10 Short Projects

Negative Voltage Generator

by Owen Bishop

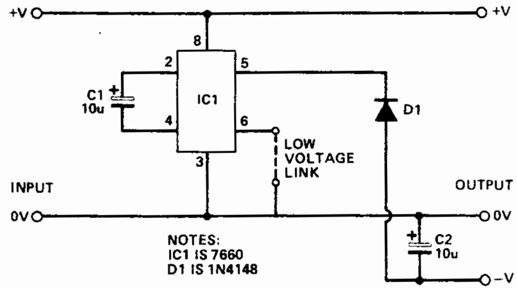
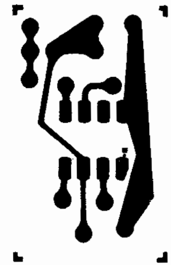


Fig. 1. The circuit of the Negative Voltage Generator uses just one IC.

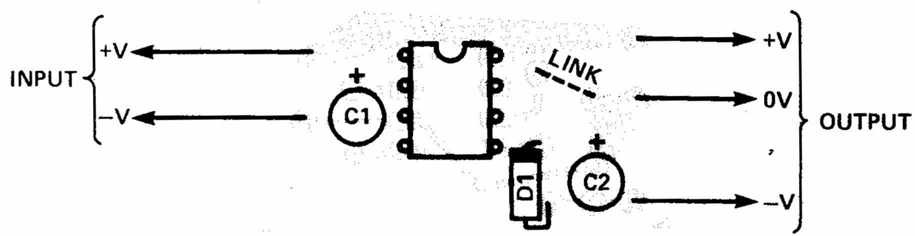


Construction

There is almost nothing to say about this, since it can be built up on a PCB the size of a postage stamp. Also, the circuit can be incorporated in any odd space on the main board of any other project that requires it.

It works for a wide range of supply voltages (+1V5 to +10V). Pin 6 must be joined to the 0V rail when the supply is less than +3V5 and for these low voltages, the diode may be omitted. The PCB design allows a wire link to connect pin 6 to the 0V rail for low voltage operation. If the unit is to be used at various voltages, some high, some low, a switch may be wired in place of the link.

The circuit works straight away — no adjustments are needed.



Overlay for the Negative Voltage Generator.

series with the diode. □

555 as switching regulator supplies negative voltage

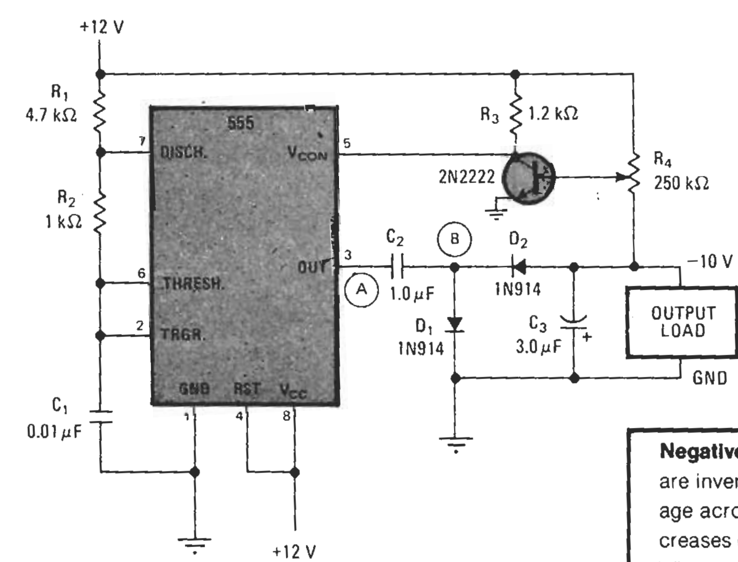
by S.L. Black
Western Electric Co., Columbus, Ohio

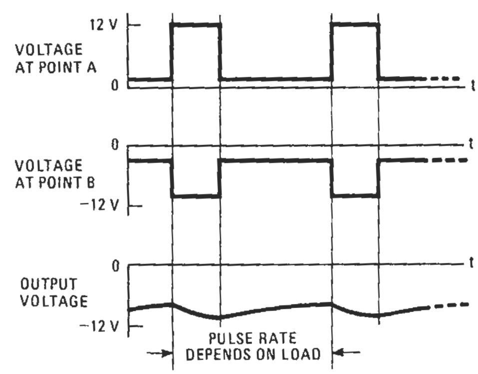
Latest addition to the 555 IC timer's seemingly endless bag of tricks is its use to generate a negative dc biasing voltage from a positive source. A current of well over 10 milliamperes can be delivered, and a form of switching regulation is employed to assure a constant output voltage. All of this is done with little more than an npn transistor and the 555 integrated circuit.

The 555 is operated in the astable mode, with the pulse width and frequency controlled by resistors R_1 and R_2 plus capacitor C_1. These parameters can be selected for maximum regulation at the output voltage level desired. Terminal 3 of the IC is connected to a network consisting of C_2, C_3, and diodes D_1 and D_2. Series capacitor C_2 causes the pulse train to lose its ground reference, so that D_1 and D_2 can rectify the signal and capacitor C_3 can filter it into a negative dc output voltage. The magnitude of this output voltage depends on the amplitude and repetition rate of the pulses coming from the IC.

