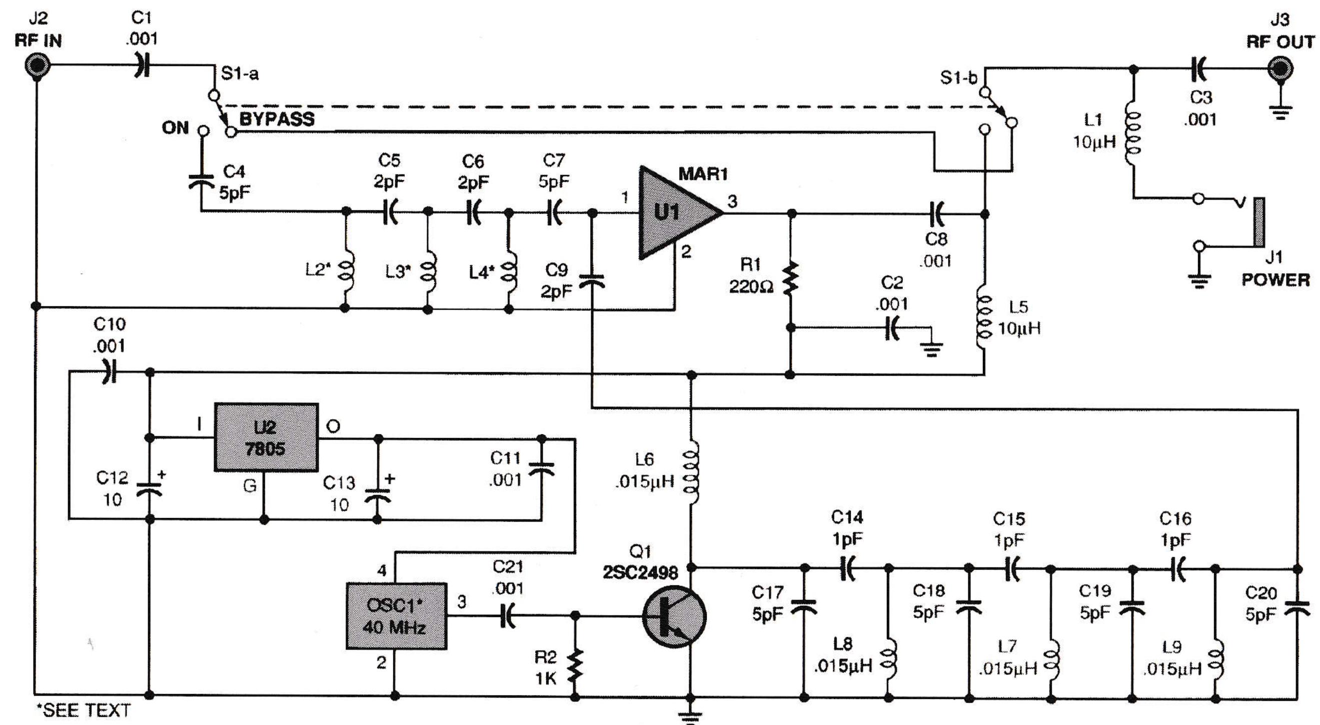
94

RF 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.

Simple Scanner Converter
VLF Converter
"Bat-Band" Converter
NE602 Direct-Conversion Output Circuit
NE602 Frequency Converter
31-m SW Converter for Auto Radios

SIMPLE SCANNER CONVERTER

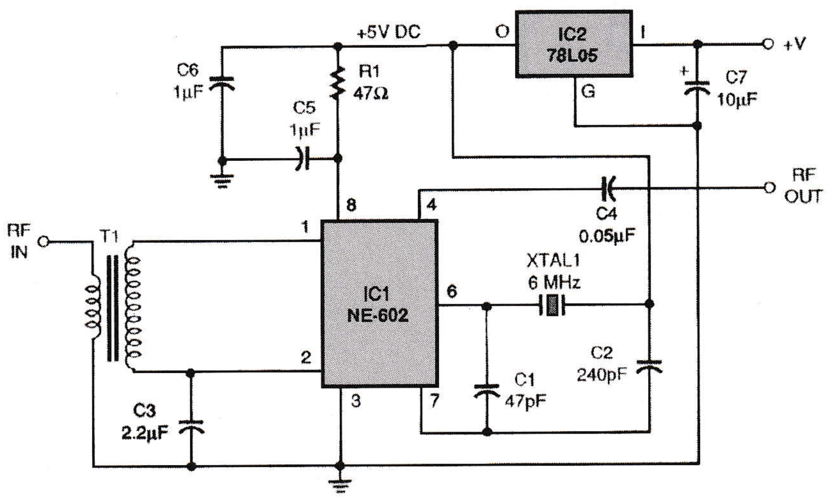


POPULAR ELECTRONICS

Fig. 94-1

This circuit can be powered from any 9- to 12-Vdc source, including a good alkaline 9-V battery. Switch S1 either puts the unit into its Bypass mode, where a scanner connected to J3 will receive its normal signals, or applies power to the circuit and down-converts all 800- to 950-MHz signals as follows: At the heart of the circuit is OSC1, a 40-MHz oscillator module. Transistor Q1 amplifies the oscillator's output, which is then bandpass filtered four times so that only the tenth harmonic at 400 MHz is presented to the input of U1, a Mini Circuits MAR1 wideband UHF/VHF amplifier. Signals from an antenna connected to J2 are high-pass filtered by capacitors C4 to C7 in conjunction with inductors L2 to L4. Those inductors are etched into the tracings on the PC board, making the exact PC board layout a necessity if the circuit is to function. Mixer U1 amplifies and mixes the two inputs—signals between 800 and 950 MHz and the 400-MHz local oscillator—and passes the 400- to 550-MHz output to J3. This converter is not suitable for areas where signal strength is low or areas where a large number of strong signals are present, as no RF stage is used and little input filtering is used before the mixer, making this circuit prone to spurious responses.

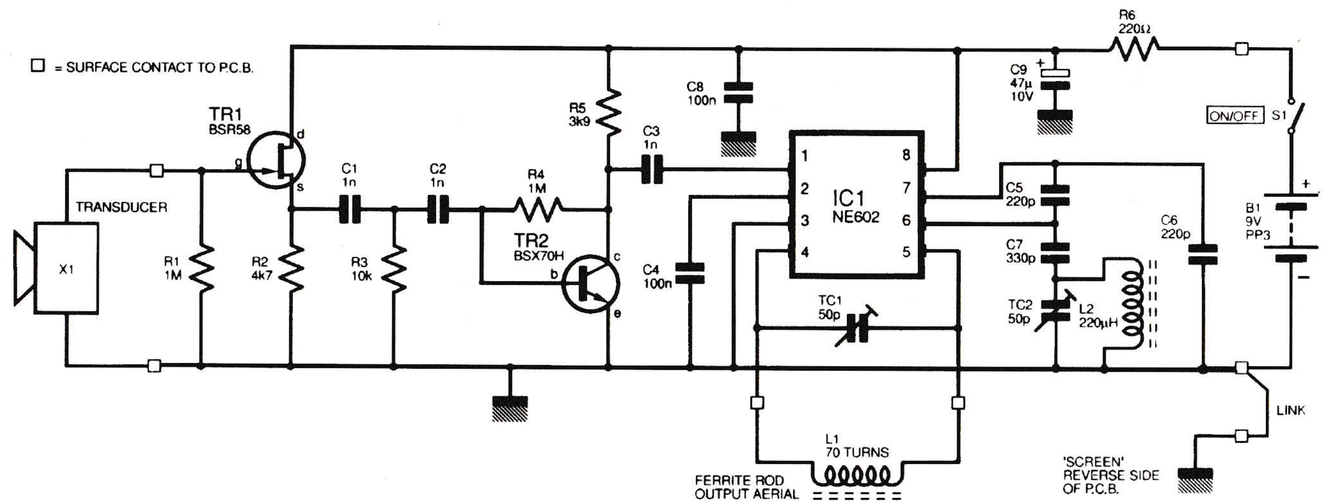
VLF CONVERTER



POPULAR ELECTRONICS *Fig. 94-2*

This very simple converter permits reception of the VLF 3- to 30-kHz band on a shortwave receiver covering the 6-MHz (49-m) shortwave broadcast band. T1 is an audio transformer of about 8 to 1000 Ω. These can easily be purchased new or found in junked transistor radios.

