design ideas

Edited by Bill Travis and Anne Watson Swager

Low-voltage interface circuits translate 1.8 to 5V

CC Poon and Edward Chui, Motorola SPS, Hong Kong

Interfacing two systems that operate at two arbitrary voltages is a challenging problem; there is no guarantee that one side operates at a voltage higher than the other side. Usually, the interface is an open-collector or open-drain type with just two transistors connecting back to back (**Figure 1a**). V_X is the lower of the two operating voltages. If you know which side has the lower operating voltage, the interface design is straightforward. If either side can have the lower operating voltage, you have to extract the lower one. Without the use of an op amp, you can use a diode-based circuit (**Figure 1b**). The 1N4148 is good for most applications. If a higher current capability is necessary, you can use the 1N4001. If the lower operating voltage is around 1V, D_3 should be a Schottky diode, such as the 1N5817 or MMBD701, and D_1 and D_2, can be normal PN-junction diodes.

An open-collector or open-drain circuit (a) typically interfaces between two systems that operate at two arbitrary voltages. A diode-based circuit (b) can extract the lower operating voltage.

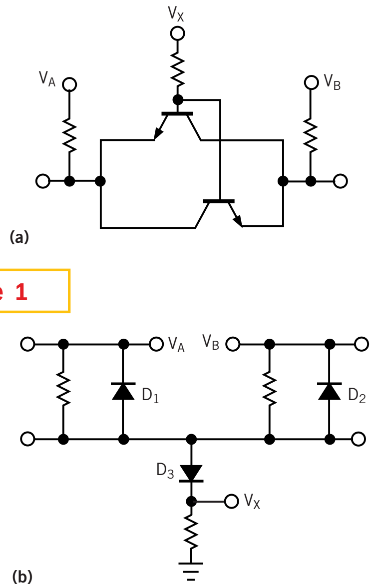


Figure 1

If level translation is necessary in one direction, you can use half of the circuit for open-drain translation, which is equivalent to simple TTL. This simple circuit is fast (**Figure 2a**). When driving one standard load on a real pc board, which has approximately 10 to 20 pF of total load capacitance, the rise and fall times are fast when you view it with a scope. Circuit performance is better than that of the traditional bipolar inverter, which needs a compensation capacitor to assist turn-off.(Replacing the bipolar transistor with an enhancement MOSFET can eliminate the capacitor but results in long rise and fall times and a longer delay.) The TTL-like circuit uses only pullup resistors, which may further save pc-board space because you can use multiple pullup resistors in one resistor pack.

For a logic high-to-low transition, the delay is just the turn-on time of the transistor. For a low-to-high transition, RC effects don't appear until the output rises to about 0.5V below the lower supply voltage, V_X, when translating up (**Figure 2b**). Before that, the output tracks the input with only a $V_{CE(SAT)}$ drop, which is analogous to a cascode amplifier. The effect of turning off a saturated transistor does not manifest itself except when translating from below 1V to 5V.

The TTL-like circuit in **Figure 2a** also works well for translating from high to low voltages ($V_B<V_A$). For a high-to-low transition, the delay is just the turn-on time of the transistor. You can replace the pullup resistor by an active transistor to increase driving strength (**Figure 2c**). You must pay attention to $V_{EBO(BR)}$, which must not ex-

Level translation in one direction requires half of the open-drain translation circuit (a). For a low-to-high transition, RC effects do not appear until the output rises to about 0.5V below the lower supply voltage (b). The circuit also works for translating from high to low voltages ($V_B<V_A$), and you can replace the resistor with an active pullup (c).

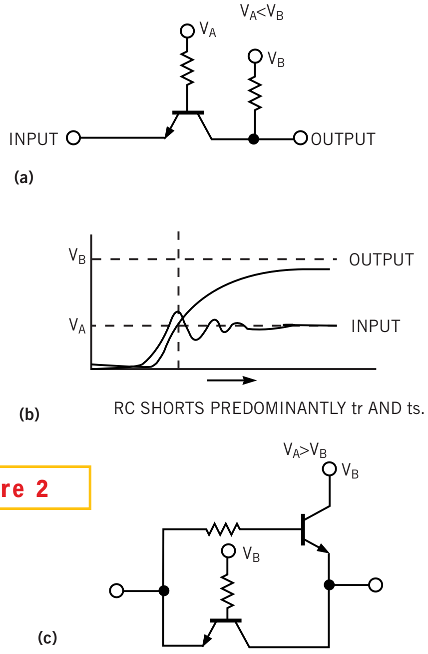
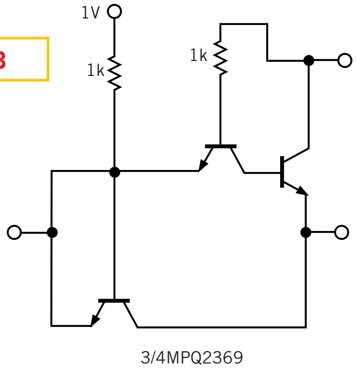


Figure 2

ceed the rated value because a violation results in premature failure of the transistor. For most small signal transistors, $V_{EBO(BR)}$ is typically 4 to 5V. Therefore, you should take care when down-shifting from 12 to 5V, such as between CMOS analog circuits and 5V logic.

