



Edited by Bill Travis

Build a negative-voltage power-side switch

Michael English, Micrel Semiconductor, San Jose, CA

WHEN YOU NEED to quickly connect a negative power supply under logic control, the negative power-side switch in **Figure 1** can help. Although originally intended for driving the gates of high-current MOSFETs, the MIC4451 can assume a different role. It provides complementary, low-on-resistance MOSFET switches to connect a system power-supply rail to a negative input voltage or to ground, enabled by a digital signal. The MIC4451 comprises an input buffer with a small amount of hysteresis and several logic inverter/buffers that ultimately drive a high-current output stage. **Figure 2** shows a block diagram of the MIC4451. The on-resistance of the n- and p-chan-

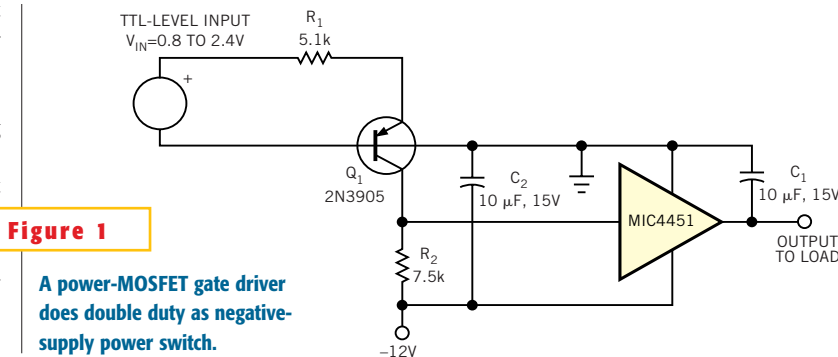


Figure 1

A power-MOSFET gate driver does double duty as negative-supply power switch.

nel devices at the output is approximately 1Ω. So, the output can connect a 100-mA load to the negative input voltage with less than 100-mV voltage drop. A noninverting version, the MIC4452, sim-

plifies inversion of logic control as needed. **Figure 1** shows details of the interface of the MIC4451 to TTL levels, using a common-base pnp transistor for level translation. The emitter current of Q_1 is approximately: $I_E = (V_{TTLH} - V_{BE})/R_1 \approx (2.4 - 0.65)/R_1$, where V_{TTLH} is the TTL-high level, 2.4V. I_E should be $\leq 400 \mu A$ in accordance with TTL specs, so $I_E = (2.4 - 0.65)/R_1 \leq 400 \mu A$.

Solving for R_1 , you obtain $R_1 \geq 1.8V/400 \mu A = 4.5 k\Omega$. The V_{IH} (lowest permissible high input) logic-level specification of the MIC4451 is 2.4V. Ignoring base-current errors, $I_C \approx I_E$, so $R_2 I_C \geq 2.4V$. Note that the MIC4451's input voltage, V_{IH} , is specified with respect to the ground pin of the part. To determine R_2 : $R_2 = 2.4V/I_C$

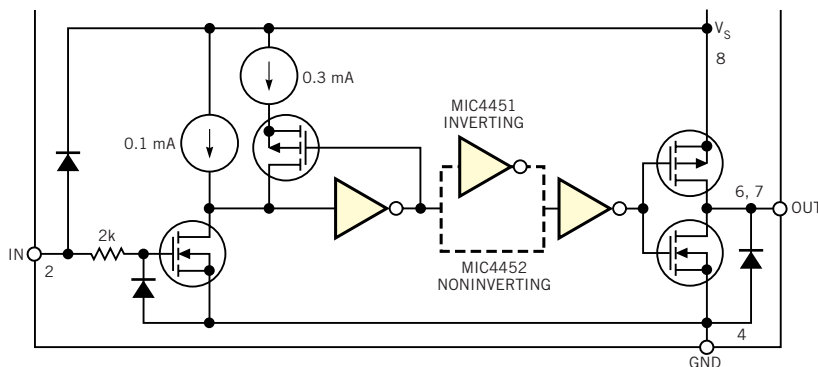


Figure 2

The MIC445x FET driver includes low-on-resistance complementary FETs.