"BAT-BAND" CONVERTER

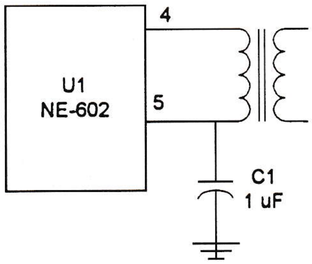


EVERYDAY PRACTICAL ELECTRONICS

Fig. 94-3

The full circuit diagram of the "bat-band" converter is shown. All components, with the exception of the transducer (X1), the ON/OFF switch, and the ferrite rod antenna, are surface-mount devices (SMDs). The signals from X1 are very small (microvolts, rather than millivolts). A low-noise FET input stage, TR1, has minimal loading effect on X1 and provides a low-impedance source for the passive high-pass filter. This simple filter consists of capacitors C1 and C2 and resistor R3. It attenuates signals below about 15 kHz, but the rolloff is very gradual. Mid-range and lower-frequency audio is strongly reduced. The falling sensitivity of transducer X1 further limits the audio frequencies reaching the mixer IC1. Despite this level of attenuation, a little audio still gets through the system, but it has no effect on the ultrasonic operation. When the receiver is tuned close to the 1-MHz local oscillator, a little audio feedback will be heard. This is a real help with tuning in because it readily identifies the low-frequency end of the "bat" band. The transistor TR2 is a low-noise amplifier, and the SMD-type BSX70H works well in this circuit. IC1 is a double-balanced mixer and Colpitts oscillator in one package. The signal inputs at pin 1 and pin 2 are used in unbalanced mode, with pin 2 decoupled by capacitor C4.

NE602 DIRECT-CONVERSION OUTPUT CIRCUIT

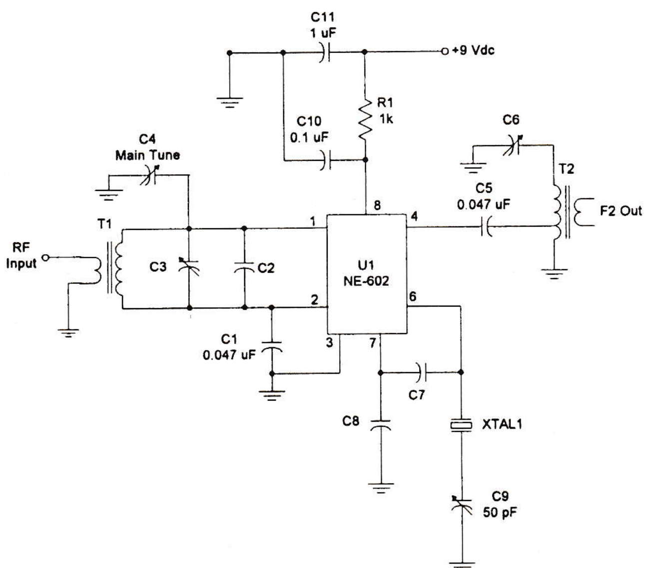


This figure shows a direct-conversion output circuit for an NE602.

73 AMATEUR RADIO TODAY

Fig. 94-4

NE602 FREQUENCY CONVERTER

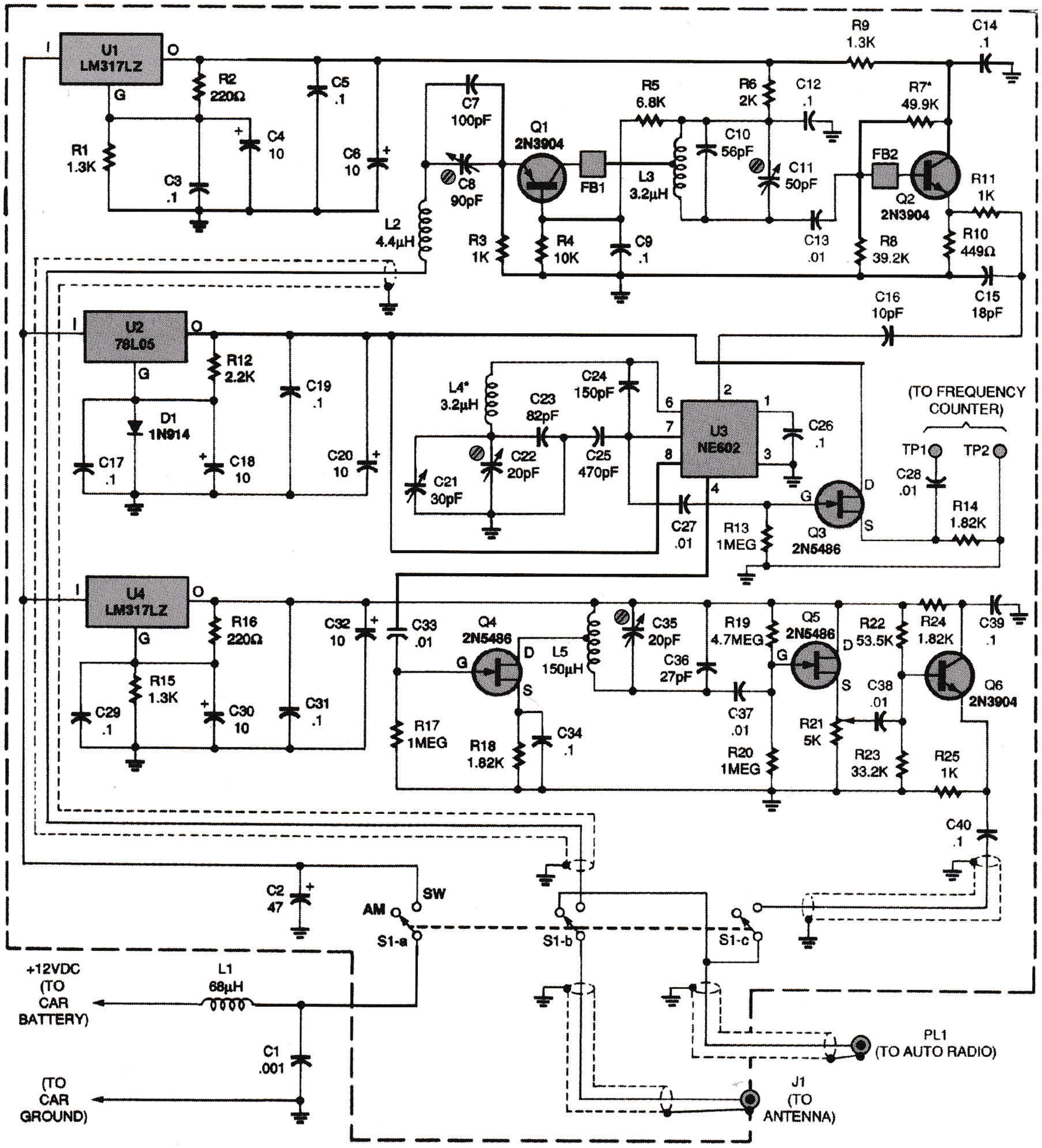


73 AMATEUR RADIO TODAY

Fig. 94-5

The NE602 can be used as a frequency converter with this circuit.

31-m SW CONVERTER FOR AUTO RADIOS



POPULAR ELECTRONICS

Fig. 94-6

Power for the circuit is taken from the car battery and is dropped to the proper voltages for three sections of the circuit by three separate regulator ICs: U1, U2, and U4. Inductor L2 and capacitors C7 and C8 act as the circuit's antenna tuner. The tuned signal is fed to an input bandpass filter composed of L3, C10, and C11. An NE602 oscillator IC, U3, is used as a combined mixer and oscillator. That configuration is known as a *series-tuned Colpitts* or *Clapp oscillator*, and is among the most temperature-stable variable oscillators. The 1710-kHz output filter consists of L5, C35, and C36. Each of the filters in the circuit was limited to a single LC section to simplify as much as possible the alignment of the converter. Transistor Q3 is a frequency-counter buffer that is used only during alignment. The gain of the converter is sufficient to overload the input of some receivers. Potentiometer R21 can be used to decrease the output level and prevent overload.

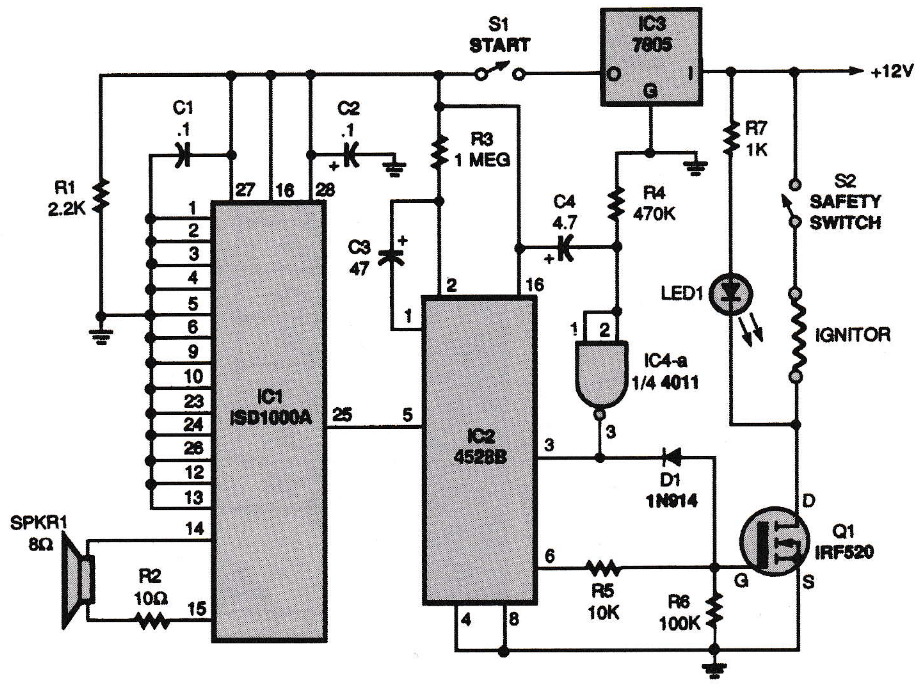
95

Rocket 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.

