design ideas

Edited by Bill Travis and Anne Watson Swager

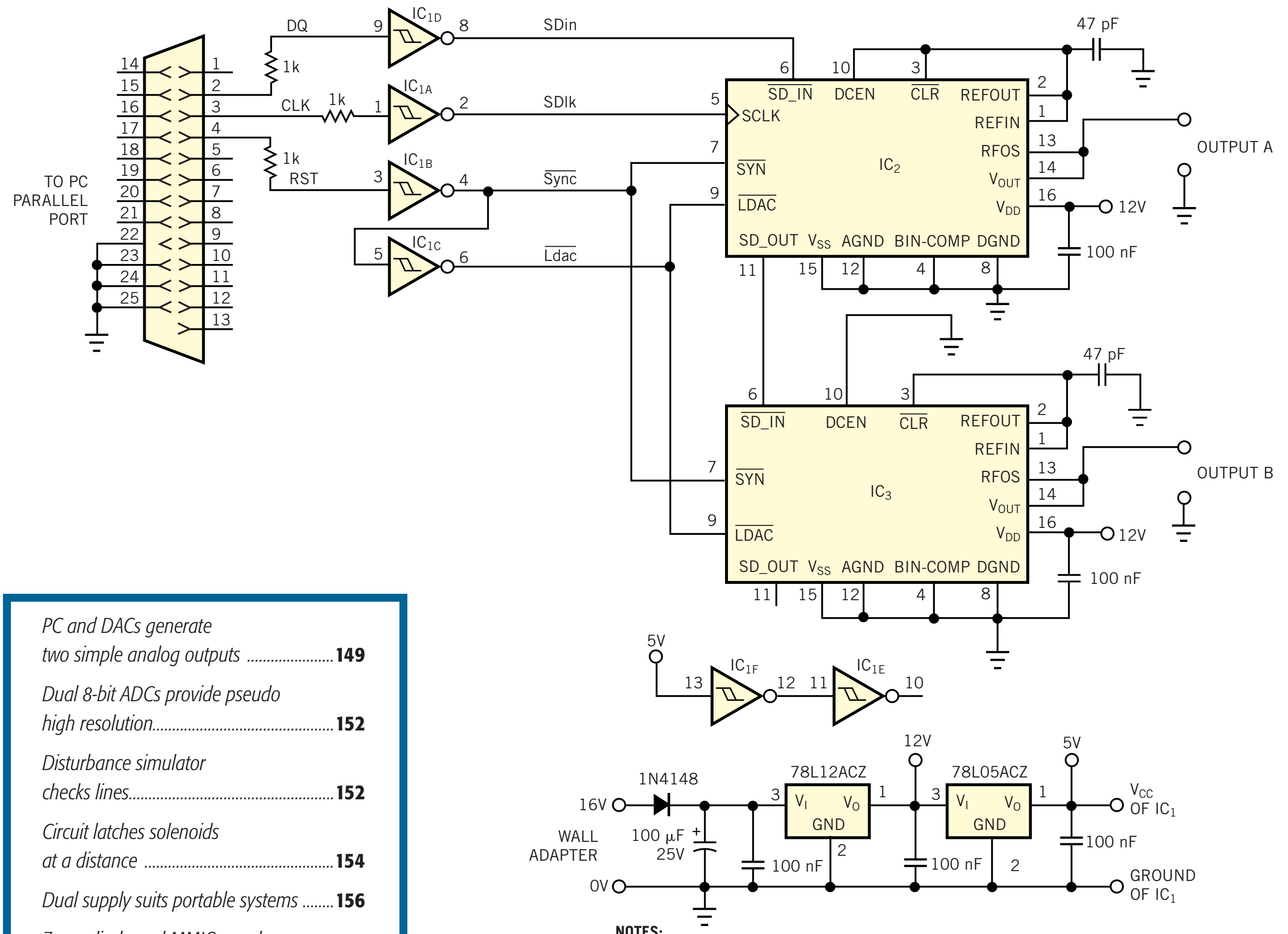
PC and DACs generate two simple analog outputs

Jim Terrade, Clermont-Ferrand, France

THE SIMPLE AND INEXPENSIVE circuit in **Figure 1** generates two PC-controlled analog reference voltages. You supply a wall-adapter supply and a parallel connector, and the circuit is ready to run. The circuit uses two 12-bit AD7243 DACs, which require only one supply voltage. These converters also include internal references, minimizing the number of external components.

