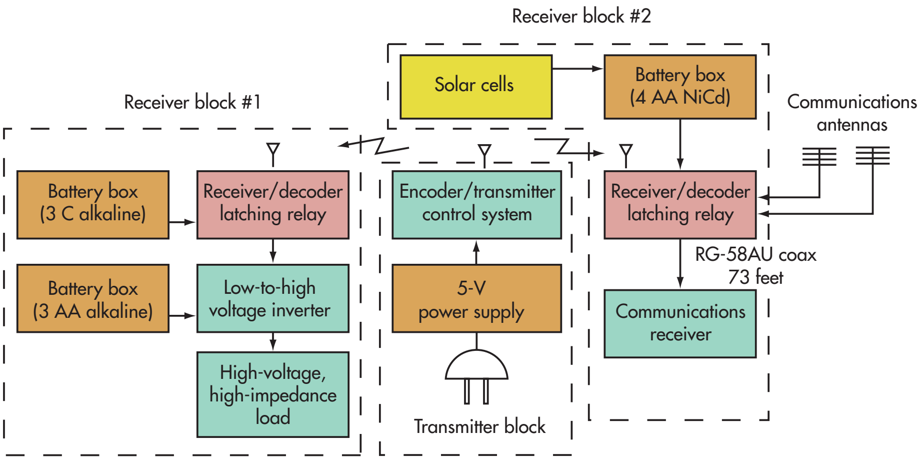
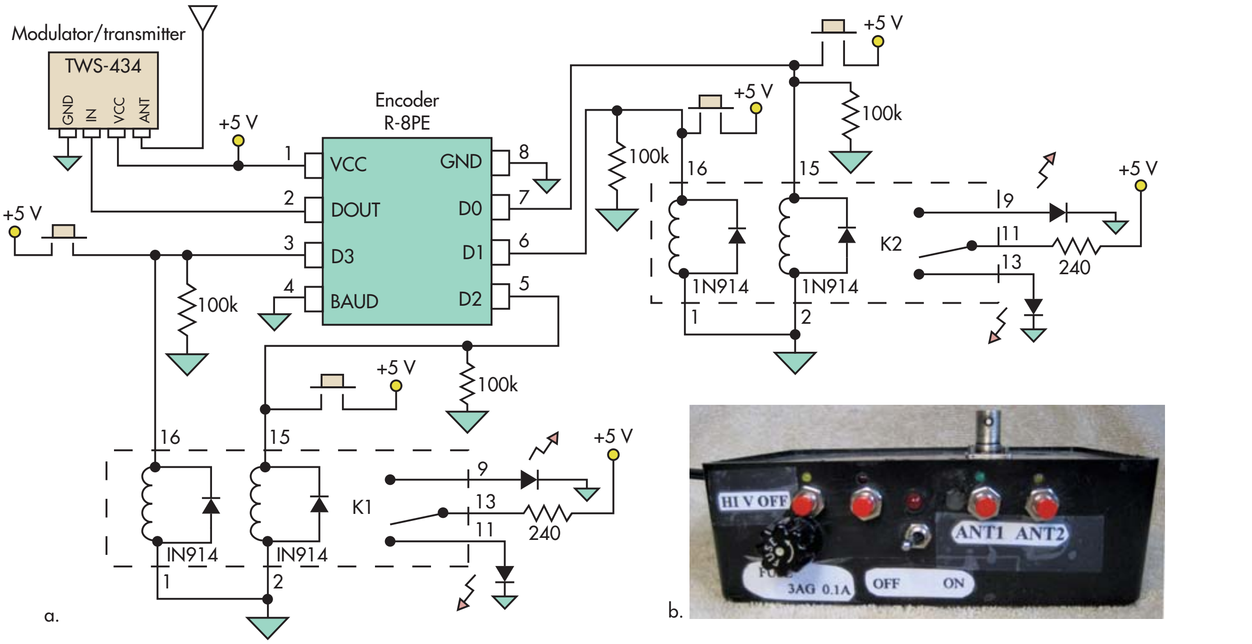
Shared, Switched RF Link Enables Multifunction Remote Control For Different Roles

WILLIAM RYNONE | RYNONE ENGINEERING rynone.eng@gmail.com

IN MANY INDUSTRIAL and commercial situations, there is often a need to energize or de-energize equipment that is remotely located or select one of two modes of operation for the equipment. This can be done via a hard-wired, RF, or even audio link, each with advantages and disadvantages in cost, reliability, maintenance, ease of installation, and longevity. For this application, a physical link was possible but difficult, so a wireless system was chosen.