Rocket Launcher Igniter Circuit
LED Rocket Countdown Launcher
Rocket Launcher Voice Countdown Recorder Circuit
Time-Delayed Model Rocket Launch Control
Model Rocket Ignition Circuit

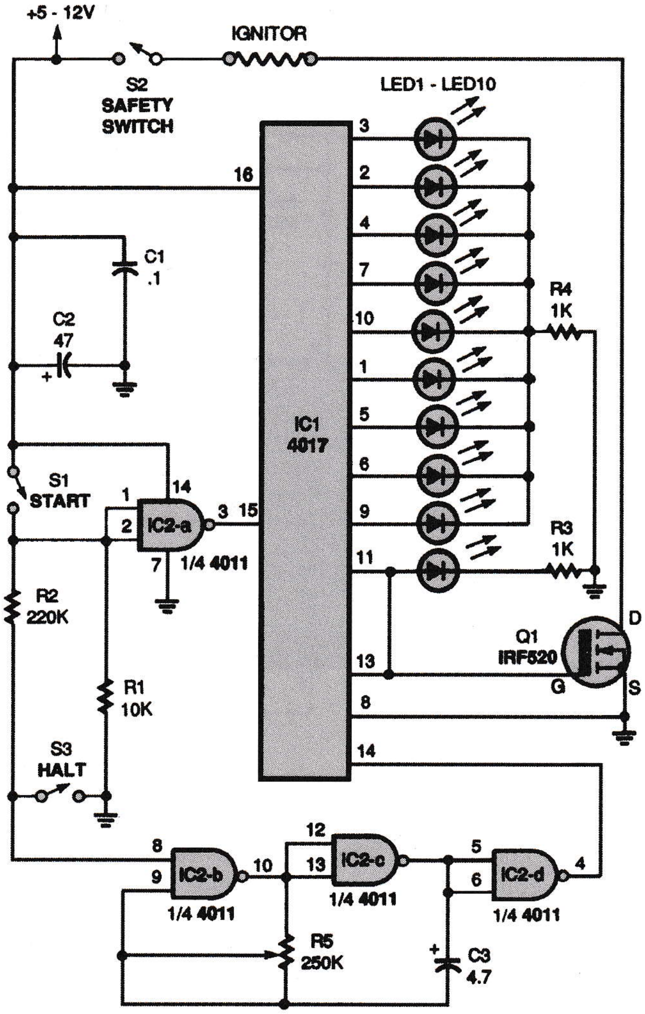
ROCKET LAUNCHER IGNITER CIRCUIT



POPULAR ELECTRONICS *Fig. 95-1*

An ISD1000A chip (IC1) containing a previously recorded message is connected in a simple playback-only circuit that operates when power is supplied by closing the START switch (S1). A 7805 voltage regulator, IC3, is used to drop the 12-V input voltage to 5 V. When the audio message is completed, IC1 produces a 16-ms low output pulse at pin 25. That low output pulse is fed to the input, pin 5, of a monostable multivibrator, IC2. That IC produces a long timed output pulse at pin 6, which turns Q1 on, supplying power to the igniter and firing the rocket engine. This circuit contains several safety features. Switch S2 removes power from the igniter fuse. One gate of a 4011 quad two-input NAND gate (IC4-a) keeps the 4528B monostable multivibrator from misfiring and igniting the rocket motor prematurely. When the Start switch is first activated, IC4-a's input goes high while C4 is charging up, and its output at pin 3 goes low, keeping IC2 from responding to any false input pulse at pin 5. IC4-a's pin 3 clamps the input of Q1 to ground, through D1, keeping it turned off. After a few seconds, C4 is fully charged and IC4-a's output goes positive, enabling IC2 and allowing Q1 to operate. Though not shown in the figure, the inputs of the quad IC's three unused gates (IC4-b to IC4-d, pins 5, 6, 8, 9, 12, and 13) must be tied to ground.

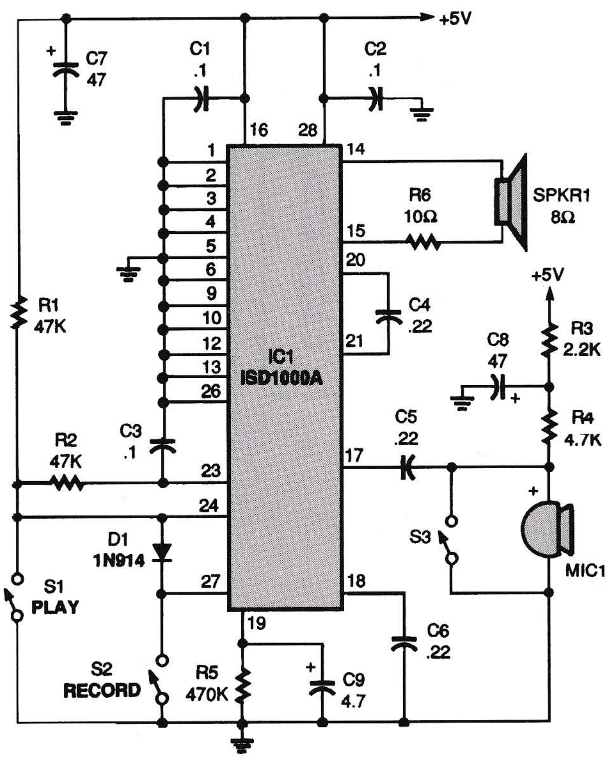
LED ROCKET COUNTDOWN LAUNCHER



POPULAR ELECTRONICS *Fig. 95-2*

A 4011 quad two-input NAND gate and a 4017 decade-counter/divider IC are the heart of the launcher. Transistor Q1, an IRF520 hexFET, sends the current through the igniter fuse to fire the rocket engine. Two gates of a 4011 NAND gate, IC2-b and IC2-c, are connected in a low-frequency oscillator circuit, with R5 and C3 setting the oscillator's frequency. Another gate of that IC, IC2-a, starts the countdown and sets pin 15 of the 4017 to the Run condition. The IC's fourth gate, IC2-d, inverts and buffers the oscillator's output and supplies the clock input to pin 14 of the 4017. The 10 LEDs indicate the count. When the last one (LED1) turns on, pin 11 goes high, turning Q1 on and firing the igniter fuse. The last LED, LED1, will remain on until S1 is switched off. The countdown can be halted by closing S3. Opening S3 continues the countdown.

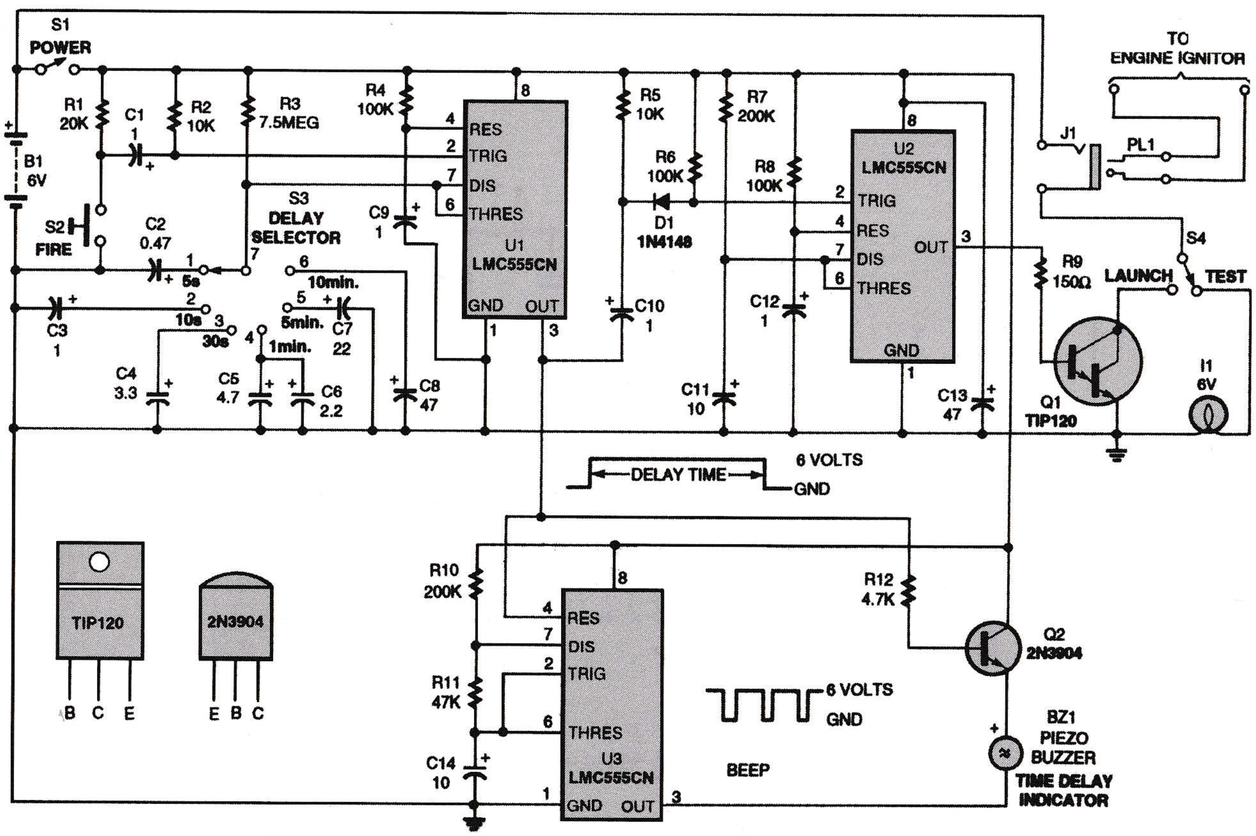
ROCKET LAUNCHER VOICE COUNTDOWN RECORDER CIRCUIT