Simple software uses the parallel port to communicate with the converters. The

Figure 1



NOTES:
IC1=74HC14.
IC2, IC3=AD7243.

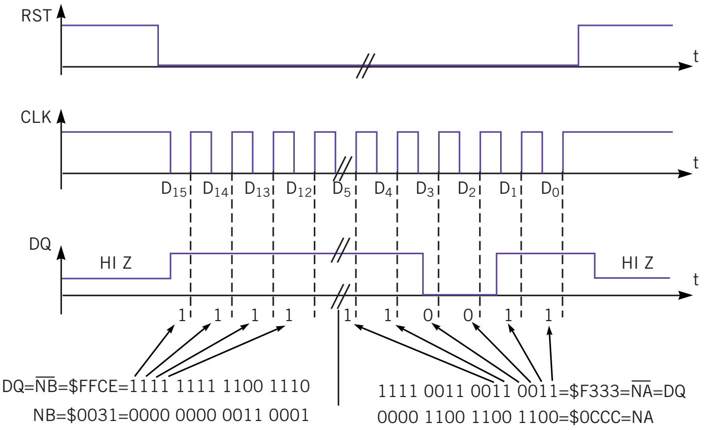
Two 12-bit DACs provide two PC-controlled reference voltages.

two converters connect in series with a connection of their Sync and Ldac inputs. This arrangement makes it possible for only three wires to drive the circuit.

The value of N can range from 0 to 4095 because the converters are 12 bits. The converters' internal reference voltages are fixed at 5V. To calculate the number N to enter, you can use the equation $N=V\times(4095/5)$, where V is the output voltage. For example, if V_B needs to be 4V and V_A needs to be 30 mV, $Nb=4.000\times(4095/5)=3276$ ($CCC), and $Na=0.030\times(4095/5)=49$ ($31).

Figure 2 shows how the transmission occurs. DQ is the 2's complement of the real numbers, Nb and Na, that the PC sends to the converters. The PC sends inverted data because of the presence of the inverting 74HC14 trigger, IC_1. RST goes low first to enable the converters. CLK must also go low because the data input is active only on the positive edge of the clock signal; the converter reads data bits only when CLK goes from a low to high level. The transmission starts when the PC sends a 16-bit word—four zeros and then the 12-bit word—for the second converter, IC_3, MSB first. Next, the PC sends the 16-bit word for the first converter, IC_2, MSB first. Niwm RST and CLK can go high, and the transmission stops.

Figure 2



Transmission begins after RST and CLK go low. Then, the PC sends the 16-bit words for Converter B and then for Converter A.

If more than two converters are necessary, you connect the Sync and Ldac signals to the other converters and connect the SD_IN input to the SD_OUT output of IC_3. Make sure that the first word the PC sends is the one for the new converter.

Because the 74HC14 is an inverter, you have to consider the following relations—and follow all data-sheet instructions for the AD7243—before reading the C program that drives the converters:

- RST=Ldac=Sync=Sync
- CLK=Sclk
- DQ=Sdin

LISTING 1—STANDARD C PROGRAM

```
Main loop :
   Read numbers to be sent : Na, Nb
   Set RST=1
   Send data for Nb     /* call sub-routine */
   Send data for Na     /* call sub-routine */
   Reset RST=0
End

Sub-routine (Send word N) :
   Set Numbit=15        MSB first   /* Numbit is the rank of the actual bit */
   do :                 /* 16 bits : 16 times */
        CLK=0
        If Numbit=1     then DQ=0
        If Numbit=0     then DQ=1
        wait
        CLK=1           (write 1 bit)
        wait
        Numbit=Numbit−1
        while Numbit # 0
end of sub-routine
```

Listing 1 shows the structure of the standard C program, which you can download from *EDN*'s Web site, www.ednmag.com. Click on "Search Databases" and then enter the Software Center to download the file for Design Idea #2407. (DI #2407)

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Circle No. 317

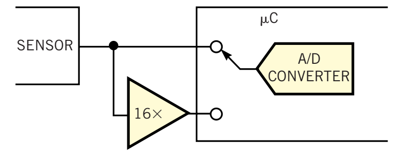
Dual 8-bit ADCs provide pseudo high resolution

Douglas Butler, Imetrix Inc, Cataumet, MA

Many inexpensive µCs now come with several 8-bit A/D-converter channels. However, many high-dynamic-range sensors need more than 8 bits of resolution. The simple technique in **Figure 1** provides a pseudo-high-resolution result for any application that has a mixture of large low-resolution signals and small signals near zero.