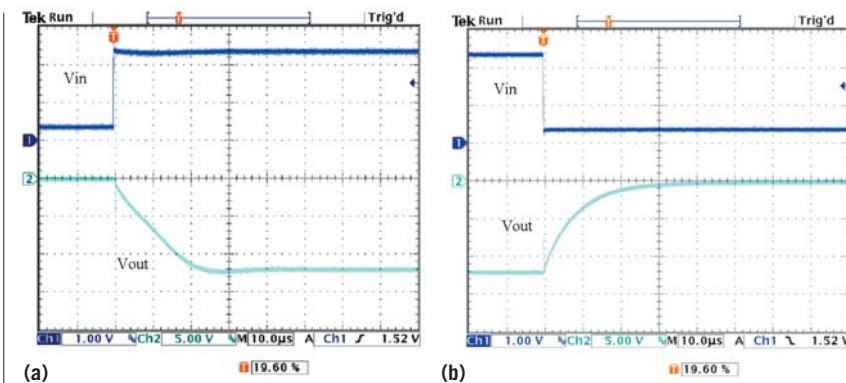


Figure 3

Turn-on (a) and turn-off (b) characteristics of the circuit in **Figure 1** are for a -12V supply.

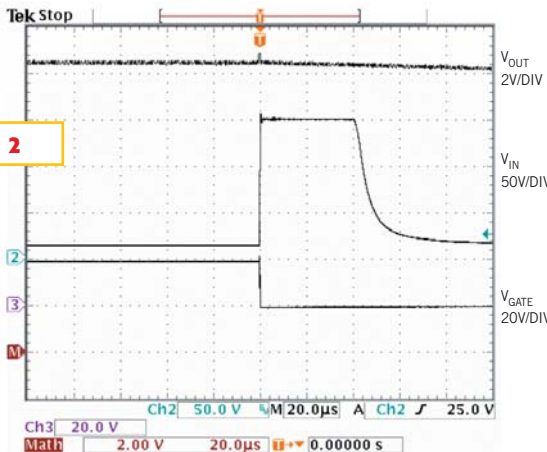
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detector. The power switch and series-connected power rectifier, D_1 , protect the load against high-voltage transients and continuous over-voltage as high as $\pm 500V$ of either polarity.

In the circuit, which powers loads as heavy as 1A from a nominal 12V power line, a high-side-switch driver, IC_1 , biases the power switch fully on. You can increase the maximum load current by changing D_1 and Q_1 . To guard against low supply voltage, IC_1 includes an undervoltage-lockout feature that allows operation only when the line voltage is greater than 10V. To protect against overvoltage, the circuit includes a three-transistor, no-bias-current, 50-nsec-operation over-voltage detector that triggers when the input voltage reaches approximately 20V. At that time, Q_4 “crowbars” the gate of the

Figure 2



A 150V transient applied to V_{in} of the Figure 1 circuit has little effect on V_{out} .

power switch to ground, turning it off hard. Rising overvoltage first turns on zener diode D_2 , which protects the IC by clamping the voltage across it to approximately 18V. Zener current flows through the 2.2-k Ω resistor, producing a base voltage that turns on Q_2 . That action ini-

tiates a rapid sequence: Q_3 turns on, which turns on Q_4 , which turns off Q_1 by quickly discharging its gate capacitance.

You can demonstrate the circuit’s performance by applying a 150V transient to the supply voltage while the circuit output is delivering 1A at 12V (Figure 2). The internal impedance of the transient source is 1 Ω , and the rise time of the applied voltage is 1 μ sec. The circuit draws 20 μ A during normal operation, including 3 μ A by the undervoltage-lockout, voltage-sensing divider and 17 μ A by IC_1 . If your design

needs high-temperature operation, note that the gate-current output of IC_1 is relatively limited. Your design calculations for high temperature should also pay close attention to leakage currents that the other circuit components contribute. □