The switching transistor can be MPS2369A to MPS3646 for high-speed switching. You can use the 2N3904 or BC547 for low-power applications. A 2N5458 can replace the pullup resistor at the collector if active pullup is necessary.

Figure 3



The ultimate 1-to-5V up-shifting driver in the laboratory produces a symmetrical delay of 6 nsec using three-fourths of an MPQ2369 when driving a single 74AC541 buffer.

The best 1-to-5V shifting driver in the laboratory produces a typical symmetric delay of 6 nsec using three-fourths of an MPQ2369 when driving a 74AC541 buffer (**Figure 3**). (DI #2290)

To Vote For This Design,
Circle No. 500

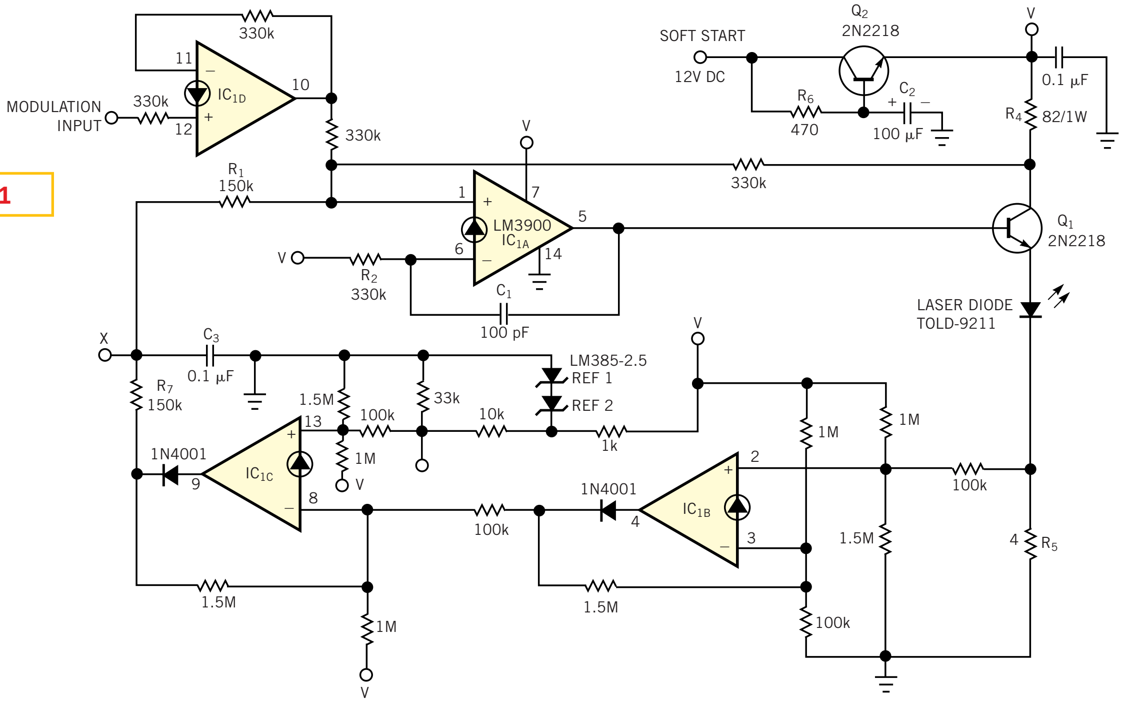
Laser-diode driver stabilizes sensitivity parameters

Anil Kumar Maini and Nita Sen, Defence Science Centre, Delhi, India

The conventional advantages of lasers—coherence, monochromaticity, and extreme compactness—make laser diodes popular in most of their potential applications. Biomedical diagnostics and high-resolution-spectroscopy applications exploit laser diodes' wavelength tunability. These applications use the laser wavelength's sensitivity to drive current and operating temperature—0.025 nm/mA and 0.3 to 0.4 nm/°C for diodes emitting approximately 700 nm, re-

The dc voltage at Point X stabilizes the drive current in the feedback mode against any variations in the IV characteristics of the laser diode and the power-supply voltage.

Figure 1



NOTES:
ALL RESISTORS HAVE 100-ppm STABILITY UNLESS OTHERWISE SPECIFIED.
C_1 IS SILVER-MICA TYPE.

spectively. However, this sensitivity also puts a stringent requirement on the stability of these parameters. The resolution with which the output wavelength can vary depends on the stability or accuracy of the sensitivity parameters. The drive-current sensitivity of 0.025 nm/mA suggests that a 10-MHz accuracy, which is a modest requirement, necessitates a drive-current stability of 0.7 μA, which is equivalent to 7 ppm, assuming a drive current of 100 mA.