POPULAR ELECTRONICS *Fig. 95-3*

Use this circuit to record your countdown sequence on the ISD1000A. Once you are satisfied with your recording, the circuit will no longer be needed. This circuit can be used as a stand-alone voice recorder circuit.

TIME-DELAYED MODEL ROCKET LAUNCH CONTROL



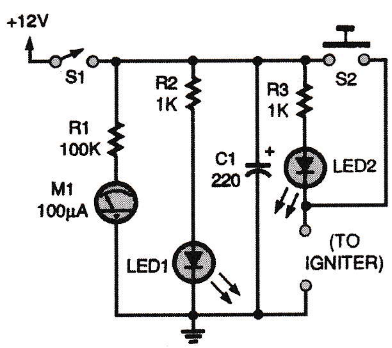
POPULAR ELECTRONICS

Fig. 95-4

The circuit, which gives a choice of six delay settings, consists of three 555 oscillator/timers (U1 to U3), a pair of transistors (Q1 and Q2), four switches (S1 to S4), a piezoelectric buzzer (BZ1), and a few support components. Power for both the control circuit and the rocket-engine igniter is provided by a 6-V power source that is composed of four AA-cell alkaline batteries. Closing switch S1 feeds power to the launch-control circuit, but does not initiate a launch sequence. A pair of series RC circuits

(R4-C9 and R8-C12, respectively) are used to debounce the RESET inputs (pins 4) of U1 and U2 (a pair of 555 oscillator/timer ICs). When S2 is closed, C1's negative terminal is connected to ground through the switch, momentarily pulling pin 2 of U1 (which is configured as a monostable multivibrator, or one-shot) low, activating it. Once triggered, U1's output goes high for an interval that is determined by R3 and one of six timing capacitors (C2 through C8). The timing capacitor is selected via DELAY SELECTOR switch S3. The high output of U1 at pin 3 causes Q2 to turn on, allowing the piezoelectric buzzer BZ1 to turn on. Monostable U1's output is also fed to the RESET input of U3 at pin 4, causing it to oscillate with a duty cycle of about 75 percent. As long as the output of U1 is high and the astable is oscillating, BZ1 beeps once every 4 s. The resistor discharges coupling capacitor C10 whenever U1's output goes high. At the end of the selected time delay, U1's output goes low. That low is coupled through C10 and D1 to the TRIGGER input (pin 2) of U2. Components R7 and C11 set U2's high-output interval to approximately 3 s. During that 3-s interval, U2's high output at pin 3 is fed to Darlington transistor Q1 through R9. With S4 in the LAUNCH position, Q1 grounds one end of the engine igniter, effectively connecting it to the battery's negative terminal.

MODEL ROCKET IGNITION CIRCUIT



POPULAR ELECTRONICS

Fig. 95-5

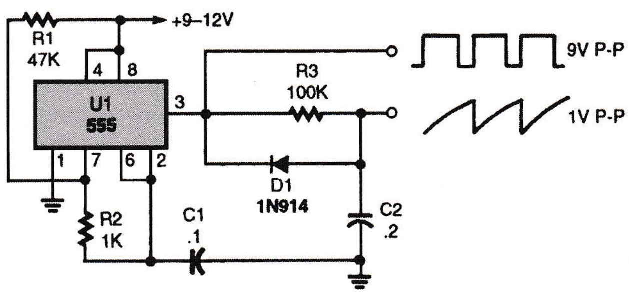
This circuit requires a 12-Vdc source. A battery pack of eight AA cells in series will work. Meter M1 gives you an indication of battery voltage; change the batteries when you see a noticeable drop in current. The circuit contains two LEDs: LED1 reminds you that the circuit is powered up, and LED2 lets you know that you have continuity through the igniter and are ready to fly. Capacitor C1 gives igniters that extra kick they occasionally need. Pushing the momentary push-button switch (S2) sends the rocket on its way. Use a red switch for that. The igniter leads are connected to the plugs marked *igniter*.

96

Sawtooth Generator 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.

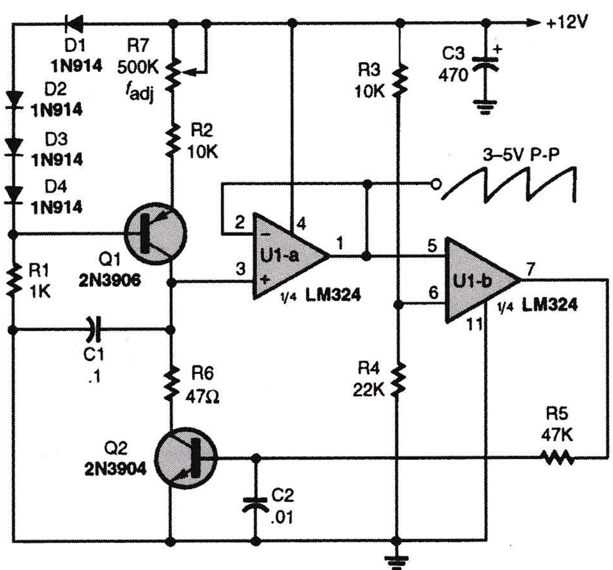
SIMPLE SAWTOOTH WAVEFORM GENERATOR



POPULAR ELECTRONICS *Fig. 96-1*

This sawtooth generator is built around a 555 configured as an astable multivibrator.

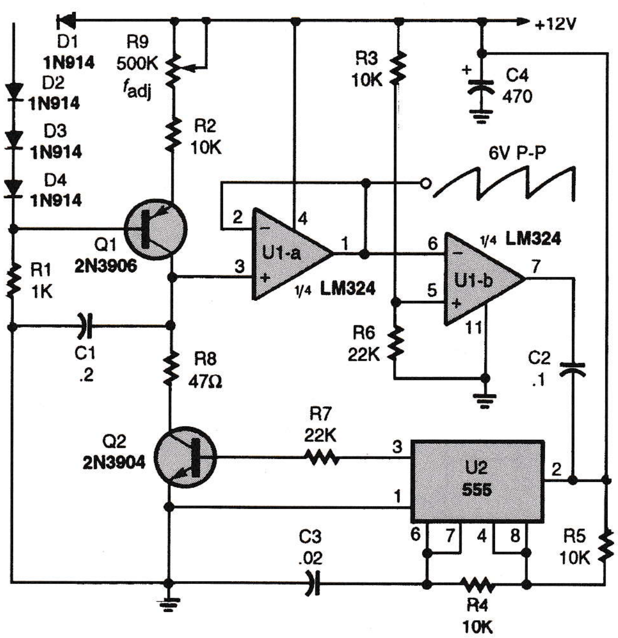
LINEAR SAWTOOTH GENERATOR



POPULAR ELECTRONICS *Fig. 96-2*

Q1 is connected in a simple constant-current generator circuit. The value of Q1's emitter resistor sets the constant-current level flowing from the transistor's collector to the charging capacitor (C1). One op amp of an LM324 quad op amp IC, U1-a, is connected in a voltage-follower circuit. The input impedance of the voltage follower is very high and offers little or no load on the charging circuit. The follower's output is connected to the input of U1-b, which is configured as a voltage comparator. The comparator's other input is tied to a voltage divider, setting the input level to about 8 V. The output of U1-b at pin 7 switches high when the voltage at its positive input, pin 5, goes above 8 V. That turns on Q2, discharging C1. The sawtooth cycle is repeated over and over as long as power is applied to the circuit. The sawtooth's frequency is determined by the value of C1 and the charging current supplied to that capacitor. As the charging current increases, the frequency also increases, and vice versa. To increase the generator's frequency range, decrease the value of C1, and to lower the frequency, increase the value of C_r. The output is about 3 to 5 V.