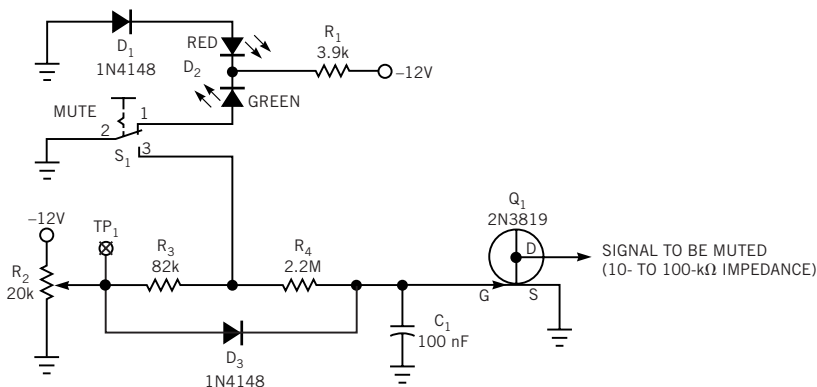
Build a simple, soft-action muting switch

John Firestone, Bremerhaven, Germany

THE CIRCUIT IN Figure 1 adds a soft muting switch with power-up/power-down muting to a line-level audio circuit. R_4 , C_1 , and JFET Q_1 quietly ground a signal in 100 to 200 msec when you close S_1 or release it when you open S_1 . Potentiometer R_2 , set to twice Q_1 ’s cut-

off voltage, makes the on/off transition times roughly equal. R_2 and D_3 quickly discharge C_1 and mute the signal during power-down. For this process to work, the signal path should remain stable to below roughly one-third the normal supply voltages—below $\pm 4V$ in this ex-

ample. Q_1 can then finish muting. Making Q_1 a more tightly defined PN4392 can soften this requirement and allow muting of lower impedance signals. R_3 unloads S_1 from R_2 , so that D_3 does not shorten the earlier transition times. S_1 ’s normally closed contact, resistor R_1 , and dual-LED D_2 add an indicator light. D_1 raises the red LED’s on-state threshold to indicate green when muting is off. Replacing D_1 with a short circuit causes the red LED to light. This scheme makes a more expensive DPDT (double-pole, double-throw) switch unnecessary, provides uninterrupted light as S_1 switches, and reduces the LED-current change for less noise (references 1 and 2). □



NOTE:
SET VOLTAGE AT TP₁ TO TWICE Q_1 ’S $V_{GS(OFF)}$,
SO THAT $0.50V_{GS(OFF)} = 0.7RC = 150$ mSEC.

Figure 1

This simple circuit provides soft muting for line-level audio circuits.

REFERENCES

- Linkwitz, SJ, “Loudspeaker System Design,” *Wireless World*, Volume 84, June 1978, pg 67.
- Self, D, “Inside Mixers,” *Wireless World*, Volume 97, April 1991, pg 280, www.dself.dsl.pipex.com/ampins/mixer/mixerdes.htm.

High-voltage amplifier uses simplified circuit

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MANY SCIENTIFIC INSTRUMENTS and sensors need ac high-voltage drive. High-voltage drive is useful for driving electrodes in many applications. The challenge is to boost the output of a conventional op amp to high voltages. Available ac high-voltage amplifier modules are limited to approximately 1200V p-p. This Design Idea presents a simplified ac high-voltage amplifier that uses complementary, cascaded NMOS and PMOS transistors (Figure 1). The OP07 op amp has low input-offset voltage, low input-bias current, and high open-loop gain. These attributes make this op amp useful for high-gain instrumentation applications. In addition, the OP07 features

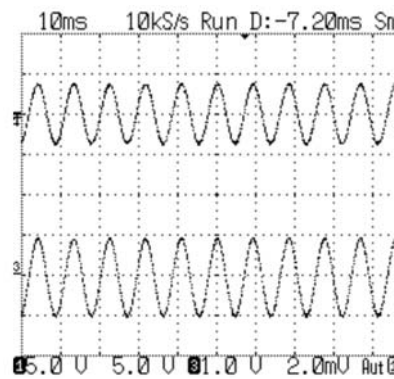


Figure 2 The sinusoidal input is 8V p-p (top trace), and output is 1800V p-p (bottom trace).