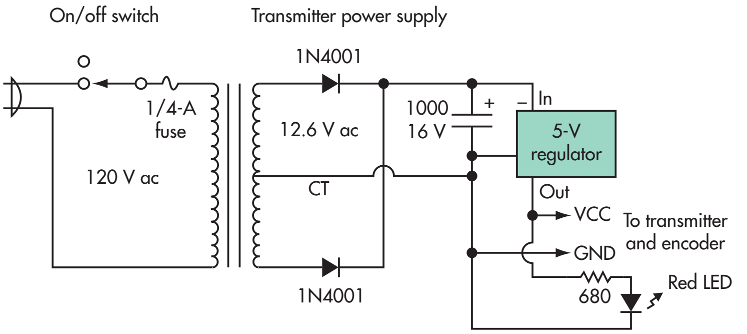
1. A single transmitter conveys one of four output commands to two similar receivers. Although similar in design, the receivers serve very different purposes.



2. The transmitter is based on commercially available modules, including a one-of-four encoder, and uses a standard transistor drive configuration for the latching relays.

This two-channel, RF-based control system initiates one of four system activations based on a low-cost, three-module control system that allows the user to control the action of two remote circuits/loads *(Fig. 1)*. The transmitter's low-power, pulse-modulated signal encodes one of four control signals. Both receivers see all signals but only one of the four possible signals activates an output from one of the two receivers *(Fig. 2)*.

The relays in the transmitter and receivers use the standard low-side switching configuration with a 2N2222 transistor to pull down the ground side of the coil and energize the coil, as well as a 1N914 diode across the coil for protection against inductive spikes when the relay is de-energized. Modules from Reynolds Electronics *(www.rentron.com)* were used to simplify the design.



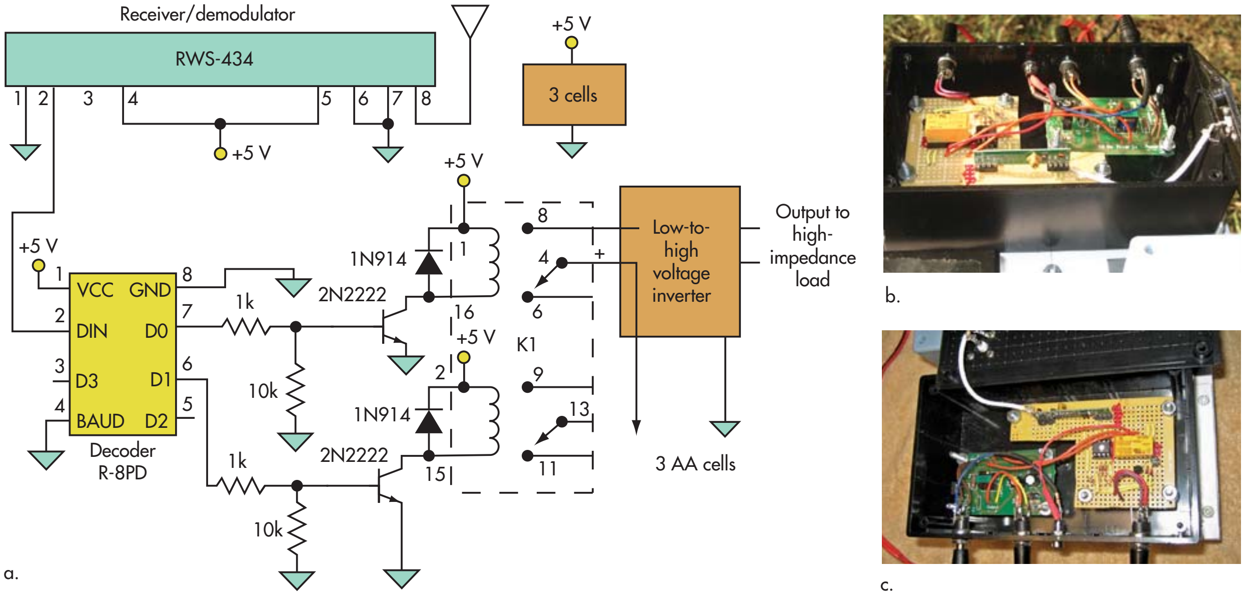
3. Power for the transmitter comes from the 120-V ac line via a step-down transformer and a 5-V low-dropout regulator.