LINEAR SAWTOOTH WAVEFORM GENERATOR CIRCUIT



POPULAR ELECTRONICS *Fig. 96-3*

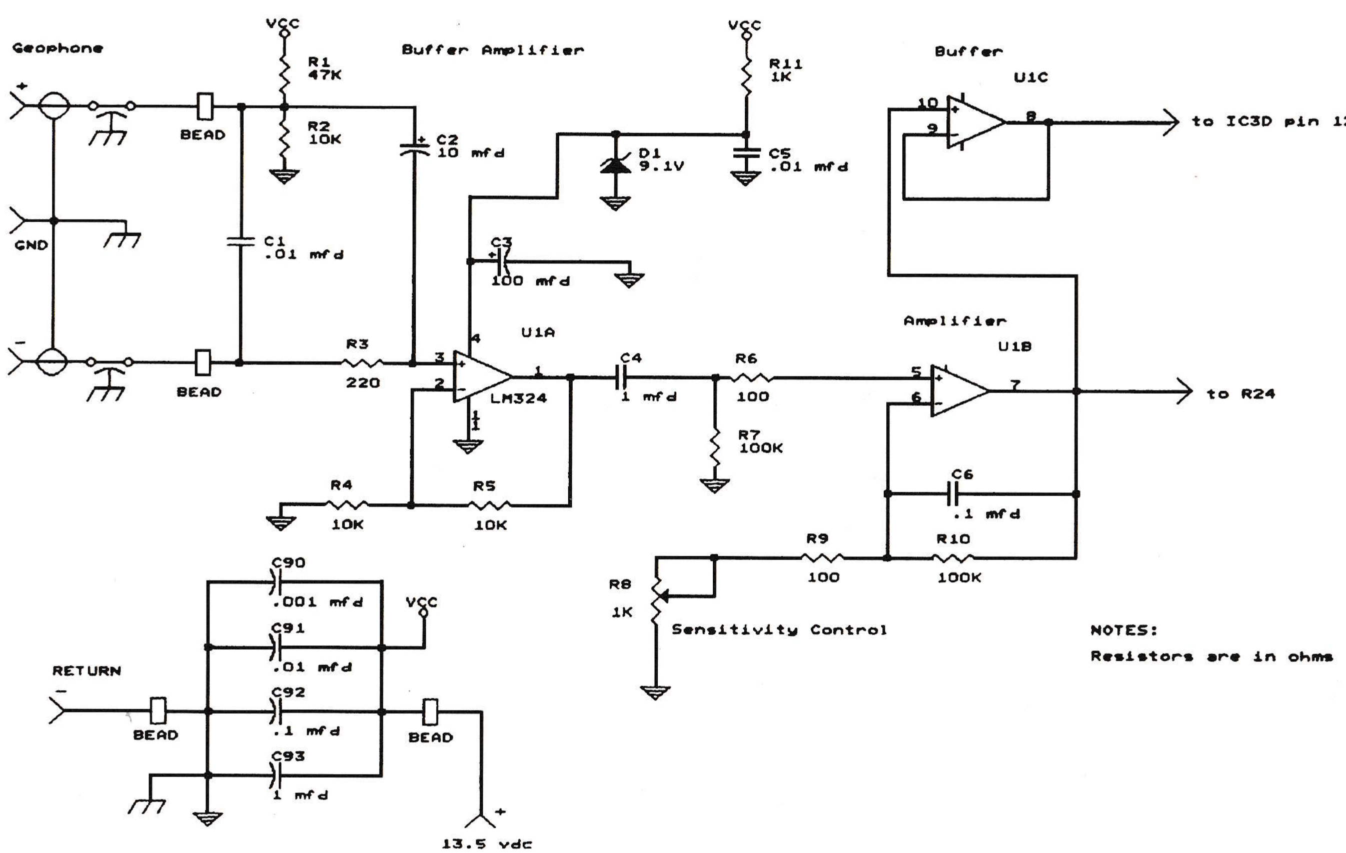
In this circuit, Q1 is a constant-current source, whose output is controlled by R9. C1 charges linearly, and follower U1-a drives comparator U1-b. When the threshold set by R3 and R6 is reached, U1-b changes state and triggers pulse generator U2, gating on Q2 and discharging C1 through R8. The cycle then repeats. The period is approximately $8 \times C_1/I_1$, where I_1 is the collector current of Q1, as set by R9 and the base bias on Q1.

97

Seismic Radio Beacon 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.

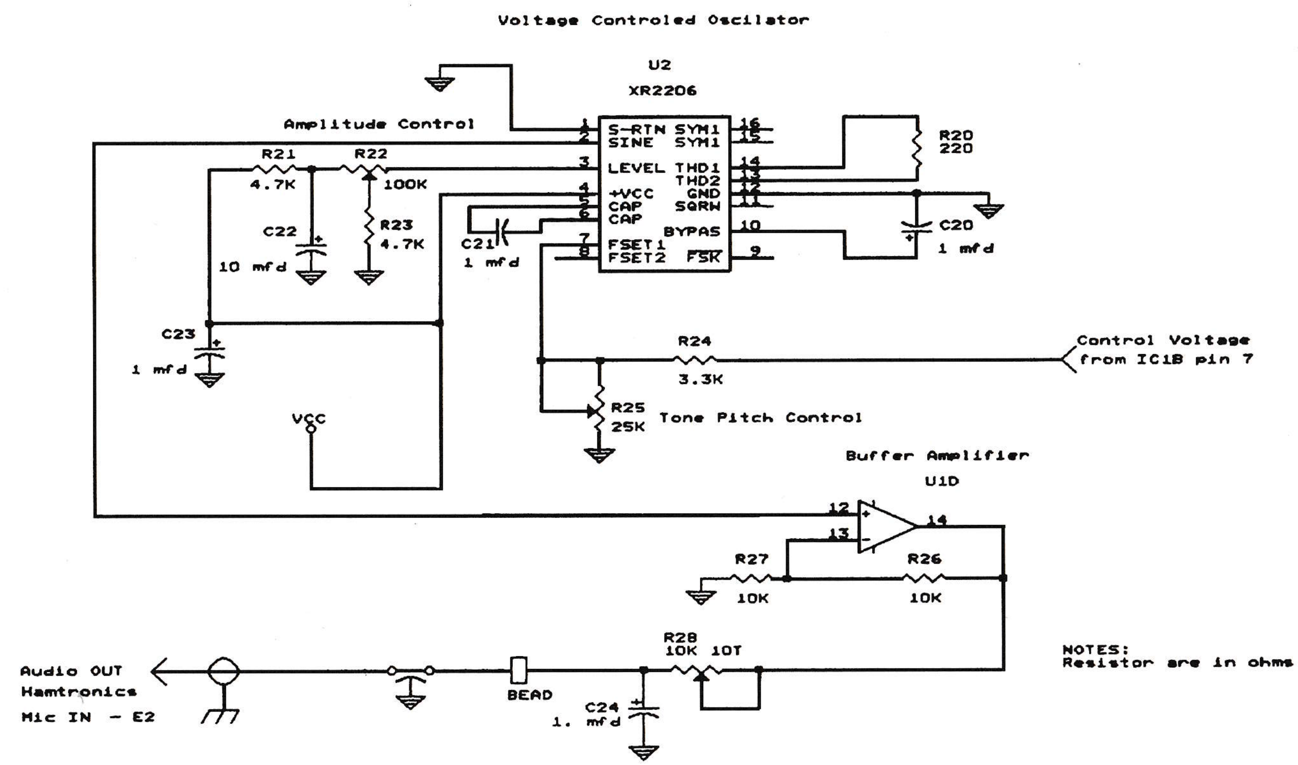
SEISMIC RADIO BEACON (GEOPHONE AMPLIFIER)



73 AMATEUR RADIO TODAY *Fig. 97-1*

This geophone amplifier and buffer was used as part of an amateur radio beacon that monitors seismic activity in an earthquake-prone area of the United States.