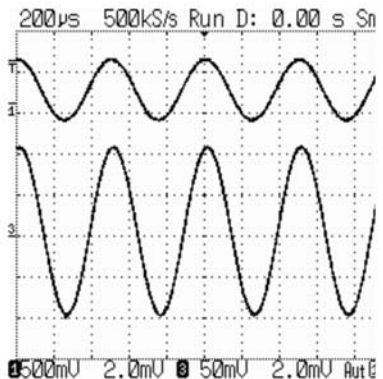


Figure 3 The input is 750 mV (top trace), and the output is 200V p-p (bottom trace).

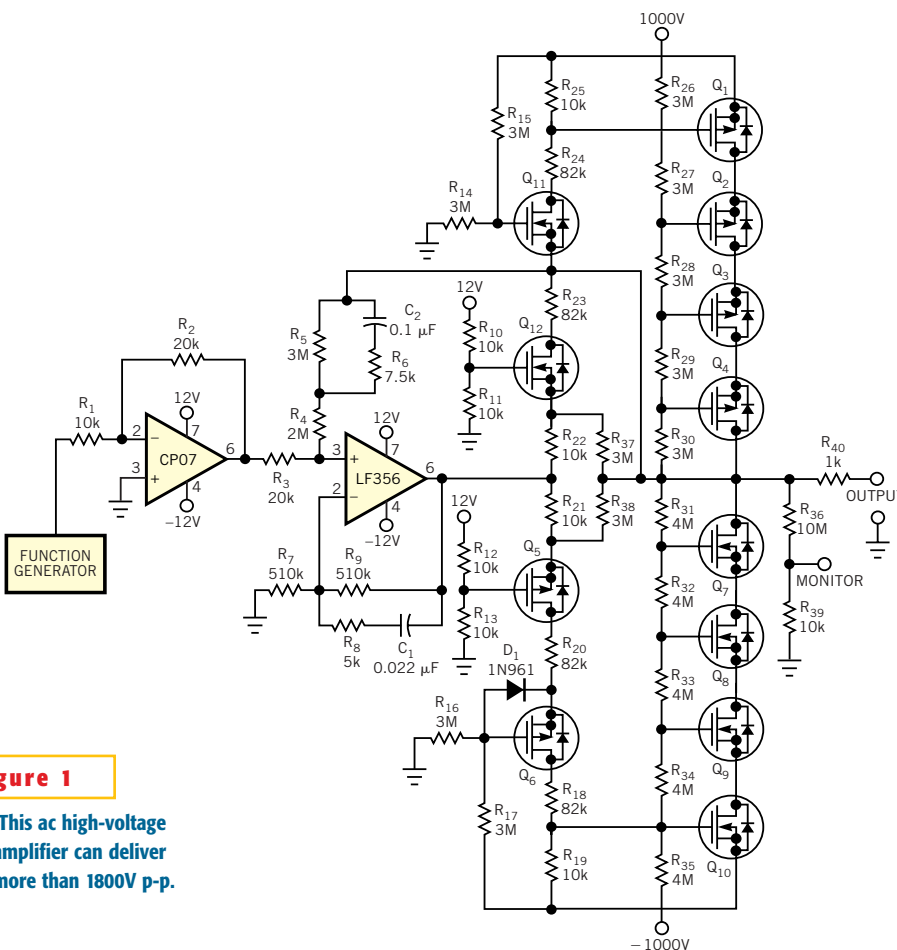


Figure 1 This ac high-voltage amplifier can deliver more than 1800V p-p.

excellent stability of offsets and gain over time and temperature. The ac gain of the LM356 stage, which R_3 , R_4 , R_5 , and R_9 determine, is approximately 100.