To regulate the output voltage, the 2N2222 transistor varies the control voltage of the 555, increasing or decreasing the pulse repetition rate. Resistor R_3 acts as a collector load for the transistor; the base is driven from potentiometer R_4, which compares the output voltage to the supply voltage. If the output voltage becomes less negative, the control voltage goes closer to ground, causing the repetition rate of the 555 to increase so that C_3 recharges more frequently. If the output voltage becomes more negative, the control voltage goes closer to the positive supply voltage, so the repetition rate decreases, and C_3 is recharged less often.

The output voltage can be set to any level from 0 to −10 volts by means of potentiometer R_4. With the components shown in the figure, this circuit supplies −10 V from a 12-V source. Regulation is less than 5% at a current of 10 mA and less than 0.05% at 0.2 mA. □





Negative-voltage source. Pulses from free-running multivibrator IC are inverted and smoothed by C_2, D_2, and C_3. Negative output voltage across C_3 is regulated by the transistor, which increases or decreases multivibrator frequency to charge C_3 as often as necessary. With components shown, output is −10 V. Regulation is 0.05% at 0.2 mA and 5% at 10 mA, providing good bias supply.

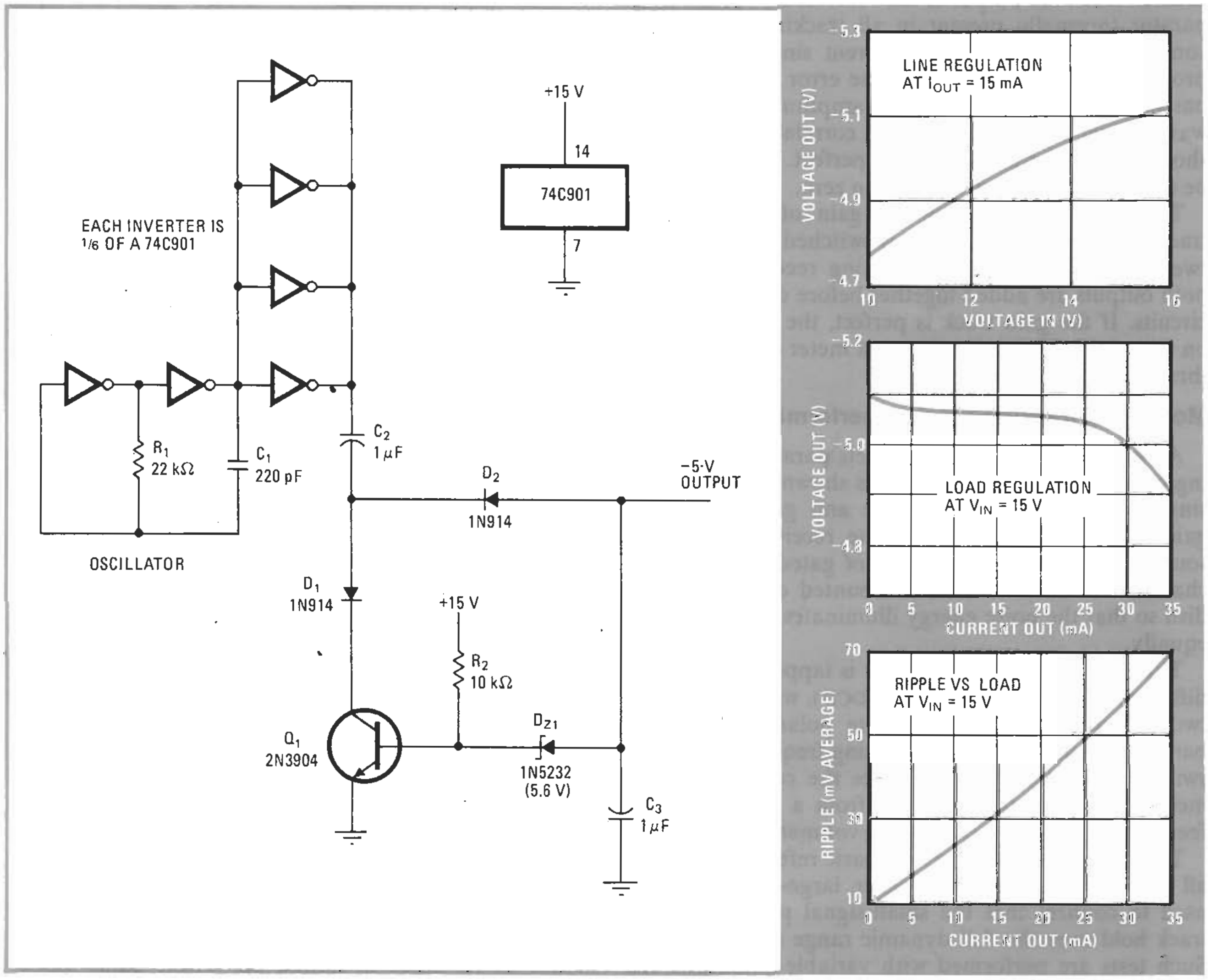
Inverting dc-to-dc converters require no inductors

by Craig Scott and R.M. Stitt
Burr-Brown Research Corp., Tucson, Ariz.