For example, the turning-rate sensor of a robot autopilot operates in two realms: Either the robot is rapidly turning to a new heading, or it is trying to travel a straight line. When the robot is turning, the least significant bits (LSBs) are meaningless because they change too fast for the system to track them. When the robot is trying to travel a straight line, the LSBs are important, but the most significant bits (MSBs) are all zero.

Figure 1



For a sensor-output signal that is a mixture of large low-resolution signals and small signals near zero, you can use two ADC channels to achieve a pseudo-high-resolution result.

By using two 8-bit ADC channels for the same signal, the technique in **Figure 1** can accommodate both conditions. One channel, which the controller uses for fast motion, reads the input directly and adds four 0 LSBs for a 12-bit result. The second channel reads the signal amplified by 16 with four 0 MSBs. The amplification gives this channel the resolution necessary for small-error signals while the robot is traveling a nearly straight line.

The controller first reads the second channel and checks for overflow. If no overflow occurs, the result is the reading plus four zeros for the MSB. If an overflow occurs, the controller discards this first reading and proceeds to read the first channel.

The controller can perform amplifier-offset correction any time the signal is in the small-signal realm by reading both channels, shifting 4 bits, and subtracting. In most cases, this correction is unnecessary. (DI #2415)

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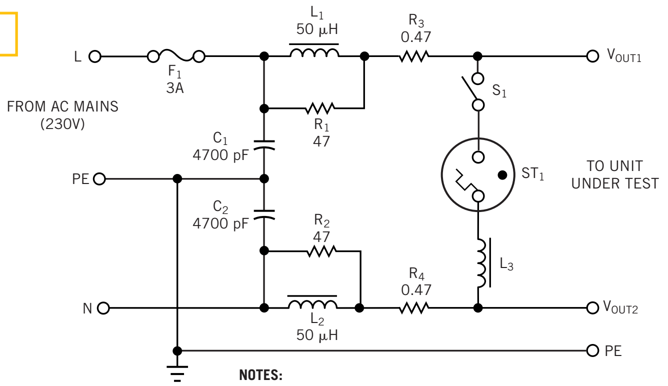
Disturbance simulator checks lines

Peter Guettler, APS Software Engineering, Cologne, Germany

The simple line-disturbance simulator in **Figure 1** helps you check the immunity of line-powered devices to line disturbances and noise; you can build the device from leftover parts found in a junk drawer. The key elements are a ballast inductor (L_3) and a slightly modified glow-discharge starter (ST_1) from a fluorescent lamp. Starters for fluorescent lamps usually contain a glow-discharge tube together with a noise-suppression capacitor in a small housing. You must remove the capacitor for this application. Electronic starters are unsuitable for this simulator. Operation of the circuit is straightforward: When S_1 closes, the glow-discharge starter switches on and off at a random rate. The abrupt current variations

Figure 1



NOTES:
R_1, R_2: 4.7Ω, 1W.
R_3, R_4: 0.47Ω, 5W.
C_1, C_2: 4700 pF, 250V.
L_1, L_2: 50 µH, 3A.
L_3, ST_1: SEE TEXT.

You can create dirty power lines for testing by using this simple circuit.

through L_3 induce noise at the output terminals, V_{OUT1} and V_{OUT2}.

L_1, L_2, C_1, C_2, and R_1 through R_4 form a decoupling filter to keep noise from flowing back into the ac mains. L_1 and L_2 must have a 3A current rating. You can wind them yourself, with 40 turns of 1-mm-diameter magnet wire wound on a ferrite rod of 10-mm diameter and 50-mm length. R_1 and R_2 are 47Ω, 5W wire-wound types. You mount all parts in a shielded enclosure. This simple circuit does not replace accurate, calibrated test equipment, but it provides a handy tool for a quick check during development. (DI #2423)

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Circuit latches solenoids at a distance