The high-voltage MTP2P50E p-channel MOSFET has maximum drain-to-source- and gate-to-drain-voltage ratings of 500V. The high-voltage BUK456800B n-channel MOSFET has maximum drain-to-source- and gate-to-drain-voltage ratings of 800V. Q_1 through Q_6 are PMOS transistors, and Q_7 through Q_{12} are NMOS devices. These FETs are well-suited for high-voltage cascade circuits. They connect symmetrically in series to increase their overall breakdown voltage for power applications. The bias-voltage circuits comprise separate biasing-resistor pairs R_{10} to R_{13} and R_{14} to R_{17} ; the result is a symmetrical output of the high-voltage amplifier. Figure 2 shows a sinusoidal input of 8V p-p at 100 Hz and an output of 1800V p-p. Figure 3 shows a sinusoidal input of 750 mV p-p at 2 kHz and an output of 200V p-p. The total power bandwidth of the circuit is approximately 200 kHz. □

Simple circuit provides power sequencing

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ASICs, FPGAs, AND DSPs can require multiple supply voltages with restrictions on their start-up sequencing. Often, I/O voltages, which usually have the highest voltage, must come up first, followed by all other voltage rails in a high-to-low order, with the core voltage last. This scenario may also require that one supply rail not exceed another by more than a diode drop; otherwise, excessive current may flow backward from the I/O voltage through the IC into a lower voltage, possibly damaging the expensive IC. Often, you can control this sequence by placing external diodes between successive voltage rails to clamp a higher voltage to within a diode drop of a lower voltage, thus preventing possible latch-up in the IC. The diode conducts only when a lower voltage rises above a higher one at turn-on, but not if a higher voltage were to increase above any lower voltage, because the diode is reverse-biased. A preferred method would be to use the power-supply controller to precisely control the start-up-voltage sequencing of the power-supply rails. **Fig-**

ure 1 shows a simple op-amp circuit that integrates a dual switching power supply to provide simultaneous output-voltage sequencing.

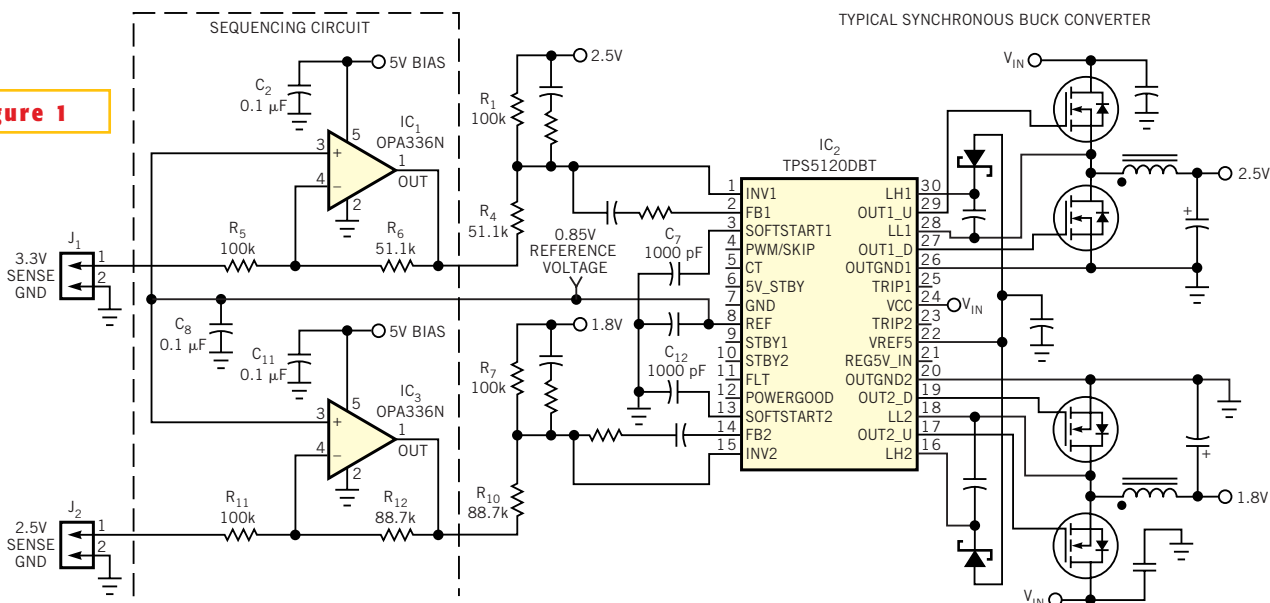
In this power-sequencing circuit, three output voltages sequence at start-up, during which each output voltage tracks the next-higher voltage rail until it reaches its fixed regulation voltage. Assume that a 3.3V “master”-I/O voltage (not shown) powers up normally. The controller for this voltage uses its soft-start function to provide a smooth linear ramping of its voltage. The TPS5120 dual switching regulator generates two additional voltages, 2.5 and 1.8V. In most standard switching-regulator circuits, the bottom sides of R_4 and R_{10} would be grounded, thus fixing the output-voltage setpoints. In this circuit, the output of an amplifier controls the voltage at the bottom of each of these resistors. An amplifier output voltage of zero sets the output voltage to its predetermined fixed voltage, but any voltage greater than zero forces the output voltage to be lower than its setpoint.