The low-cost and small circuit in **Figure 1** is a stable laser-diode driver with an optional modulation-input facility. The circuit features soft start, soft decay, and immunity to noise transients. The circuit operates from a single supply of 12V and uses a quad "Norton" op amp, the LM3900. IC_{1A}, Q_1, R_1 to R_4, and C_1 constitute the basic constant-current source with the magnitude of current depending on the dc voltage present at Point X and the value of R_4. The dc voltage at X stabilizes the drive current in the feedback mode against any variations in the IV characteristics of the laser diode and the power-supply voltage. The feedback signal consists of a proportional voltage appearing across sense resistor R_5, which noninverting IC_{1B} amplifies by a gain 15. The output of this amplifier drives differential amplifier IC_{1C}. One of the inputs to IC_{1C} is a bandgap-derived reference voltage. The differential amplifier has a gain of 15.

A small change in the drive current results in a large change in the control voltage at X in a direction that restores the current to the nominal value. The closed-loop gain of the circuit is approximately 20. Changing the reference voltage to the differential amplifier, which is the voltage at Point Y, changes the nominal value of the current. Although the chosen component values produce a drive current of 60 mA, the circuit can produce drive current of 50 to 80 mA. R_6, C_2, and Q_2 provide soft-start and soft-decay features. The observed soft-start and soft-decay times are approximately 200 and 500 msec, respectively. A lowpass filter comprising R_7 and C_3 has a cutoff of approximately 10 Hz in the feedback loop to provide immunity to fast transients.

Tests show that the circuit has a stability better than ±0.05%/hour. The observed short-term current stability is better than ±0.02%. The observed variation in drive current for a ±2V variation in power-supply voltage is less than 0.1%. Experimental measurements by connecting an appropriate resistance across R_4 introduce a step change of 2 mA. Measurements also show the resultant change in current and a closed-loop gain of approximately 20. The Toshiba (www.toshiba.com) TOLD-9211 laser diode emitting approximately 4 mW tested the circuit for a drive current of 60 mA at 670 nm. The circuit fits into a DIP-like, eight-pin metal package. (DI #2291)

To Vote For This Design,
Circle No. 501

Voice-storage chips talk to each other

Jerzy Chrzaszcz, Warsaw University of Technology, Poland

Of the many solid-state voice-storage chips available, the ChipCorder family from Integrated Storage Devices (ISD, San Jose, CA) is one of the most user-friendly. A single chip integrates nonvolatile voice memory, a microphone preamplifier, and an output stage capable of driving a 16V loudspeaker. A simple interface allows you to record and play messages under manual or μP control. The configuration in **Figure 1** allows you to copy the contents of one chip to another. For single units, consider recording each chip anew. For regular production, you could purchase a gang programmer from ISD. However, for prototyping and short production runs, the circuit in **Figure 1** offers an attractive cost/performance ratio.

The programmer accommodates 25-xxx-series chips with recording time as fast as 120 sec. It consists of two ZIF sockets, control logic, and some passive components. The output signal from the Master chip traverses R_1, R_2, C_1, and C_2 to the Target inputs. R_3 and C_3 couple the Target's preamplifier and amplifier. R_4 and C_4 provide an AGC delay to the Target (Consult the ISD data sheet for details.) Strapping of the control pins ensures that the Master can only play back and the Target can only record; however, to avoid hazardous transient states, you should lock the voice chips in their sockets before switching on the power.

The controller is configured as an asynchronous state machine that uses just two 7474 flip-flops. Its simplicity results from the highly autonomous operation of the voice chips. This design uses the M4 function mode (A4, A8, and A9 pulled high), which provides sequential addressing of the messages without controller intervention. Closing the Copy switch starts Master playback simultaneously with Target record (CE set low, LED1 on). When the Master issues "End of Message" (EOM), recording stops (CE set high, LED1 off) and the EOM marker automatically goes into the Target's memory. The cycle repeats whenever you close the Copy switch, so you can copy messages one by one.

After you copy the entire Master contents, the overflow (OVF) line goes low, signaling an overflow condition. This signal turns LED2 on. Closing the Reset switch clears the flip-flop and resets the internal address counters of the voice chips. The capacitor across the Reset switch generates a power-on reset pulse. The circuit uses internal clocking for the voice chips; therefore, actual message addressing may differ slightly from copy to copy. This effect is negligible, as long as all messages fit into memory and your application uses a sequential-access mode. However, even if your target system directly addresses the chip, you can still use this programmer if the Master copy provides some spacing between consecutive messages. You thus avoid the potential errors of overlapping EOM markers past the nominal start address of the next message. Also, because of AGC regulation, the sound level of Target messages may, and probably will, differ from the original. (DI #2272).