J Pelegri and D Ramirez, University of Valencia, Spain

The circuit in **Figure 1** controls low-cost, latching solenoid valves over long distances. For example, it can control one valve 1 km away using two wires and a 12V supply. The circuit provides 700 mA at 12V for the 20 msec necessary for latching a solenoid valve. The CD4538 monostable multivibrator provides an output-pulse width of 100 µsec to 1 sec. The IC consumes 5-nA standby current. The RX_1CX_1 and RX_2CX_2 network determines the output-pulse duration and accuracy. When the voltage on C_{A1} reaches 6V, an input trigger occurs, monostable IC_{1A} delivers an output pulse to Q_1's gate, and Q_1 sinks the current needed to open the latching solenoid valve. When the voltage on C_{A1} drops below 6V, monostable IC_{1B} turns on Q_2, and Q_2 sinks the current needed to close the latching solenoid valve. C_1 provides power to the solenoid valve. (DI #2426)

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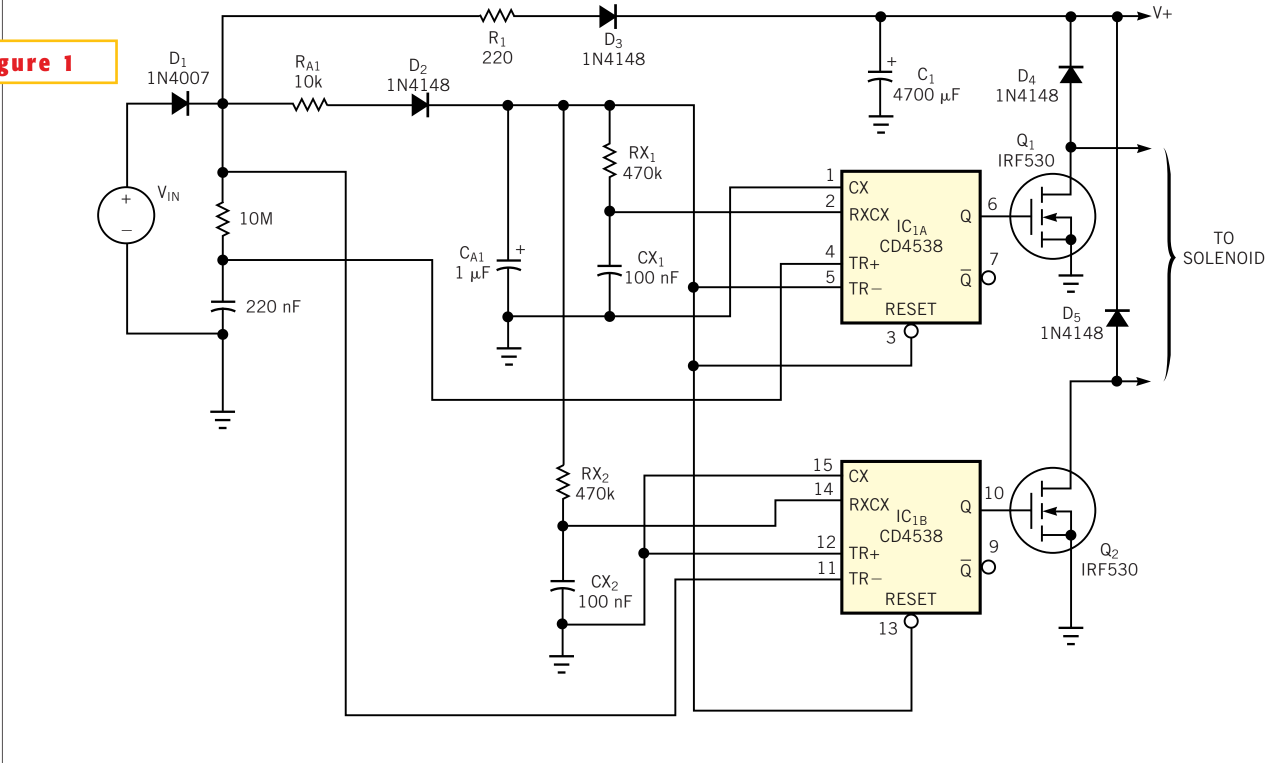
Figure 1



This circuit can drive a latching solenoid valve over a 1-km distance.