SEISMIC RADIO BEACON (AUDIO VCO AND BUFFER)

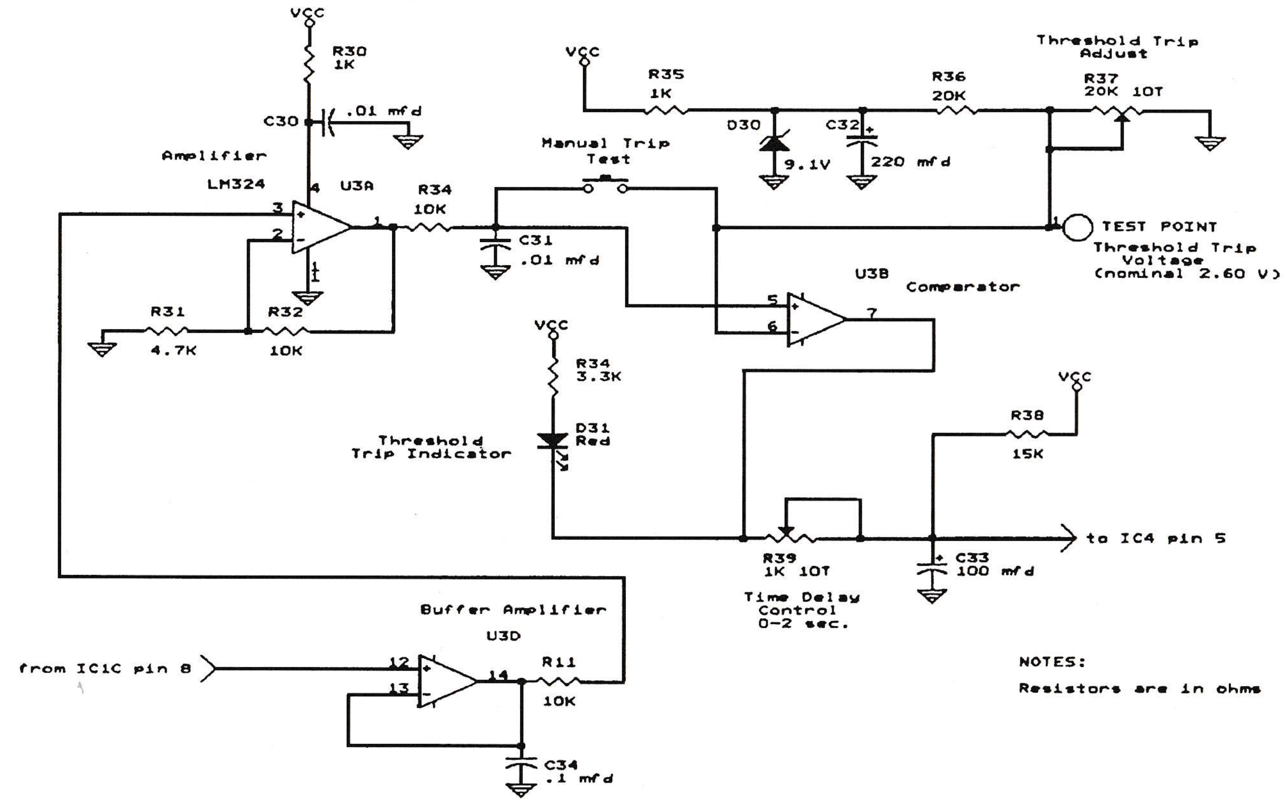


73 AMATEUR RADIO TODAY

Fig. 97-2

This audio and VCO buffer is fed by a geophone amplifier and produces a tone modulated by seismic activity, as picked up by a geophone.

SEISMIC RADIO BEACON (THRESHOLD CIRCUIT)

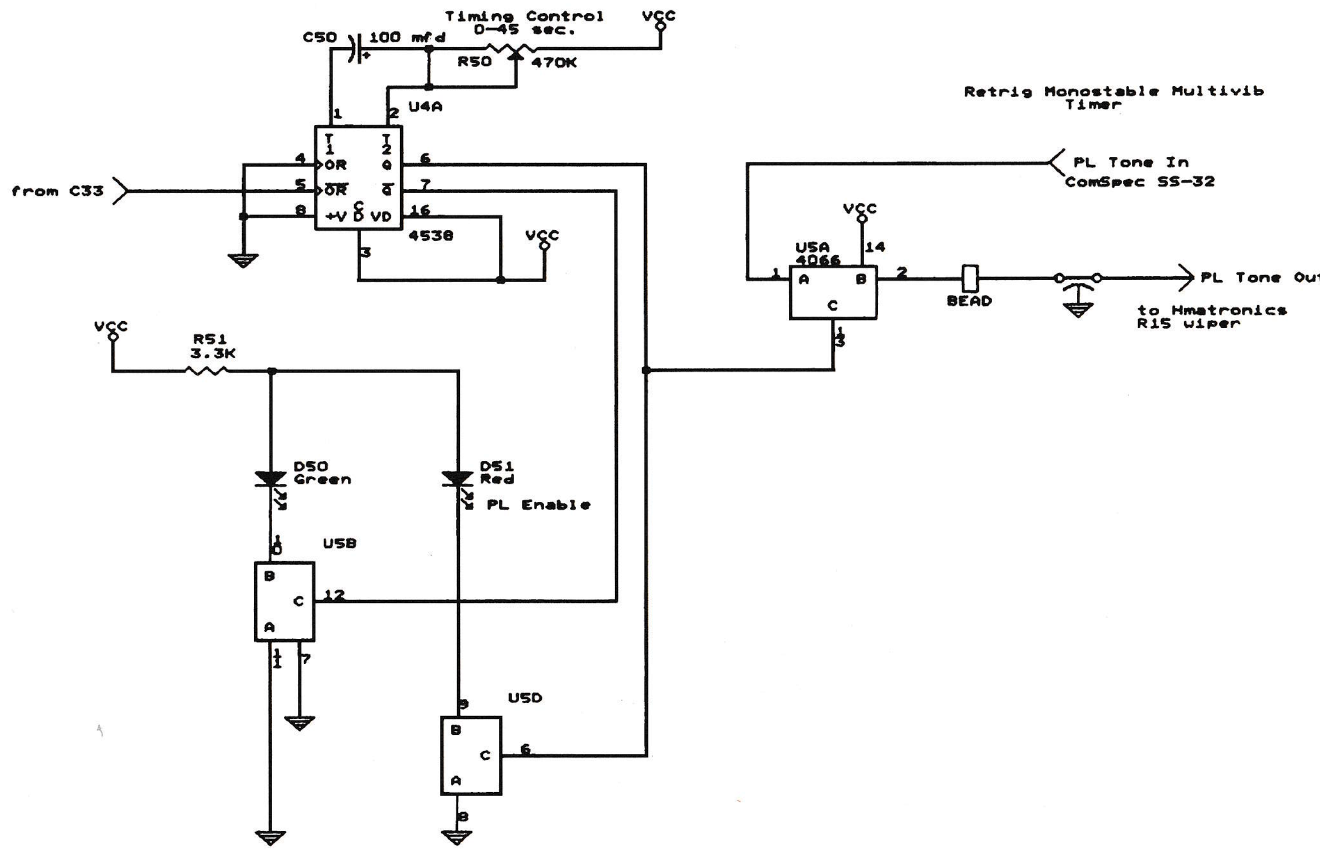


73 AMATEUR RADIO TODAY

Fig. 97-3

This threshold circuit is fed by a geophone amplifier and is actuated by seismic activity, as picked up by a geophone. The threshold is adjustable.

SEISMIC RADIO BEACON (TIMER AND SWITCHING)

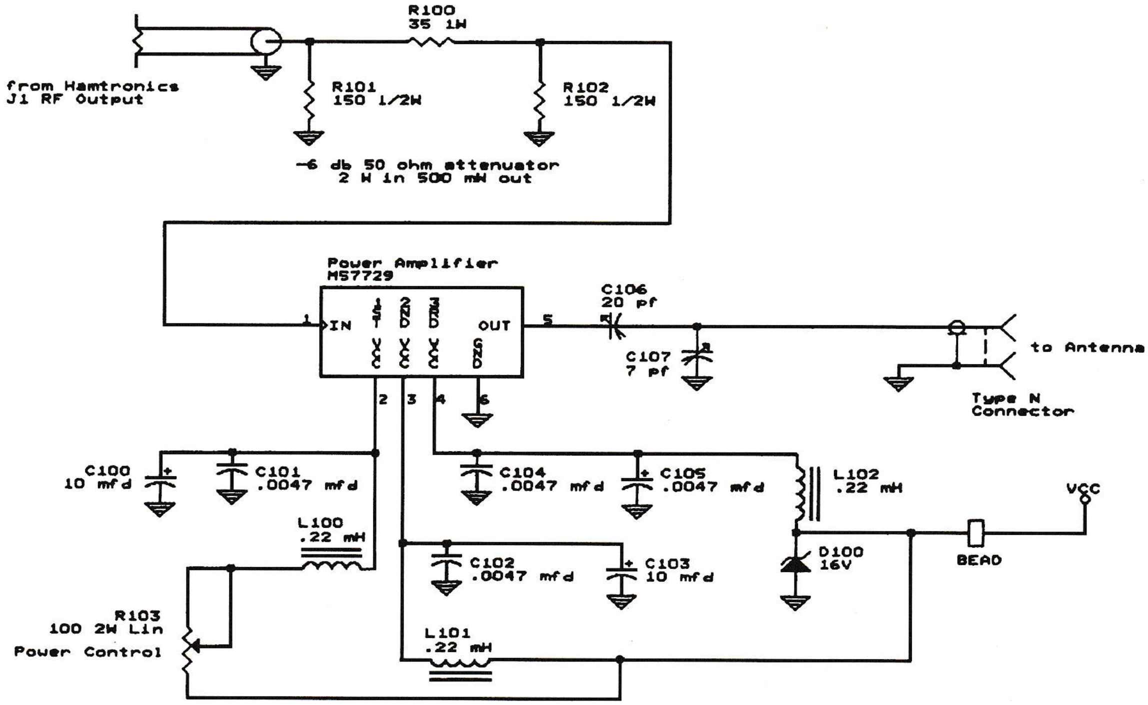


73 AMATEUR RADIO TODAY

Fig. 97-4

This timing circuit is fed by a threshold circuit that is actuated by seismic activity, as picked up by a geophone. The timing is adjustable and controls a 123-Hz PL tone that feeds a transmitter.