To Vote For This Design,
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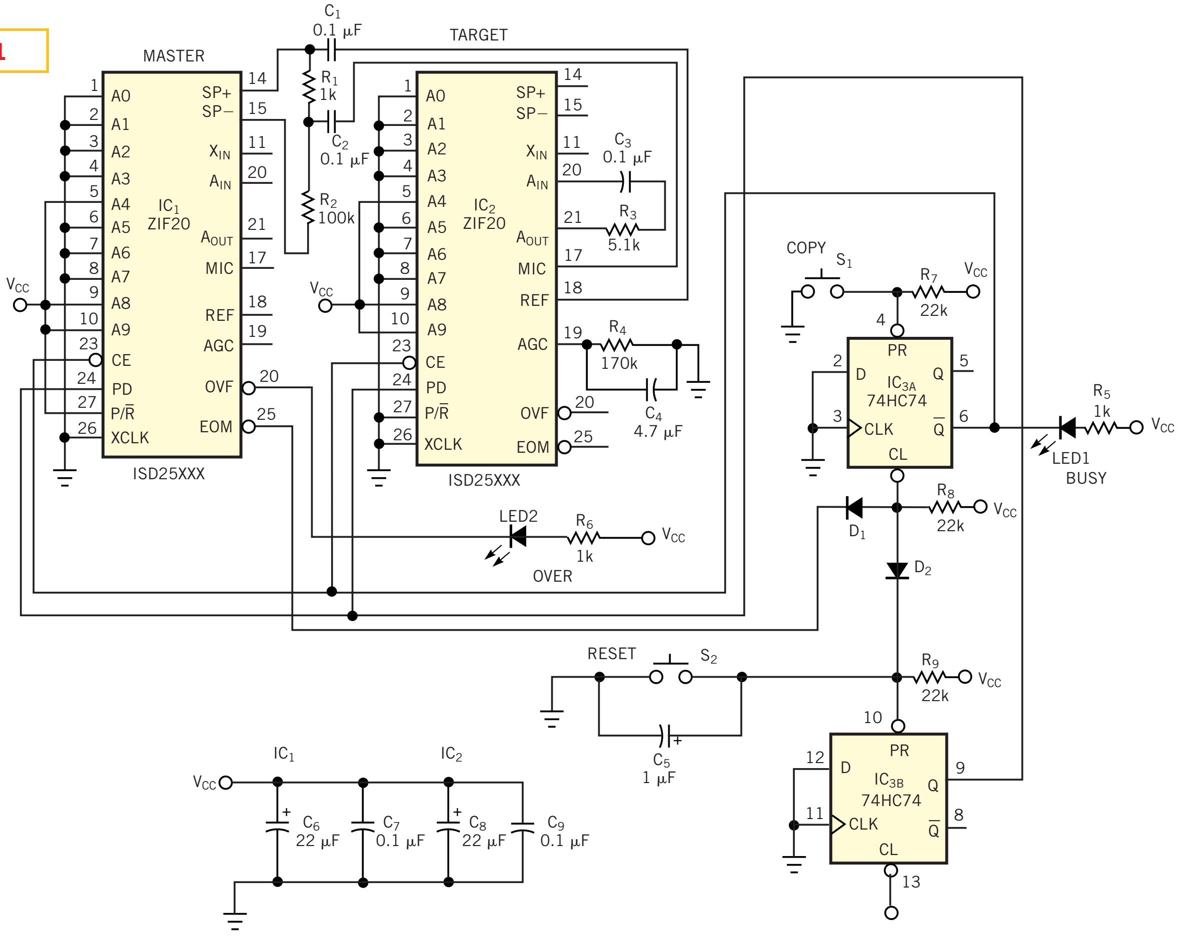
You can avoid the expense of a gang programmer by using this simple scheme to copy voice-chip messages.

Figure 1



3.3V converter delivers 3W from Li-ion battery

David Salerno, Unitrode Corp, Merrimack, NH

Lithium-ion batteries are rapidly gaining popularity in portable applications because of their superior energy density, low self-discharge rate, and high cell voltage. When you use one Li-ion battery to power a 3.3V dc/dc converter; however, you encounter a problem, because the battery voltage can be higher or lower than 3.3V. When fully charged, a Li-ion cell has approximately 4.2V output; when fully discharged, the voltage is approximately 2.5V. Therefore, you cannot use a simple buck or boost topology with a single inductor to generate a regulated 3.3V output. Some designs boost the voltage to approximately 4.3V and then use a low-dropout regulator to produce the 3.3V. This approach is inefficient, and efficiency is a crucial consideration in battery-powered applications. The circuit in **Figure 1** offers a solution to the problem.