Dual supply suits portable systems

Budge Ing, Maxim Integrated Products, Sunnyvale, CA

The primary concern with power management in portable equipment is to prolong battery life by eliminating unnecessary energy consumption. The dual-output power supply in **Figure 1** meets this objective and maintains regulated 5 and 3.3V outputs as long as the battery or ac-wall-cube voltage or both are present. The circuit draws battery power only when the ac source is absent. Switch-over between the battery and the wall cube requires no user intervention, and the circuit imposes no extra diodes or MOSFETs in the battery path. The switch-mode regulators deliver as much as 600 mA at 5V, and the linear regulator supplies as much as 200 mA at 3.3V. IC$_1$, which contains a switch-mode regulator and a linear regulator, has separate internal on/off controls that enable its linear regulator to remain on (powered by IC$_2$'s output) when its switch-mode regulator is off.

IC$_2$ is a switch-mode dc/dc converter that boosts the unregulated 2 to 5V wall-cube output to a regulated 5.1V level. Note that the wall cube's output variation would produce excessive power dissipation in a linear regulator. IC$_1$'s POUT terminal, which can deliver 300 mA at 95% efficiency, provides a regulated 5V output. Thus, when IC$_2$ is producing 5.1V, IC$_1$'s feedback tells it to stop switching and wait. IC$_1$ goes into idle mode, drawing less than 1 µA of quiescent current, and waits for its output to drop below the setpoint. Similarly, a comparator in IC$_1$ (LBN/LBO) tells IC$_1$ to shut down whenever the ac supply goes off. This shutdown prevents a flow of reverse current through IC$_2$. (DI #2427)

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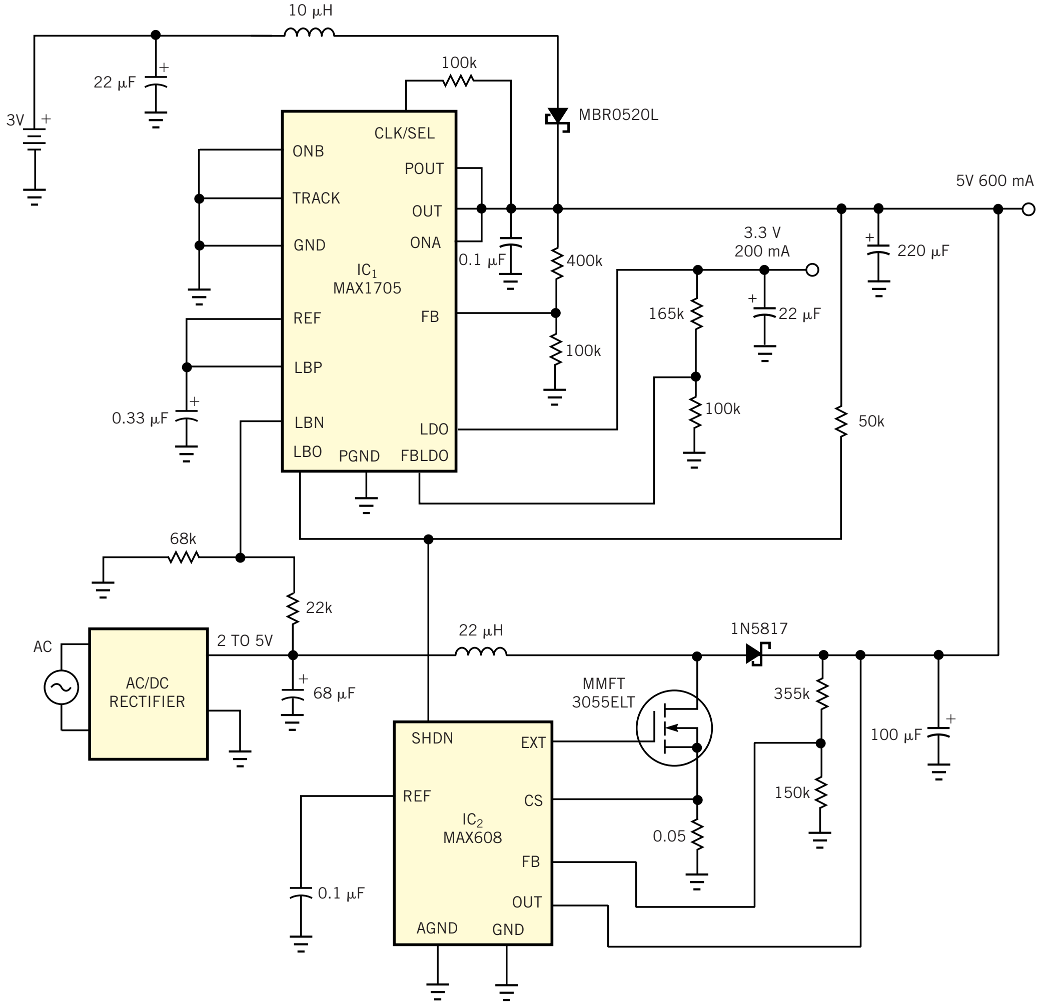
Figure 1



This energy-efficient dual supply works from either an ac supply or a battery.