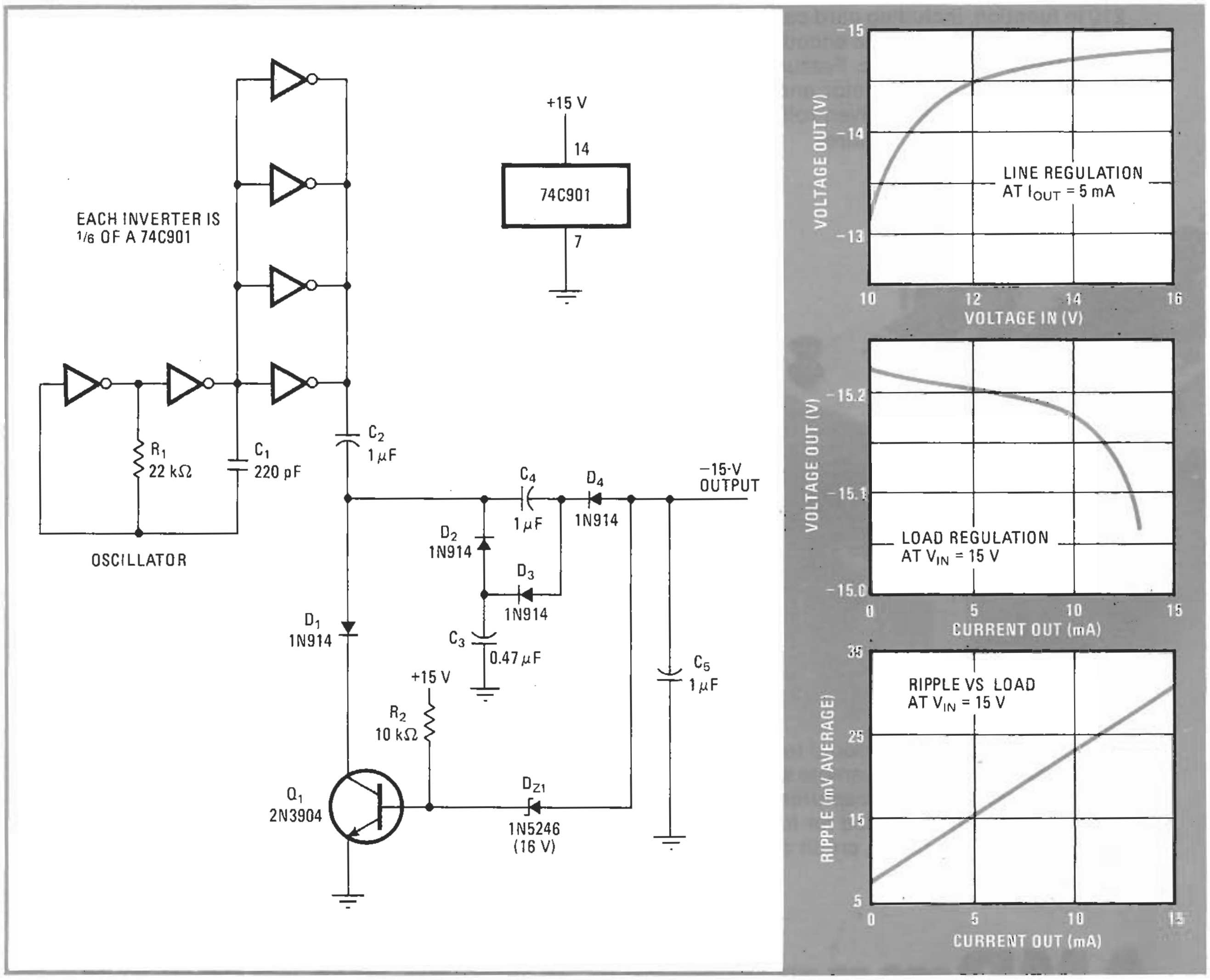
Many systems require a modest negative power source where only a positive power supply is available. Such a negative voltage can be produced by an inverting dc-to-dc converter installed right where it is needed. This arrangement is especially convenient in systems where the dc power is supplied remotely because only two wires need to be run to the point of use, instead of three. The inverting dc-to-dc converter described here requires no expensive transformers or inductors. Noise spikes associated with switching inductive loads are therefore eliminated.

To understand the operation of the circuit, consider first the -5-volt converter shown in Fig. 1. Resistor R_1, capacitor C_1, and two inverters form a free-running 100-kilohertz oscillator. The remaining four inverters in the hex-inverter package form a power driver. On the positive swing at the output of the power driver, C_2 is charged through diode D_1 and transistor Q_1 (assuming that Q_1 is on). When the output of the power driver drops back to zero, D_1 reverse-biases and D_2 forward-biases, so charge is transferred to C_3.

As the cycle repeats, C_3 is charged to a negative voltage that approaches the positive-output swing minus the diode drops, power-driver drop, and the drop across Q_1. Q_1 is held on by R_2 until the base-drive current is shunted away by the breakdown of D_{Z1}. This occurs when the negative output voltage exceeds the break-



1. Converts and inverts. Dc-to-dc converter provides inverted regulated output of –5 volts without use of transformer or inductor. Instead, it puts negative potential on C_3 by discharge of C_2 during off-cycle of oscillator. Performance curves show data for typical units.