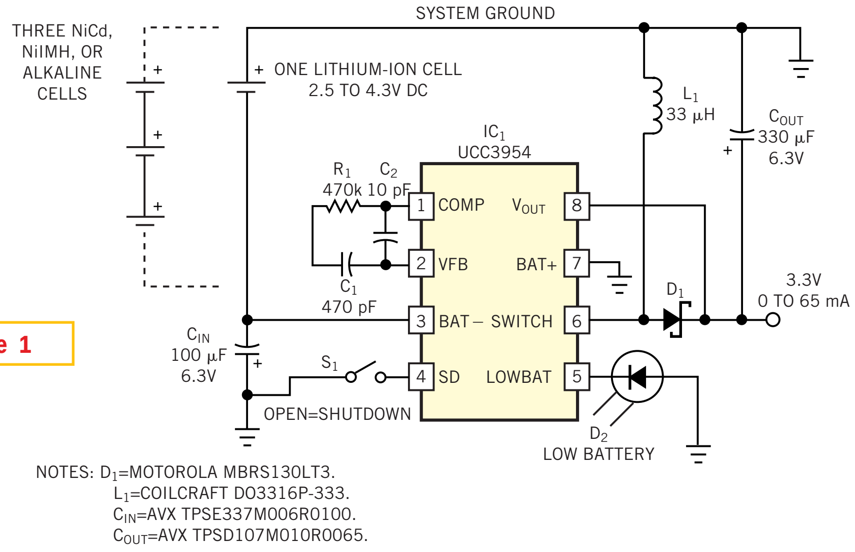
The circuit works by referencing the

positive terminal of the battery to system ground and using a flyback topology with a single low-cost inductor to generate 3.3V, with respect to system ground. IC$_1$, a UCC3954, is a fixed-frequency, 200- kHz voltage-mode PWM converter that includes an internal 0.15V MOSFET switch. Gate drive for the FET comes from bootstrapping off the 3.3V output. The converter works efficiently over a load of 0 to 650 mA. Note that the input and output filter capacitors should be low-ESR tantalums or OSCONs. Output ripple is lower than 1% at maximum load. The inductor value is not critical; 33 mH is a good compromise between size and efficiency.

The compensation components (R$_1$, C$_1$, and C$_2$) ensure stability and provide good transient response over a wide load. For applications in which no sudden changes in load current occur, you can use a simpler, dominant-pole compensation method. In this case, you can omit R$_1$ and C$_1$ and increase C$_2$ to 0.039 μF. The UCC3954 includes a low-battery-warning output and a shutdown input. The low-battery warning is a current-limited, open-drain output that turns on when the battery voltage approaches the shutdown threshold of the IC. You can use it to turn on an LED or to drive an input to a μP to provide an alert that power will soon be lost.

To enable IC$_1$, you should pull the shutdown input up to output ground. When this input is left open, it pulls down to the battery (–) potential, and IC$_1$'s quiescent current reduces to less than 1 mA. To prevent overdischarging the Li-ion battery, IC$_1$ automatically turns off when the input voltage drops to less than 2.5V, and the quiescent current reduces to 30 mA. Although IC$_1$ is designed for use with single-cell Li-ion batteries, you could also power the converter using three nickel-based rechargeables or three alkaline cells in series. As with any high-frequency converter, layout and grounding critical to proper operation. Keep all connections as short as possible, and use a ground plane. (DI #2263).

Figure 1



NOTES: D$_1$=MOTOROLA MBRS130LT3.
L$_1$=COILCRAFT DO3316P-333.
C$_{IN}$=AVX TPSE337M006R0100.
C$_{OUT}$=AVX TPSD107M010R0065.

This 3.3V dc/dc converter takes full advantage of the benefits of an Li-ion battery and works over the battery's full range of 4.2 to 2.5V.

To Vote For This Design,
Circle No. 503

Pulsing charge pump drives capacitive loads

Paul J Rose, Mental Automation Inc, Bellevue, WA

The test circuit in **Figure 1** efficiently drives various capacitive loads, such as memory cells and simple capacitors, so that you can observe their leakage effects. Essentially, the circuit is a pulsed and variable current source acting as a charge pump. A pulsed voltage source drives a one-shot oscillator. This one-shot drives two MOSFET switches that convert the 10V rail-to-rail output of the oscillator to the desired rail-to-rail voltage drive—in this case, 15V—for the controlled current mirror with the same voltage- switching polarity. The current mirror drives the variable load.

R$_1$ and C$_1$ determine the timing pulses that IC1's one-shot oscillator produces. When IC1's output is high, Q$_1$ is on, and Q$_2$ is off. The floating drain of Q$_2$ causes the emitter and base of Q$_3$ to have the same potential, so that Q$_3$ is off. Then, the pnp current mirror of Q$_4$ and Q$_5$ turns on to drive the variable load of R$_2$ and C$_2$ high. R$_3$ controls the charge rate of the load. As you make R$_3$ smaller, the current mirror provides more current to the load to charge it up faster, as required for testing.

When the output of the one-shot is low, Q$_1$ is off, and Q$_2$ is on. In this case, the drain of Q$_2$ is at ground potential, and the base of Q$_3$ is at a lower potential than its emitter so that Q$_3$ turns on. Current through Q$_3$ flows through R$_3$, causing a voltage rise at the bases of Q$_4$ and Q$_5$, which turns them off. Turning off Q$_4$ and Q$_5$ disconnects the variable load from its power supply so that the load is free to bleed stored charge through R$_2$.

This pulsing charge pump has three unique features: It can generate various pulse widths, the variable resistor in the coupled-collector circuit of the pnp current mirror provides a variable charging rate, and the circuit accommodates separate voltage drives for the one-shot oscillator and load using MOSFET switches. Any signal-propagation delay or asymmetrical switching effects through the pump cause no adverse latency effects if the pulse periods are on the order of 100 msec or more. Note that you can replace Q_1 and Q_2 with a variable gain buffer follower as **Figure 1** indicates. In this case, one 15V supply drives the follower.