Zener diode and MMICs produce true broadband noise

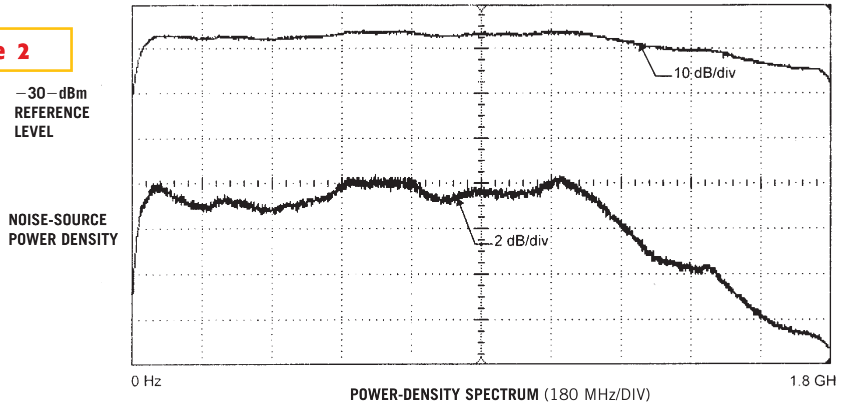
Lukasz Sliwczynski, University of Mining and Metallurgy, Institute of Electronics, Krakow, Poland

A BROADBAND SOURCE OF white noise can be useful for measuring and testing communications equipment. The source in **Figure 1** is simple and produces a large noise signal at its output terminals. The circuit comprises a zener diode and a few amplifying stages. The breakdown occurring in the zener diode is the true source of broadband noise in this design. This process is truly broadband because a substantial amount of noise is measurable at frequencies higher than 2 GHz.

The circuit ac-couples the zener diode into the first amplifier stage, and subsequent stages build up the zener diode's tiny noise voltage. The amplifiers—the MAR6, MAR3, and ERA5 (Mini-Circuits, www.minicircuits.com)—are monolithic-microwave ICs (MMICs). The total voltage gain of approximately 58 dB is high enough to produce an output voltage of approximately 224 mV rms at the 50Ω terminating load, which is equivalent to approximately 0 dBm. Each amplifier in the chain has a compression point 1 dB higher than that of the previous amplifier. Good amplifier linearity is important to ensure that the output signal has a Gaussian probability-density function. The 1-dB compression point for the last amplifier in the chain is more than 18 dBm to ensure that the amplifier operates in the linear mode.

From observations and measurements, it appears that the noise level of the avalanche-type breakdown diodes prevails over the noise based on the tunnel effect, and this noise level increases with the zener voltage of the diode. The frequency spectrum of the noise signal