SEISMIC RADIO BEACON (RF POWER AMPLIFIER)



73 AMATEUR RADIO TODAY ***Fig. 97-5***

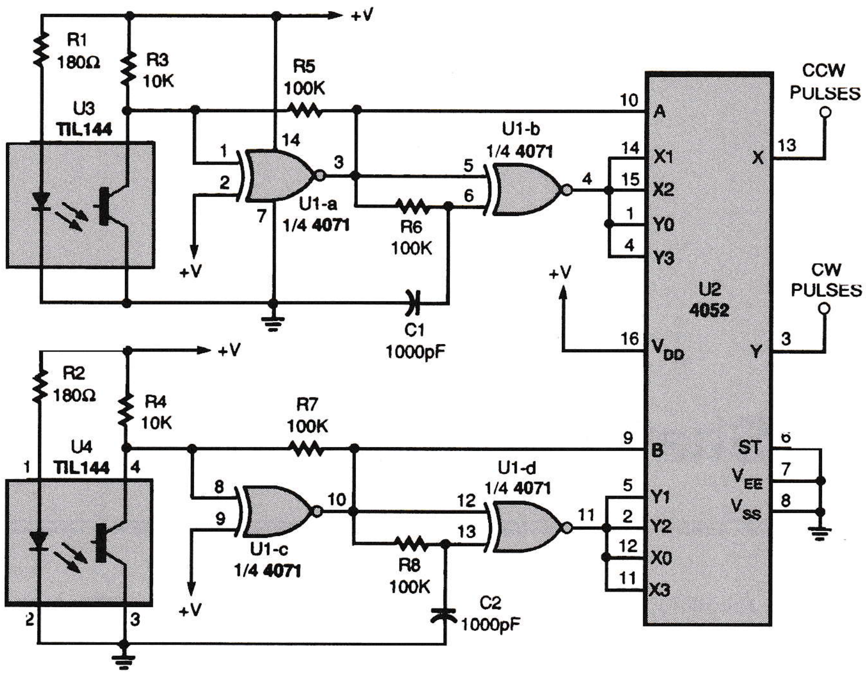
This RF power amplifier operates at 432 MHz and was used as a power amplifier for a small transmitter used in an amateur radio beacon that also has seismic monitoring capability.

98

Shaft Encoder 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.

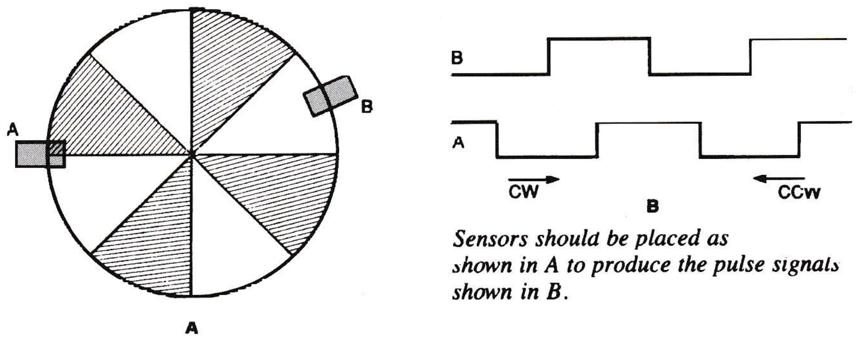
SHAFT ENCODER PULSE-GENERATING CIRCUIT



POPULAR ELECTRONICS ***Fig. 98-1***

This circuit produces one output pulse for every transition of the photosensor output or four pulses for every section or line pair. The exclusive-NOR gates U1-b and U1-c produce a pulse on every transition, and U2, a dual four-channel data selector, decodes them into "up" pulses or "down" pulses. The number of sections or lines that can be accommodated on a disk is determined by its diameter and the width of the sections. As an example, if the sections are made approximately 0.125" wide, 25 section pairs can put on a 2" diameter disk and 100 pulses will be generated with every revolution of the disk. The only limiting factor is that the sections must be wider than the photosensor's aperture at the point they pass in front of it. The alignment of the photosensor assembly is not critical. The only concern is that one sensor be over a light area while the other sensor is at a transition from light to dark or dark to light. Two sections of U1, U1-a and U1-c, act as buffers and waveshapers for the outputs of the sensor, while U1-b and U1-d generate a pulse at each transistor of the sensor's output. The 100-kΩ resistors between the output and the input of U1-a and U1-c provide positive feedback to speed up the rise and fall times and also generate hysteresis to eliminate noise during the transitions. The pulses produced by U1-b and U1-d at the transitions are the result of the delay produced by the RC circuits located at one input of each gate. For example, U1-b pin 5 follows the transition immediately, whereas pin 6 follows slowly. With the values shown, the two inputs are different for about 100 μs after every transition. While the inputs are different, the output is low. Therefore, U1-b generates a negative pulse for every transition of sensor U3 and U1-d generates a negative pulse for every transition of U4. The states of U3 and U4 determine whether the pulse is sent to the X output of the data selector (U2, pin 13) to indicate a CCW pulse or to the Y output (pin 3) to indicate a CW pulse.

SHAFT ENCODER



Sensors should be placed as shown in A to produce the pulse signals shown in B.

POPULAR ELECTRONICS

Fig. 98-2

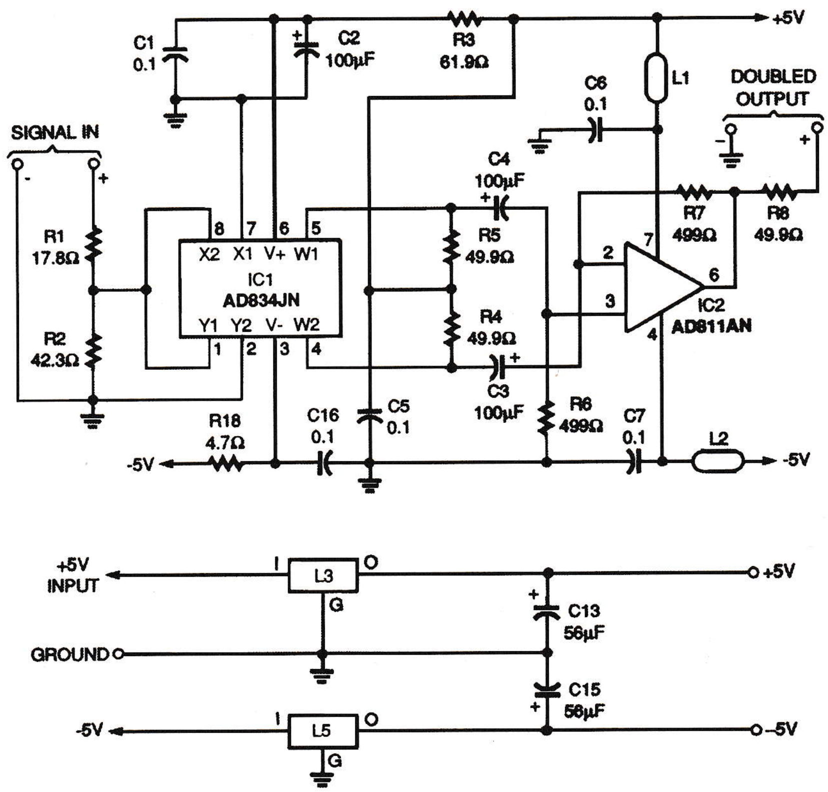
The electro-optical shaft encoder is a combination of encoding disk, photosensors, and counters. The encoding disk and photosensors generate a pulse train that can be counted to determine rate. The disk's direction of rotation can be sensed and used to determine count direction (for example, count up for clockwise and count down for counterclockwise). The disk need not be a precision part; it can be made from clear plastic with dark sections or lines painted on it. The number of lines on the disk determines how many pulses are generated per revolution. If two photosensors are used, two signals in quadrature are generated; from those, the direction can be sensed. A simple encoding disk is shown in A; note the alternating transparent and opaque sections. A pair of electro-optical photosensors are positioned (as shown) so that when one is centered over a section, the other is positioned over a transition. As the disk is rotated, each photosensor will be alternately illuminated and obscured and will produce outputs (as shown). A clockwise rotation is indicated when there is a positive transition (from dark section to light section) at sensor B while sensor A is low (obscured by a dark section), a positive transition at A while B is high (over a light section), a negative transition of B (going from light to dark) while A is high, and so forth. A counterclockwise rotation is indicated when there is a positive transition of B when A is high, a negative transition of A when B is high, etc.