In the installation, the transmitter is located at the ground-floor level and is powered via the 120-V ac line *(Fig. 3)*. Pushing one of four momentary pushbutton switches activates the transmitter. The transmitter was based on a small, low-cost printed-circuit module (TWS-434) that generates an output at 433.92 MHz and is modulated via a separate R-8PE encoder module. The tested maximum range of the transmitter module with a corresponding receiver module was approximately 200 yards (180 m).

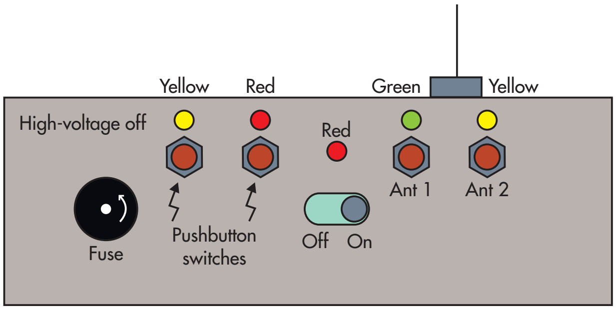
The equipment associated with Receiver Block #1 is located at ground-floor level 32 feet (9 m) from the transmitter *(Fig. 4)*. The role of this module, which consists of an RWS-434 demodulator, an R-8PD decoder, and a latching relay (Panasonic model SDE-SL2-DC5V, a low-power with 36-mA pull-in current) is to enable a user to "chase" invasive wildlife via activation of an operator-controlled "tickler circuit" (a high-voltage, high-impedance module; details not shown).

The two left-most pushbutton switches on the transmitter front panel provide a momentary input to data channels D0 and D1, the "energize" and "de-energize" commands that activate and de-activate the tickler circuit via this receiver *(Fig. 5)*. Latching relays are used so the user does not have to hold the pushbuttons down.

No source of ac-line or solar power was available, so alkaline batteries were used, as the receiver draws only 4-mA



4. The "core" of Receiver #1 is a pair of commercial modules, one for the receiver/demodulator and one for the decoder function, and powered by C-cell batteries. The inverter (circuit not shown) is powered by AA-cell batteries.



5. The simple front panel with momentary pushbutton switches is the only user interface.

quiescent current. An alkaline C-size cell has an energy rating of about 8000 mAh (according to a Google-researched value), corresponding to a standby battery life of 2000 hours (almost three months) in this application. The AA-size battery life in the inverter is difficult to predict since the low- to high-voltage inverter is mostly in idle mode. To activate and de-activate the tickler, the two left-most buttons on the front panel of the transmitter module are momentarily depressed in sequence.

Receiver Block #2 is used for an unrelated application from the same transmitter *(Fig. 6)*. It enables the user to select the antenna output of one of two co-located antennas on the roof and connect the desired output to a communications receiver via a coax cable.

Though a separate cable for each antenna could have been used, snaking the additional cable needed through two floor levels and two walls was undesirable due to the completion of building remodeling. The solution was to use a data-selection receiver that enables a latching relay to route the signal from one or the other antenna to a common coax.

A 120-V ac source to power the receiver circuit and latching relay was not practical, so two solar panels from a surplus electronics dealer feed a battery pack of four AA-size nickel-cadmium (NiCd) cells. To select the output of a particular antenna, the user momentarily depresses one of the two buttons located on the right side of the transmitter panel. This activates either the D2 or D3 inputs to the transmitter encoder and thus generates the corresponding decoder output.

Each of the three antennas was constructed using a UG-88 connector (a male BNC plug) where the center pin was replaced by a 7-in. (18 cm) piece of 0.050-in. (1.3 mm) diameter brazing rod. The brazing rod was epoxied into the connector and a 0.75-in. (20 mm) wooden bead was added to the end of each rod for safety.