The amplifiers are in an inverting con-

figuration with the next-higher output voltage as its input or “sense” voltage. Thus, at power-on, when the 3.3V output is 0V, amplifier IC_1 's output voltage is high, also forcing the TPS5120 controller to regulate its output voltage to 0V. The output voltage of amplifier IC_3 is also high, because the 2.5V output, which is also 0V, controls input voltage. As the 3.3V output rises linearly, the amplifier's output voltage decreases linearly to 0V. The 2.5V output voltage thus increases from 0V to its maximum setpoint of 2.5V. The 1.8V output voltage tracks the 2.5V output in a similar manner. Set the amplifier's component values such that when the sensing voltage, such as the 3.3V, reaches the tracking-voltage level—here, 2.5V—the amplifier's output voltage just attains 0V. Therefore, increases in the sense voltage higher than 2.5V cannot further raise the tracking output voltage, because the amplifier's output voltage has already saturated to ground level.

Simultaneous tracking requires several important design criteria. The amplifier's feedback ratio, R_5-R_6 , must be equal

Figure 1



An amplifier circuit forces the converter's output voltages to track during start-up.

to the feedback-resistor divider ratio set by R_1 and R_4 . In addition, you must use the TPS5120 controller's reference voltage, 0.85V in this example, as an input to the amplifier's noninverting terminal. Any reference-voltage value other than this one forces the tracking-voltage output to a voltage different from the sense voltage. The amplifier you select should have a low input-offset voltage and be capable of an output voltage at least as great as the controller's reference voltage.

A rail-to-rail amplifier works well in this application. Individual amplifiers to allow localized component placement, avoiding routing near any noise sources. This design uses an additional decoupling capacitor near the

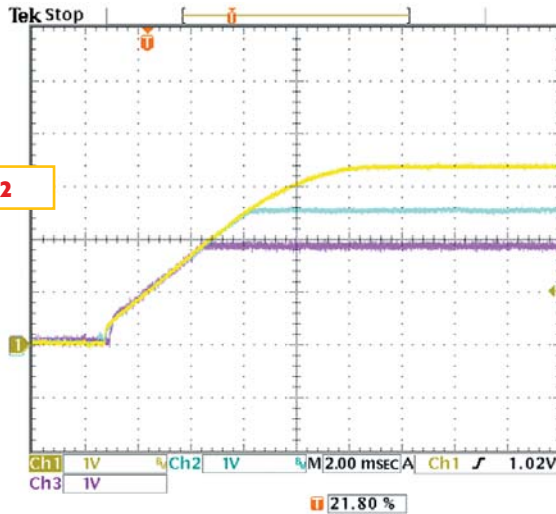


Figure 2

The 2.5 and 1.8V outputs track the 3.3V output at start-up.

amplifier's noninverting input for the reference voltage. It uses a small, soft-start capacitor value for the TPS5120 controller so that the controller was in-

herently faster at start-up than the 3.3V sense voltage. A large soft-start capacitor value does not allow for fast tracking on the outputs. Too small a value may cause output-voltage overshoot when you initialize power. **Figure 2** shows the start-up voltages for three synchronous buck converters. The 3.3V acts as a master, and 2.5 and 1.8V track their respective higher voltages. You can set the sense voltage for the 1.8V output to track the 3.3V output rather than the 2.5V with equally good linear tracking during start-up. You can add this sequencing circuit to any

power-supply controller that provides access to its reference voltage, soft-start capacitors, and output-voltage resistor-divider network. □