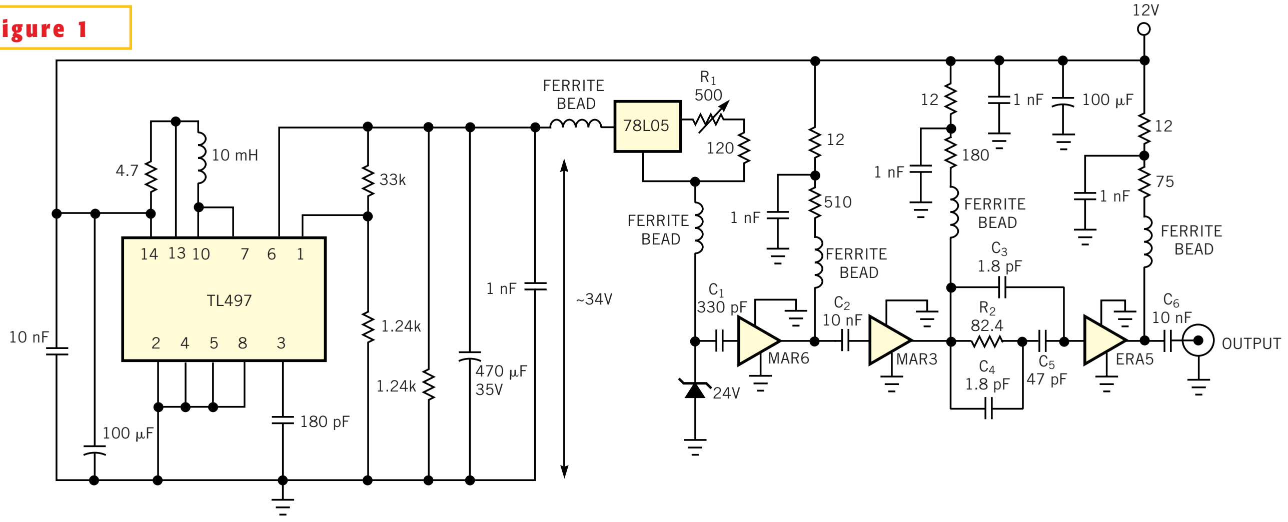
Figure 2



NOTE:
RESOLUTION=300 kHz.

A power-density spectrum of the noise source shows a flat spectrum with an accuracy of ±1 dB from 20 MHz to 1 GHz.

Figure 1

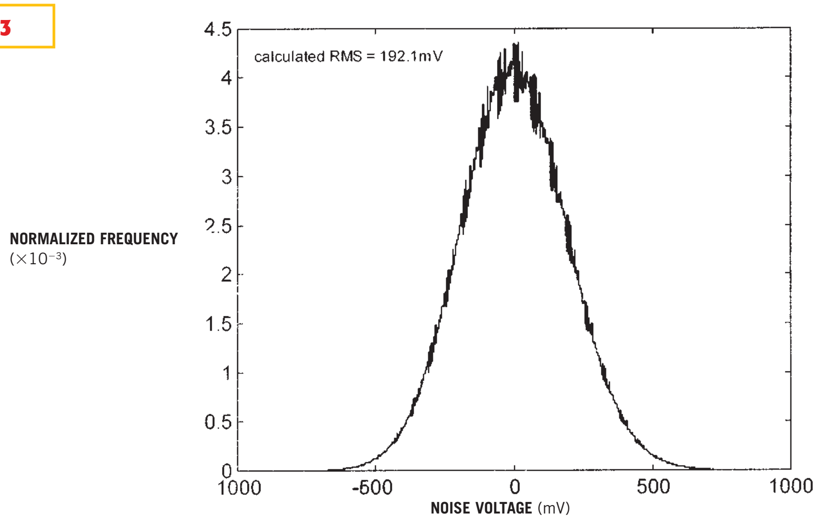


A 24V zener diode and a series of MMIC amplifiers create a broadband noise source.

is independent of the zener diode's voltage value, although a higher breakdown voltage typically means lower bandwidth. Using a zener diode with a 24V breakdown voltage for the circuit in **Figure 1** allows the design to produce a 10-dB-greater output signal than a design that uses a 9.1V zener diode.

A switching regulator, the TL497, and associated components provide the supply voltage for the zener diode; a 12V source supplies power for the rest of the circuitry. An additional linear regulator, the 78L05, supplies current to the zener diode. Changing the value of the current through the zener diode by trimming R_1 allows you to obtain a flat frequency spectrum from the source. You can increase the current to some value to find an optimum point for which the noise spectrum is flat and the noise level is as high as possible. For this design, the optimum current is approximately 21 mA. Increasing the current beyond this optimum point is not recommended because further increases cause a decrease of the output signal. **Figure 2** is a plot of the noise-power-density spectrum, measured with a spectrum analyzer. In the frequency range of 20 MHz to approximately 1 GHz, the spectrum is flat with an accuracy of ±1 dB, and the 3-dB bandwidth is approximately 10 MHz to 1.35 GHz. The probability-density function measured for 10^7 samples has the well-known Gaussian shape (**Figure 3**).

Figure 3



The probability-density function has a Gaussian shape, and the calculated rms value is 192.1 mV.

The calculated rms value from the histogram differs slightly from the power-measurement value; this difference stems from the limited bandwidth of the sampling gate used to acquire the samples.