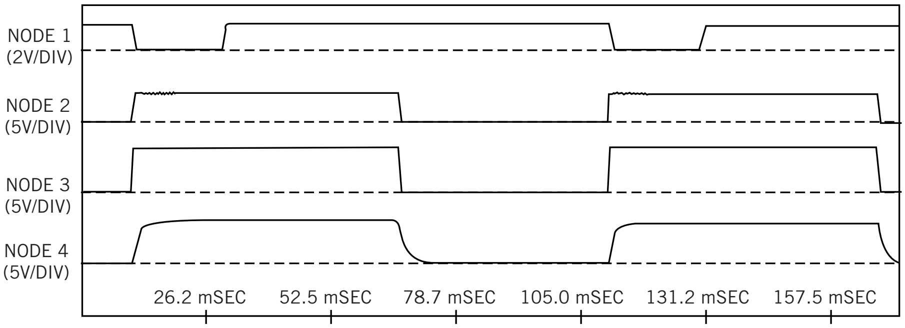
Spice simulations, using models developed in-house and by semiconductor vendors, confirm the circuit's operation (**Figure 2**). (DI #2248)

To Vote For This Design,
Circle No. 504

Acknowledgment

The author thanks Mental Automation Inc, whose ECAD tools he used to implement and test the circuit. The company provided the author the company time to submit this idea. The author also thanks Seattle Silicon Inc (Bellevue, WA) for permitting him to publish this Design Idea, which the author built and tested in Seattle Silicon's laboratory as part of a test project.

Figure 2



Spice simulations illustrate the waveforms at nodes 1 through 4 in the pulsing charge-pump circuit.

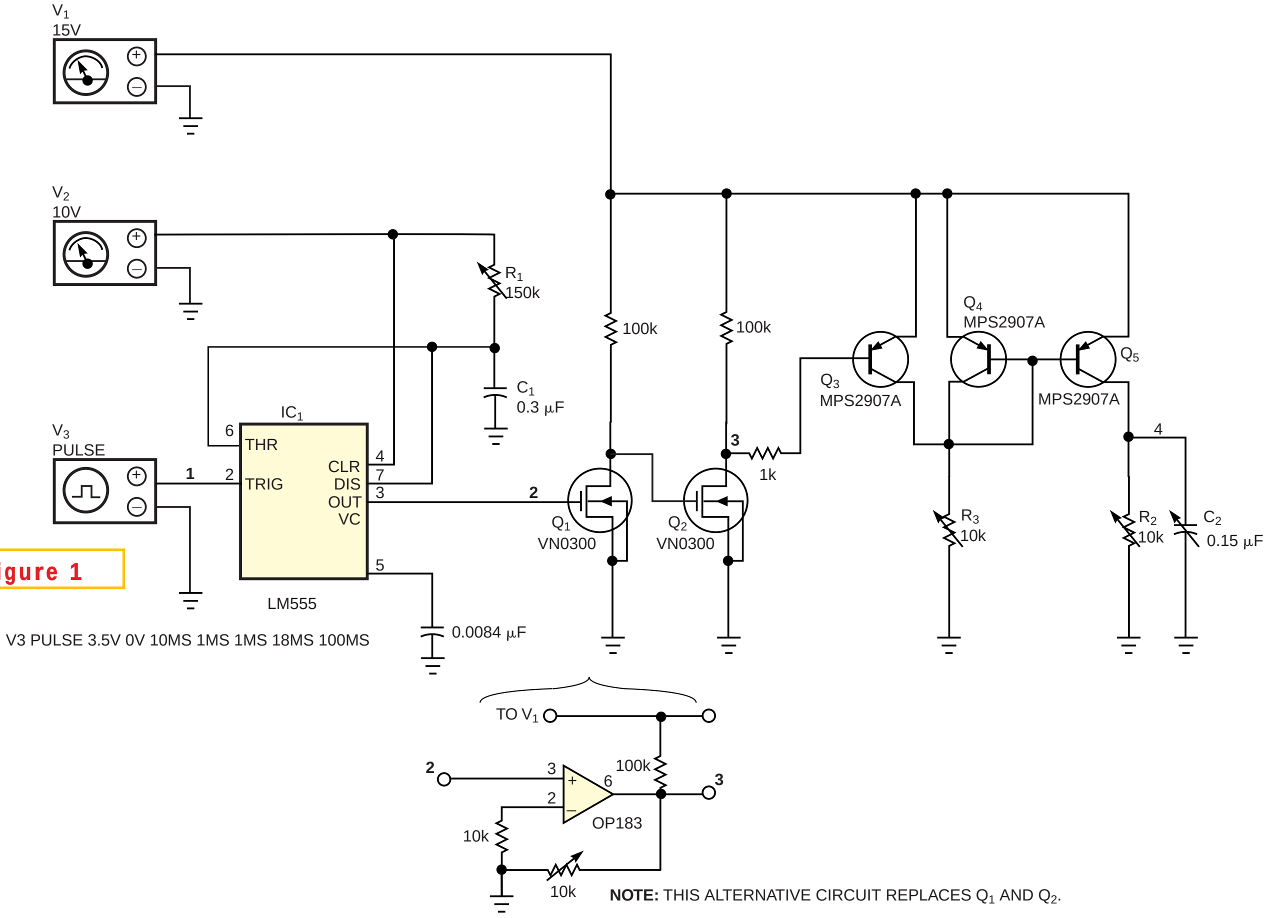


Figure 1

This pulsed and variable current source acts as a charge pump to efficiently drive various capacitive loads.