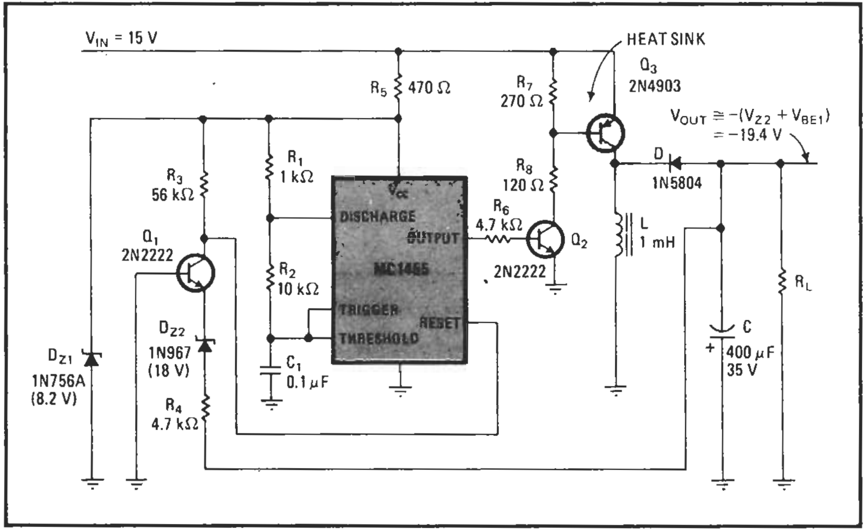
2. More volts. Addition of voltage-multiplier stage to circuit in Fig. 1 allows it to deliver a regulated output of −15 V. These inverting-converter circuits are convenient for producing negative voltages at locations remote from the main positive power source.

down voltage rating of D_{Z1}, less the V_{BE} of Q_1. Thus, the output voltage is regulated at $V_{out} = -(V_{Z1} - V_{BE})$.

With the output loaded, the negative output voltage of this circuit evidently cannot exceed that of the positive power-supply input in size. It is possible, however, to modify the circuit so that it produces a negative voltage equal to or larger than the input voltage. By adding a voltage-multiplier stage to the circuit of Fig. 1, for instance, the maximum possible output voltage can be doubled.

Such a circuit is shown in Fig. 2, in which C_4 is charged through D_3 on the positive swing of the power-output stage. However, now C_4 is charged from the negative voltage that appears at the negative terminal of C_3. The voltage across C_4 then approaches twice the input voltage, minus the drops. This voltage is transferred to the output capacitor as before. The negative-output voltage can therefore approach twice the input voltage, less the drops. □

Have you used a microprocessor to replace either hard-wired or mechanical logic in a circuit or made some other use of these versatile devices? Engineers who are just starting to design with microprocessors would be interested in learning about your experiences. We'll pay $50 for each microprocessor item published, as we do for all published Designer's Casebook ideas. Please send them to our Circuit Design Editor, summarizing the problem and how a microprocessor provides a novel solution.



2. Polarity reversed. Positions of inductor, commutating diode, and feedback elements are changed here for negative output voltage. This circuit arrangement can step up magnitude of either voltage or current; components chosen here provide voltage step-up. Regulation is same as before.

OP-AMP POWER SUPPLY

Whenever one of my articles on an audio construction project is published, I get several letters asking how to adapt the circuit for use in an automobile. The problem is this: Op-amps typically run from supply rails of ±18 V, while a car's battery supplies only +12 V. The voltage isn't the issue. An op-amp will run fine on ±12 V. It's the lack of a negative supply rail that's the serious problem.

There are many possible solutions. You might redesign a circuit to run on a single positive supply, but this isn't really satisfactory. Op-amps designed to run on a single supply, such as the LM324, do not have such good performance as a TL072 or a TL082: Their input impedance is lower, they are noisier, and their frequency response (bandwidth) is not as great. You might use a voltage divider to create an artificial ground reference for the op-amps, but you then have an effective supply of ±6 V, which is barely adequate even for an undemanding circuit. Performance is not likely to be satisfactory with some filter circuits, and the circuit will not sink more current than the voltage divider can dissipate.

You could use an inverter to convert +12 V d.c. to ±12 V d.c. Building inverters from scratch can be tricky, but they are available ready-made. In fact, Mouser Electronics sells d.c.-to-d.c. converters that are mounted in a single in-line package (SIP) that is about the size of an op-amp. Their ME 461-MNA1212S will deliver ±12 V from +12 V in, at 750 mW. Performance is optimum with a load current of 30 mA, which is enough to power several op-amps. The price, $23.55, is probably too high for most people, but if space is at a premium, this is a very attractive solution.

As an alternative, you could build a negative supply from discrete components, using the circuit in Fig. 1, for less than half the cost of the SIP converter. In this circuit, IC1 is a 555 timer, configured as an astable multivibrator (in layman's language, it turns on and off continuously). It switches at about 70 kHz, with a duty cycle (on period) of roughly 8 μS. The purpose of the timer is to turn Q1 on and off. When Q1 is off, C3 charges up to 12 V through D2. When Q1 is on, C3 is grounded by the transistor, and D2 is reverse-biased by the charge on C3; C3 then passes a negative charge through D1. In fact, the chopped d.c. voltage at the drain terminal of Q1 looks like alternating current to C3, C4, D1, and D2, which act as a voltage doubler; the cathode of C4 will have a charge of −24 V. Diode D3 is a 12-V zener that regulates the output to −12 V.