To achieve a flat power-density spectrum of the noise in the low-frequency region, some spectrum whitening is necessary because of the existence of 1/f-type noise. This circuit achieves the necessary frequency shape of the amplifier gain using properly chosen values of coupling capacitors between amplifier stages—C_1, C_2, and C_6—and by using a correcting network before the last stage—C_3, C_4, C_5, and R_2. The values of all frequency-shaping components were chosen experimentally while observing the power-density spectrum on the analyzer screen.

To obtain good performance from the circuit, you must obey all RF design rules. In particular, keep the pins of the zener diode as short as possible and locate all decoupling capacitors near the MMIC amplifiers. Screening the entire circuit is also recommended. (DI #2406)

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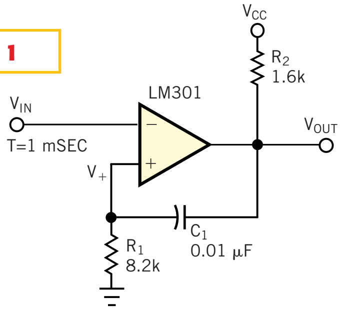
Comparator exhibits temporary hysteresis

Victor Axenenko, CSRI, St Petersburg, Russia

Figure 1

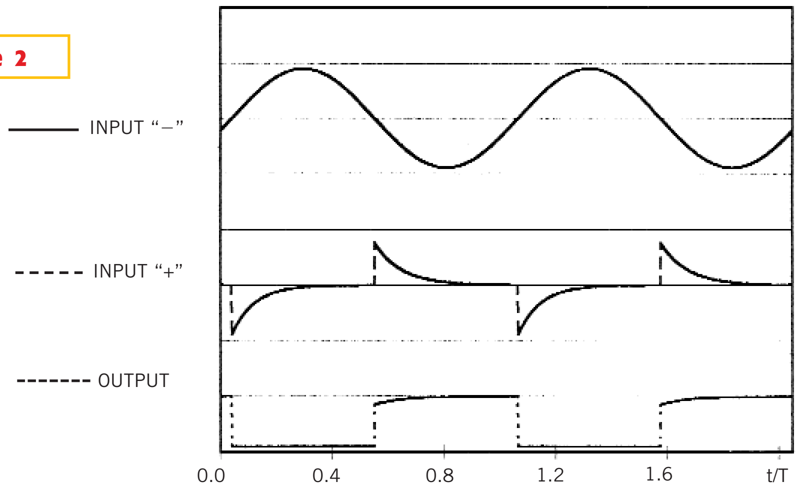


Replacing a resistor by a capacitor eliminates asymmetry by providing "temporary hysteresis."

Noise and interference can be significant problems when you transform a signal from a sine wave to a square wave. When the sine wave crosses the reference level, a comparator can exhibit uncertainty, or jitter. A common method to eliminate comparator uncertainty is to introduce positive feedback by using a resistor divider at the comparator's output. The drawback of this method is that the resulting hysteresis produces an offset that's a function of the state of the comparator. With an asymmetric output, the offset of the comparator's input is also asymmetric. The result is asymmetry in the desired rectangular output signal. You can eliminate this drawback by creating a "temporary-hysteresis" characteristic. You create this characteristic by substituting a capacitor for one of the positive-feedback resistors, as in **Figure 1**.

When the comparator's output switches, the voltage step transfers to the noninverting input through C_1. When the comparator's output switches from a high level, V_H, to a low level, V_L, its output transistor saturates. C_1, initially charged to V_H, begins to discharge through R_1. The noninverting-input signal, V_+, rises exponentially from its initial value (V_H-V_L) to 0V with a time constant $T_1=R_1\cdot C_1$ (**Figure 2**). When the comparator's output switches from V_L to V_H, its output transistor switches off. C_1 charges through R_1 and R_2 and creates a voltage step $V_+=(V_{CC}-V_L)\cdot R_1/(R_1+R_2)$ at the noninverting input. V_+ then decreases exponentially with the time constant $T_2=(R_1+R_2)\cdot C_1$. Note that the hysteresis is present only in the time intervals defining the time constants, T_1 and T_2. Note also that upon termination of transients, the signal V_+ on the comparator's noninverting input in both cases is equal to 0V (if $T_1<0.1T$ and $T_2<0.1T$, where T is the input signal's period). For maximum symmetry, you should select $R_1>>R_2$. (DI #2425)

Figure 2



The feedback capacitor in Figure 1 provides a step voltage to the noninverting input each time the comparator switches.

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