Short-circuit finder uses few parts

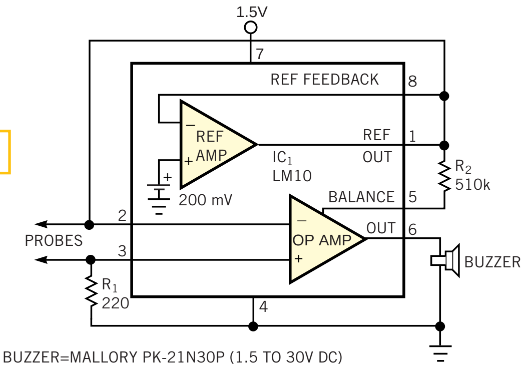
Boris Khaykin, Candid Logic Inc, Madison Heights, WI

The simple tester in **Figure 1** detects short circuits on assembled pc boards and also rings out cables and harnesses. The short finder has a narrow zone of threshold uncertainty and very low "insertion" voltage and current, and it's not confused by capacitors. The circuit uses an LM10, an IC that combines a precision 200-mV reference, a reference buffer, and an independent, high-quality op amp. It can operate from supply voltages of 1.1 to 40V. The op amp in this design serves as a comparator. The voltage from the reference buffer, via R_2, creates a positive-going bias shift at the balance input and a negative-going bias shift at the comparator's inverting input.

When the tested circuit resistance exceeds 2V, the negative-going bias overrides the positive-going bias, and the comparator delivers 0V to the buzzer. Otherwise, the comparator delivers full output voltage to the buzzer to indicate a short circuit. R_1 limits the current to the circuit under test to less than 1 mA. The circuit's current drain is less than 300 μA with open test probes and approximately 2 mA with the probes shorted together. Open-circuit voltage is 200 mV, which is less than the turn-on voltage for pn junctions. If desired, you can set the voltage as low as 15 mV by adding 18Ω resistance between pins 2 and 3 of IC_1. However, the quiescent current increases to 1 mA.

You can change the resistance threshold by changing the value of R_2. With the values shown, the threshold is approximately 2V. The supply voltage can be within 1.1 to 30V, depending on the buzzer's voltage range. You can use any piezo buzzer with current consumption lower than 20 mA. You can easily build the short finder as an adapter for a DMM, provided that the DMM has a continuity function (**Figure 2**). Upon detection of a resistance that is less than 2V, the short finder delivers a virtual negative resistance to the DMM. By nature, this signal is lower than any DMM continuity threshold (which is always positive); therefore, the circuit works with any DMM. R_3 limits the current to the DMM's input circuitry to approximately 1 mA. (DI #2264).

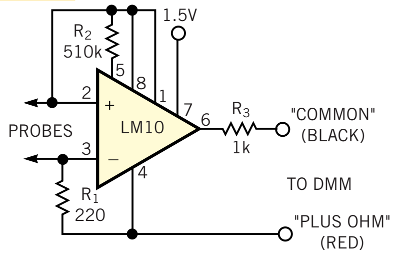
Figure 1



NOTES: BUZZER=MALLORY PK-21N30P (1.5 TO 30V DC)
OR RADIO SHACK 273-065 (1.5 TO 15V DC).

Keep an ear open for short circuits, with this easy-to-build short-circuit tester.

Figure 2



Add a short-circuit test capability to your DMM, using this modification of the circuit in Figure 1.

To Vote For This Design,
Circle No. 505

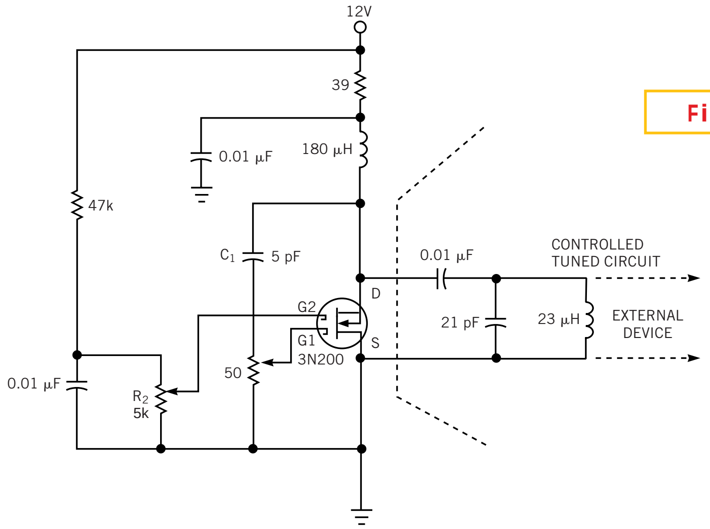
"Tube" circuit provides linear tuning

Lyle Williams, Electronic Technical Services, New Orleans, LA

Parallel LC circuits that you tune by changing capacitance have a nonlinear frequency-versus-voltage or frequency-versus-shaft-position characteristic. The frequency of an analog-tuned circuit is proportional to the reciprocal of the square root of the tuning capacitance. When you tune a bandwidth that is say, 5% or less of the center frequency, the frequency-versus-capacitance over this limited band is essentially linear. Because the frequency is proportional to capacitance, it's desirable to have a linear capacitance-versus-shaft-position or capacitance-versus-voltage characteristic. A mechanical variable capacitor can provide a linear capacitance-versus-rotation characteristic. However, mechanical tuning capacitors are expensive and large and have limited reliability.