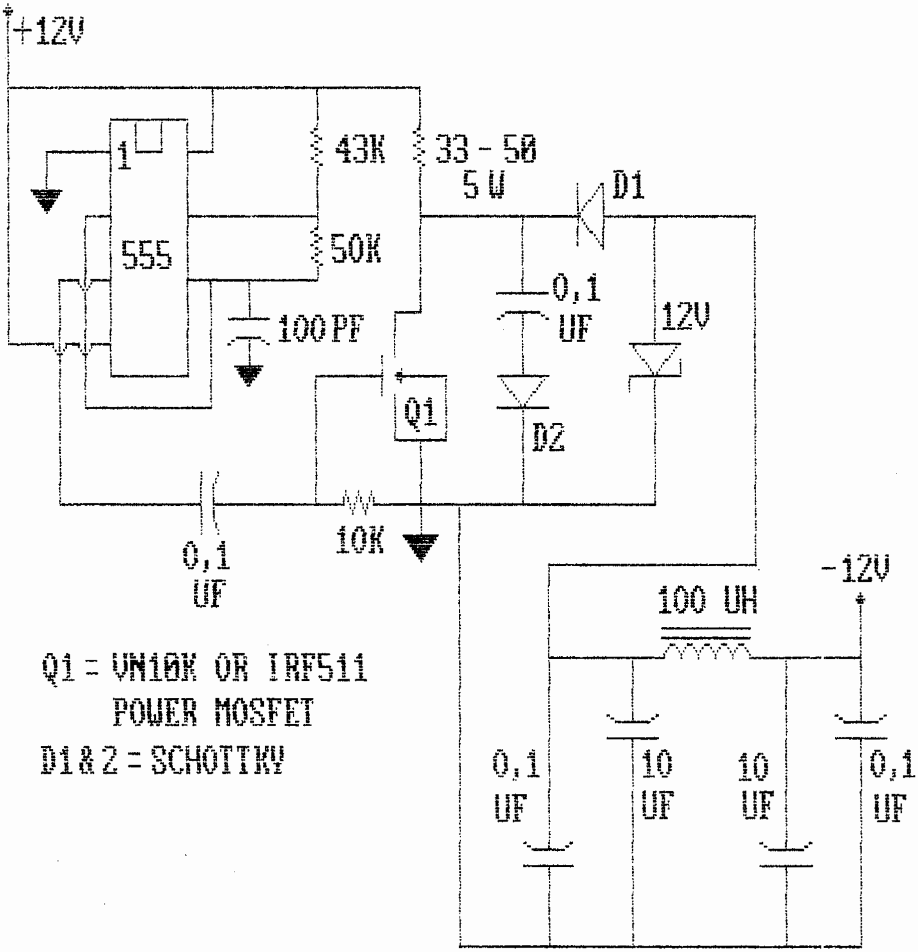
Note that Q1 is a power MOS-FET. Such transistors switch faster than bipolar transistors, making them better suited for this circuit, and the gate drive requirements are much lower than the base drive requirements of bipolars. Thus, no extra circuitry is required to drive them from the 555 timer. I used a VN10K in my prototype, but Radio Shack has not carried this transistor for several years. The larger IRF511, which they currently carry, can be used without modifying the circuit because higher powered MOS-FETs do not impose an increased drive requirement, as bipolar transistors would. The only penalty is an extra dollar or so in cost. Active Electronics carries the VN10K (see "Parts List").

Both D1 and D2 are schottky barrier diodes. They switch faster than ordinary power rectifiers, so less energy is lost when they turn on and off. In addition, schottkys have a lower voltage drop than bipolar rectifiers. You could also use 1N914 switching diodes.

The biggest drawback to such a switching power supply is electrical noise. The switching speed is high enough to make this noise inaudible, but precautions are needed in order to prevent it from interfering with your tuner or other equipment. The circuit should be enclosed in a metal box by itself. Overly large holes for ventilation are likely to leak r.f. energy, which could be a problem. The inductor, L1, and the extra capacitors, C5 through C7, are included to reduce switching noise. Using ferrite beads, if they are available, on all wires entering and leaving the box will also help. Mouser carries a selection of ferrite beads, and Radio Shack has a toroid choke core (273-104) that will perform the same function. However, no noise was audible without ferrite beads, when this supply was used to power the crossover shown in Fig. 2—even when the power supply and crossover were not mounted in enclosures and were placed near each other.

The power supply draws about 200 mA, which a car's generator can easily provide, though it is somewhat inefficient; this circuit can deliver 40 mA into a load. There will be enough power for several op-amps, for the bass-boost filter described in my article "Tailor-Made Bass" (August 1985), or for an active crossover for a subwoofer.

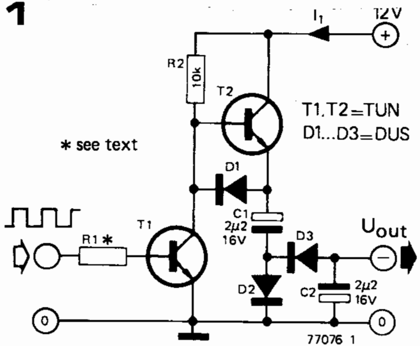
If you want to drive more than about eight op-amps, you should use multiple negative supplies of this type. To keep the noise level down, use the same drive circuitry for both MOS-FETs. The 555 will easily supply enough current for several of these.