99

Sine-Wave Generator 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.

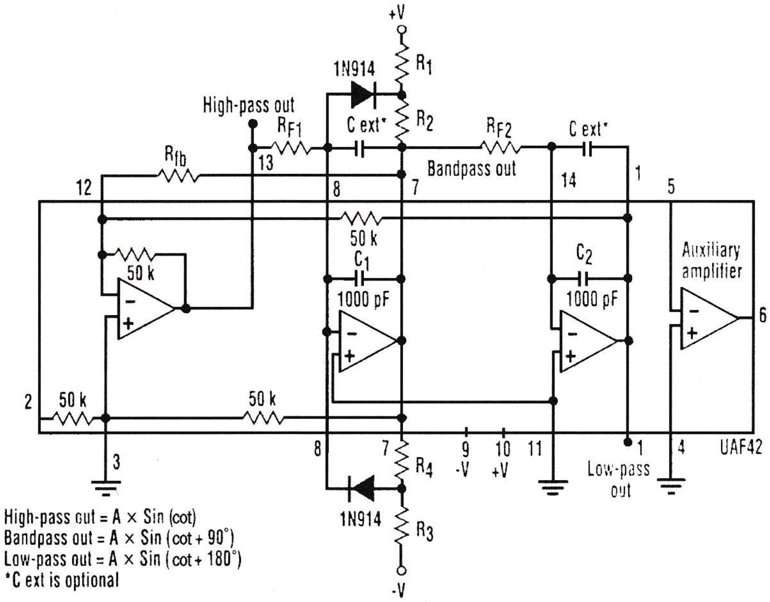
SINE-WAVE DOUBLER



ELECTRONIC EXPERIMENTERS HANDBOOK ***Fig. 99-1***

This circuit uses a four-quadrant multiplier by Analog Devices to perform frequency doubling on a sine-wave input signal. By applying a sine wave to both x and y inputs, the multiplier multiplies the sine wave by itself, resulting in a sine-squared waveform. This waveform is equivalent to a dc level and a cosine component at twice the frequency and half the original amplitude, i.e., $\sin^2 x = (1 - \cos 2x)/2 - 3$ dB bandwidth is typically 30 MHz.

ONE-FILTER THREE-PHASE SINE-WAVE GENERATOR



ELECTRONIC DESIGN *Fig. 99-2*

It is possible to build a three-phase sine-wave oscillator using just one UAF42 state variable filter along with some resistors and diodes. Three output nodes are available: high-pass out, bandpass out, and low-pass out. The signals at the bandpass and low-pass out nodes are 90° and 180° out of phase, respectively, with those at the high-pass out node. An on-board auxiliary op amp is available for use as a buffer or gain stage. The frequency of oscillation is set with resistors RF1 and RF2 using the simple equation:

$$f_{osc} = 1/2\pi RC (1)$$

where $R = R_{F1} = R_{F2}$, and $C = C_1 = (C_2) = 1000$ pF.

The maximum f_{osc} obtainable using the UAF42 state-variable filter is 100 kHz. However, distortion becomes a factor for frequencies above 10 kHz. Resistance R_1, R_2, R_3, and R_4 should be selected using the following equation to set the desired signal amplitude:

$$R_1/R_2 = R_3/R_4 = [(V_O + V_{CC})/(V_O - 0.15)] - 1 (2)$$

Resistor R_{fb} provides a positive feedback path from the bandpass out node to the summing-amplifier input. This provides the necessary "startup" required to begin oscillation. Suggested values are as follows:

- If f_{osc} ±1 kHz, then $R_{fb} = 10$ MΩ.
- If 10 Hz $\leq f_{osc} < 1$ kHz, then $R_{fb} = 5$ MΩ.
- If $f_{osc} < 10$ Hz, then $R_{fb} = 750$ kΩ.

To design a 1-kHz, 1.2-V peak oscillator, use Eq. 1 to calculate R_{F1} and R_{F2}:

$$R_{F1}=R_{F2}=1/(2 \times \pi \times 1 \text{ kHz} \times 10^{-9})=159.2 \text{ k}\Omega$$

Use Eq. 2 to determine values for the signal-magnitude-setting resistances R_1/R_2 and R_3/R_4:

$$R_1/R_2=R_3/R_4=[(V_O+V_{CC})/(V_O-0.15)]-1$$

Assuming V_{CC}=15 V, then

$$R_1/R_2=R_3/R_4=15.4$$

Setting R_1 and R_3 equal to 15.4 kΩ and R_2 and R_4 equal to 1 kΩ would provide the proper resistor ratios. These resistors act as loads to the internal op amp

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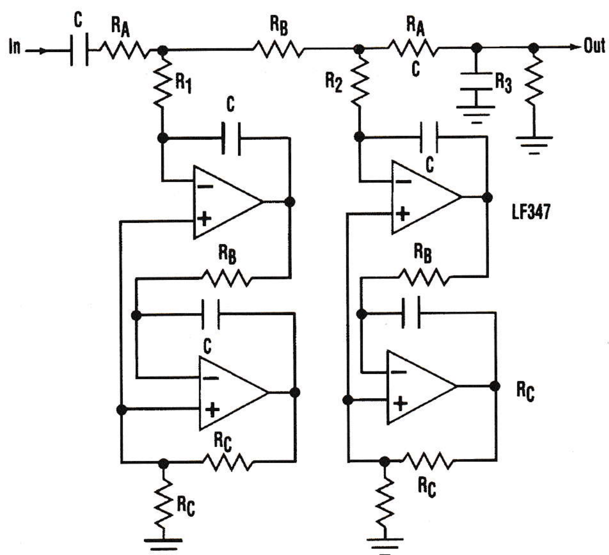
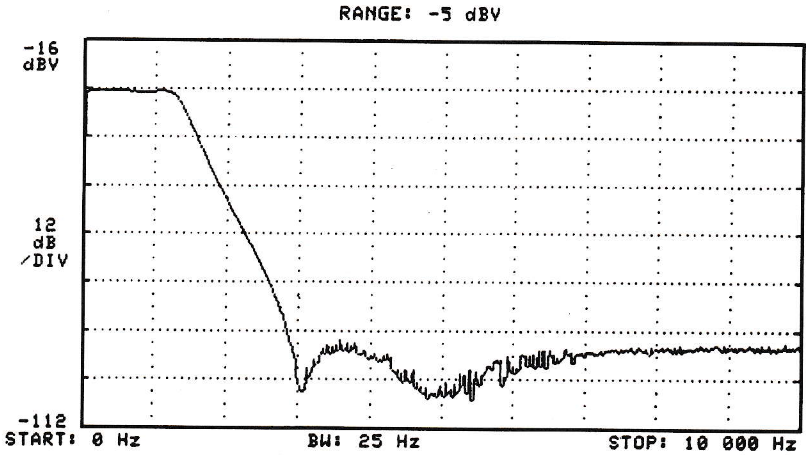
STABLE SINE-WAVE GENERATOR



Notes: Values for 1-kHz signal
C = 0.01 μF, 1%*
R_A = 10 k, 1%*
R_B = 20 k, 1%
R_C = 20 k nominal; matched required
R_1 = 1.407 k calculated; 1.40 k, 1% used
R_2 = 506.6 Ω calculated; 511 Ω, 1% used
R_3 = 100 k nominal; for dc bias
***Looser tolerance with matching is okay if R_1 and R_2 are adjusted.**



ELECTRONIC DESIGN

Fig. 99-3

Semidigital circuits (e.g., crystal oscillators and dividers) can create square waves of very stable amplitude and frequency. Removing the odd harmonics is a reasonable task for a filter. The obvious solution, a narrowband filter, isn't acceptable because analog types are notorious for poor stability. Digital and semidigital types (e.g., switched capacitor) are better in this respect, but they add their own noise and harmonics. The task can be accomplished using the filter shown. Without R1 and R2, it is an active version of a five-pole passive low-pass LC ladder. This type has excellent amplitude stability in the passband, 30 dB/octave slope outside the passband, low component sensitivity, and a capacitor to ground at the output, which ensures continuous high-frequency rolloff and minimizes stray noise pickup. The rejection would be inadequate at the third and fifth harmonics, but notches at these frequencies can be created with just two more resistors, R1 and R2. This turns the device into an elliptic-like filter.