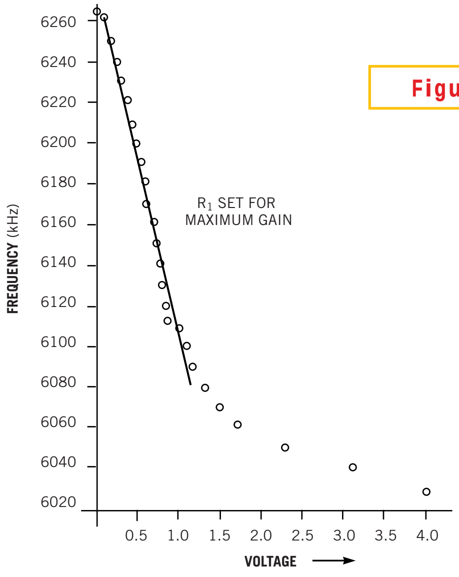
You frequently use varactor diodes for voltage control of capacitance. But their capacitance-versus-voltage characteristic is approximately logarithmic, not linear. In the days of vacuum tubes, designers used reactance-tube circuits for automatic frequency control in FM receivers and for

Figure 1



Use Grandpa's circuit without a filament to heat the room for linear frequency tuning in a regenerative radio receiver.

Figure 2



The frequency-versus-voltage characteristic is linear when you use voltage control in Figure 1's circuit.

modulating FM transmitters. It's possible to make the capacitance of the circuit proportional to the transconductance (g_m) of the tube. Over a certain bias range, the tube's g_m is proportional to the grid bias voltage. You can build such a reactance circuit using FET or bipolar transistors (**Figure 1**). The current in the drain circuit is in quadrature with the drain voltage because of the feedback elements R_1 and C_1. As a result, the drain circuit emulates a capacitor.

You can control the capacitance using voltage, via potentiometer R_2, or by adjusting R_1's shaft position. (You should set the unused potentiometer to maximum.) The L and C values in this controlled tuned circuit are chosen for a frequency range in the vicinity of the 49m short-wave band. The controlled LC circuit serves to tune a regenerative-type receiver. The tuning dial for this radio is linear—a feature uncommon in analog receivers. A modern version of the regenerative receiver can provide performance comparable with that of a simple superheterodyne receiver. Regenerative receivers are unique in that they require only one LC resonant tuning circuit. A superhet requires at least two resonant circuits that must track each other as you tune the receiver.

You can change the frequency band of a regenerative receiver by switching a single two-terminal inductor. You could also use **Figure 1**'s controlled tuned circuit to tune an RF amplifier, a filter, or an oscillator. The reactance circuit produces a maximum capacitance of $C_R = g_m \times R_1 \times C_1$. R_1 is the total resistance of potentiometer R_1. The reactance of C_1 should be much larger than R_1 at the frequency of interest: $X_{C1} >> R_1$. **Figure 2** shows the result of using voltage tuning via potentiometer R_2. The curve is linear from 0.1 to 1.3V. The change in frequency that accrues in this voltage range is 6.2 to 6.07 MHz for a 190-kHz bandwidth.

Figure 3 shows the results of shaft tuning. The bend at the lower end of the curve comes from the potentiometer characteristic. The curve is linear throughout the entire tuning range, which is 210 kHz wide. In the reactance-"tube" circuit, it's desirable to use a transistor with high output impedance. In this respect, a pentode vacuum tube with an output impedance of approximately 750 kV is superior to a transistor. However, MOSFETs have a considerably higher g_m than tubes. The transistor's g_m determines the amount of change in capacitance that is possible. The maximum g_m of a 3N200 MOSFET is 15,000 µmho, and the output impedance is 13 kV. (DI #2267).

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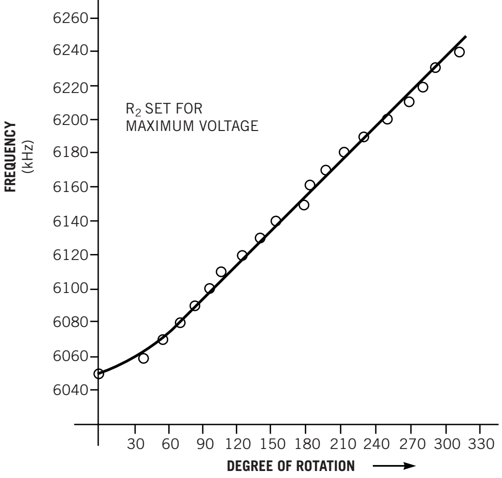
Circle No. 506

Figure 3



A rare feature in analog receivers, shaft (dial) angular position is linear with respect to frequency.

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