+12V
1
555
43K
33 - 50
5 W
D1
50K
0,1
UF
100 PF
12V
Q1
D2
0,1
UF
10K
-12V
100 UH
0,1
UF
10
UF
10
UF
0,1
UF
Q1 = VN10K OR IRF511
POWER MOSFET
D1&2 = SCHOTTKY

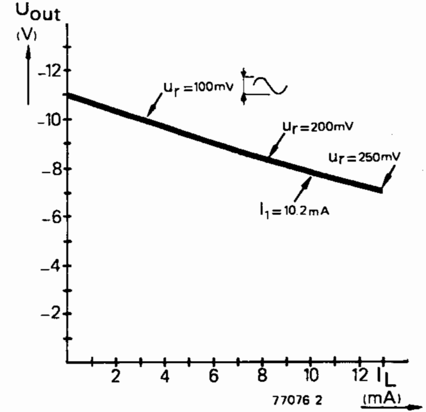
74

negative supply from positive supply

1



2



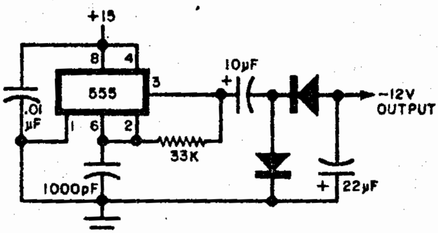
It is sometimes necessary to provide a negative supply voltage in a circuit that otherwise uses all positive supply voltages, for example to provide a symmetrical supply for an op-amp in a circuit that is otherwise all logic ICs. Providing such a supply can be a problem, especially in battery operated equipment.

In the circuit shown here T1 is turned on and off by a squarewave signal of 50% duty-cycle at approximately 10 kHz. In logic circuits it is quite conceivable that such a signal may already be available as clock pulses. Otherwise an oscillator using two NAND gates may be constructed to provide it.

When T1 is turned off, T2 is turned on and C1 charges through T2 and D2 to about 11 V. When T1 turns on, T2 turns off and the positive end of C1 is pulled down to about +0.8 V via D1. The negative end of C1 is now about 10.2 V negative so C1 discharges through D3 into C2, thus charging it. If no current is drawn from C2 it will eventually charge to around −10 V. Of course, if a significant amount of current is drawn, the voltage across C2 will drop as shown in the graph and a 10 kHz ripple will appear on the output.

Needs Negative Supply

***Q.** I have an IC system that uses a +15-volt dc power supply. Now I want to include one IC that requires a −15-volt supply, but I don't want to make a separate power supply. There must be a simple way of getting the negative voltage. Any suggestions?*



A. The circuit shown here is suggested by NASA. The 555 oscillator works at about 20 kHz and supplies a voltage-doubling rectifier. You can get between 40 and 50 milliamperes from this circuit.

AVI SOUND INTERNATIONAL LTD.
UNIT 170, 11120 VOYAGEUR WAY
RICHMOND, B.C. CANADA V6X 3N8
PHONE: [604] 276-0099 FAX: [604] 276-0409

OP-AMP POWER SUPPLY

Whenever one of my articles on an audio construction project is published, I get several letters asking how to adapt the circuit for use in an automobile. The problem is this: Op-amps typically run from supply rails of ±18 V, while a car's battery supplies only +12 V. The voltage isn't the issue. An op-amp will run fine on ±12 V. It's the lack of a negative supply rail that's the serious problem.

There are many possible solutions. You might redesign a circuit to run on a single positive supply, but this isn't really satisfactory. Op-amps designed to run on a single supply, such as the LM324, do not have such good performance as a TL072 or a TL082: Their input impedance is lower, they are noisier, and their frequency response (bandwidth) is not as great. You might use a voltage divider to create an artificial ground reference for the op-amps, but you then have an effective supply of ±6 V, which is barely adequate even for an undemanding circuit. Performance is not likely to be satisfactory with some filter circuits, and the circuit will not sink more current than the voltage divider can dissipate.

You could use an inverter to convert +12 V d.c. to ±12 V d.c. Building inverters from scratch can be tricky, but they are available ready-made. In fact, Mouser Electronics sells d.c.-to-d.c. converters that are mounted in a single in-line package (SIP) that is about the size of an op-amp. Their ME 461-MNA1212S will deliver ±12 V from +12 V in, at 750 mW. Performance is optimum with a load current of 30 mA, which is enough to power several op-amps. The price, $23.55, is probably too high for most people, but if space is at a premium, this is a very attractive solution.

As an alternative, you could build a negative supply from discrete components, using the circuit in Fig. 1, for less than half the cost of the SIP converter. In this circuit, IC1 is a 555 timer, configured as an astable multivibrator (in layman's language, it turns on and off continuously). It switches at about 70 kHz, with a duty cycle (on period) of roughly 8 µS. The purpose of the timer is to turn Q1 on and off. When Q1 is off, C3 charges up to 12 V through D2. When Q1 is on, C3 is grounded by the transistor, and D2 is reverse-biased by the charge on C3; C3 then passes a negative charge through D1. In fact, the chopped d.c. voltage at the drain terminal of Q1 looks like alternating current to C3, C4, D1, and D2, which act as a voltage doubler; the cathode of C4 will have a charge of −24 V. Diode D3 is a 12-V zener that regulates the output to −12 V.

Note that Q1 is a power MOS-FET. Such transistors switch faster than bipolar transistors, making them better suited for this circuit, and the gate drive requirements are much lower than the base drive requirements of bipolars. Thus, no extra circuitry is required to drive them from the 555 timer. I used a VN10K in my prototype, but Radio Shack has not carried this transistor for several years. The larger IRF511, which they currently carry, can be used without modifying the circuit because higher powered MOS-FETs do not impose an increased drive requirement, as bipolar transistors would. The only penalty is an extra dollar or so in cost. Active Electronics carries the VN10K (see "Parts List").

Both D1 and D2 are schottky barrier diodes. They switch faster than ordinary power rectifiers, so less energy is lost when they turn on and off. In addition, schottkys have a lower voltage drop than bipolar rectifiers. You could also use 1N914 switching diodes.

The biggest drawback to such a switching power supply is electrical noise. The switching speed is high enough to make this noise inaudible, but precautions are needed in order to prevent it from interfering with your tuner or other equipment. The circuit should be enclosed in a metal box by itself. Overly large holes for ventilation are likely to leak r.f. energy, which could be a problem. The inductor, L1, and the extra capacitors, C5 through C7, are included to reduce switching noise. Using ferrite beads, if they are available, on all wires entering and leaving the box will also help. Mouser carries a selection of ferrite beads, and Radio Shack has a toroid choke core (273-104) that will perform the same function. However, no noise was audible without ferrite beads, when this supply was used to power the crossover shown in Fig. 2—even when the power supply and crossover were not mounted in enclosures and were placed near each other.

The power supply draws about 200 mA, which a car's generator can easily provide, though it is somewhat inefficient; this circuit can deliver 40 mA into a load. There will be enough power for several op-amps, for the bass-boost filter described in my article "Tailor-Made Bass" (August 1985), or for an active crossover for a subwoofer.

If you want to drive more than about eight op-amps, you should use multiple negative supplies of this type. To keep the noise level down, use the same drive circuitry for both MOS-FETs. The 555 will easily supply enough current for several of these.

PRECISION · LOUDSPEAKERS

AVI SOUND INTERNATIONAL LTD.
UNIT 170, 11120 VOYAGEUR WAY
RICHMOND, B.C. CANADA V6X 3N8
PHONE: (604) 276-0099 FAX: (604) 276-0409

PARTS LIST

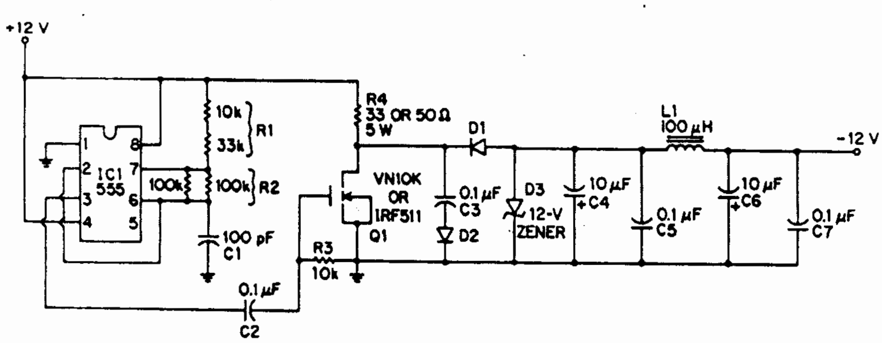
Power Supply

IC1—555 timer.
Q1—VN10K or IRF511 power MOSFET.
R1—43 kilohms (10 kilohms in series with 33 kilohms), ⅛ watt minimum.
R2—50 kilohms (100 kilohms paralleled by 100 kilohms), ⅛ watt minimum.
R3—10 kilohms, ⅛ watt minimum.
R4—33 or 50 ohms, 5 watts minimum.
L1—100-μH choke coil.
C1—100 pF.
C2, C3, C5, C7—0.1-μF plastic film; may be Mylar, metallized polyester (metal film), polystyrene, etc.
C4, C6—10-μF electrolytic.
D1, D2—Schottky barrier diode (Radio Shack #276-1165).
D3—12-V zener diode.

Sources

All parts, or acceptable substitutes, may be found at Radio Shack.
Mouser Electronics, (800) 346-6873. Mail-order only, free catalog. Minimum order, $20. Distribution centers in Cal., Tex., and N.J.
Active Electronics, (800) 228-4834; in Mass., (508) 366-0500. Free catalog. Minimum order, $20. Stores in Westborough and Woburn, Mass. and Seattle, Wash.

Op-amps require ±12 V, but car batteries deliver only +12 V. This inexpensive inverter circuit delivers the missing −12 V, to power your car audio projects.



Stabilizer boosts current of ±dc-dc converter

by Gerald Girolami, *Université Pierre et Marie Curie, Physique et Dynamique de l'Atmosphère, Paris, France*

The power-handling capacity of Intersil's popular positive-to-negative voltage converter can be increased by a factor of 10 with this circuit. Using an efficient, low-cost stabilizer to hold output voltage constant for an operating current generally above that which the ICL7660 is normally used, the circuit is a viable alternative to using an expensive modular dc-dc converter when a 0-to-10-volt, 0-to-100-milliampere source is required.

Although the ICL7660 is used almost exclusively in low-power applications, its maximum load current is in excess of 50 mA for a 5-V, 100-mA input. At this level, however, the output voltage drops from the expected −5-V value to near zero. By using the LM301 operational amplifiers (A_1 and A_2) in a feedback loop, however, the output voltage, V_{out}, can be made to equal the negative of the given reference voltage, $-V_{ref}$, at the desired output current.

As seen, the output voltage, V_{out}, is compared with V_{ref} at op amp A_1. As a consequence of the circuit configuration:

$$V_1 = V_{ref}\left[1+\frac{R_4}{R_3 \| R_5}\right]\left[\frac{R_2}{R_1+R_2}\right]-\frac{V_{ref}R_4}{R_3}-\frac{V_{out}R_4}{R_5}$$

where $R_3 \| R_5 = R_4$, $R_1 = R_2$, and $R_3 = 2R_4$. Thus $V_1 = \frac{1}{2}(V_{ref} - V_{out})$. Similarly, op amp A_2 generates a voltage:

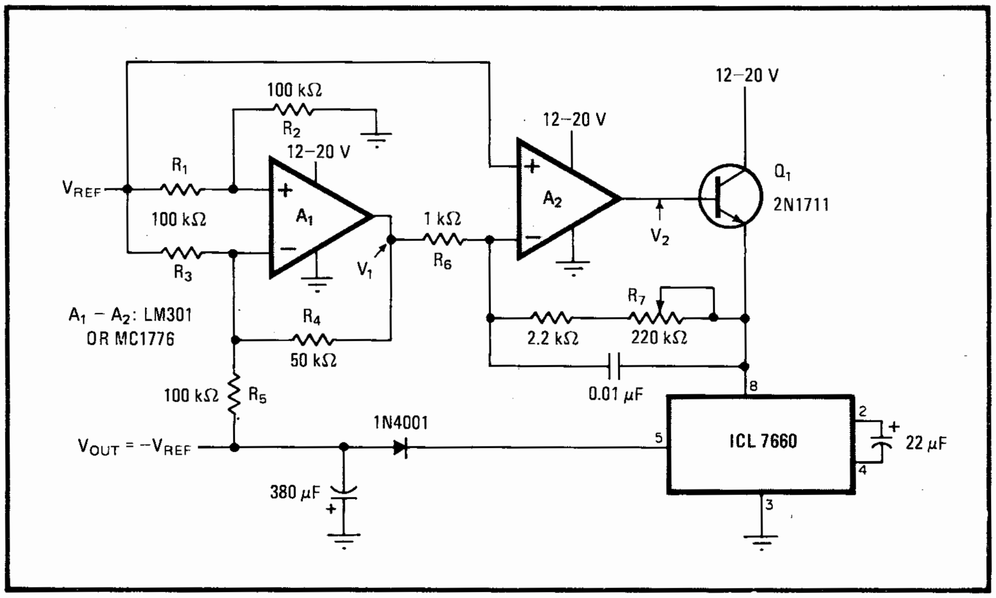
$$V_2 = V_{ref}[1+(R_7/R_6)] - V_1R_7/R_6$$

where $R_6 = R_7$, and so $V_2 = 2\,V_{ref} - V_1$. Combining the final expressions of V_1 and V_2 yields $V_2 = 3/2\ V_{ref} + \frac{1}{2}\ V_{out}$.

Thus, an increase in V_{out} will cause V_2 to increase. Because $V_2 = -V_{out}$, as specified under normal conditions for the ICL7660, an increase in V_2 will cause V_{out} ultimately to decrease, and vice versa, and negative feedback is achieved. Thus, under conditions for stabilization, $V_2 = -V_{out} = 3/2\ V_{ref} + \frac{1}{2}\ V_{out}$, or $V_{out} = -V_{ref}$, and only V_{ref} will have any effect on V_{out}, with the required driving and load currents provided by A_1 and A_2 and power transistor Q_1.

In practical applications, the output voltage is adjustable from −2 V to −10 V for a positive V_{ref} of similar range. The maximum output current is 100 mA at V_{out} = −5 V and drops thereafter. But it is possible to use two such circuits and two diodes to double the output current. That may not seem too interesting because many good dc-dc converters that deliver high current are available, but note that this circuit allows selection of the output voltage, a feature not usually found in commercial units. The regulation is good and the mean output voltage variation will be only 70 millivolts at I_{load} = 100 mA. This specification is adequate for digital circuits that can withstand a ±5% variation (that is, 250 mV) at the 5-V level.

Note that the MC1776CG is suitable for use as A_1 and A_2. It is necessary to add an 8.2-megohm resistor between pins 4 and 8 of each device, however, to set the operating current in the amplifier. □



Steady power. Negative feedback provided by A_1 and A_2 stabilize output voltage of ICL7106 converter for medium-range currents giving user a 2-to-10-V negative voltage source capable of delivering 100 mA. Reference voltage controls output such that $V_{ref} = -V_{out}$. Output voltage regulation is only 70 mV at 5 V.