ACKNOWLEDGMENTS
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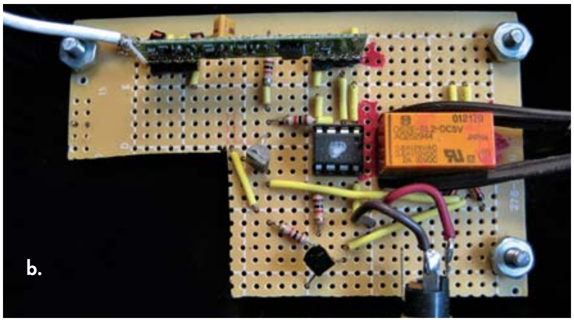
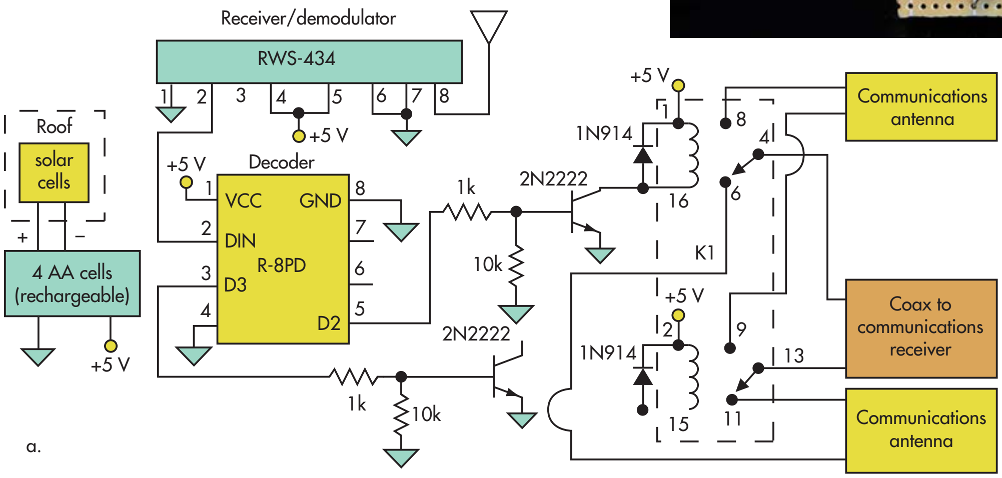
WILLIAM RYNONE, PhD, PE, Rynone Engineering, has designed electronics and is presently a technical writer. He taught electrical engineering at the U.S. Naval Academy and Johns Hopkins University. He is also president of the Annapolis Chapter of the Maryland Society of Professional Engineers.



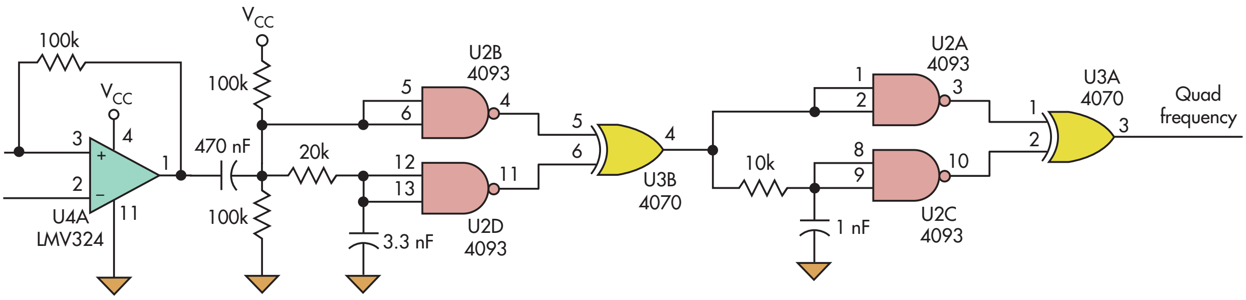


6. Receiver #2 is similar to Receiver #1, but it controls which of two antenna signals goes to a nearby receiver via a coaxial cable.

ideas for design

Frequency Quadrupler Enables Low-Frequency Measurements, Spans Up To Four Decades

DAVID CONRAD | dconrad@yahoo.com



1. The initial circuit implements ×4 multiplication for inputs up to 40 kHz to enable effective frequency counting despite short frequency-counter gating times.

IN FREQUENCY COUNTERS, THE gating time allotted for counting is often too short to resolve low frequencies. A phase-locked loop could be used to multiply the input frequency. But in some cases, the signal changes too fast or too far for lock to be acquired or maintained.

To solve the problem, the circuit of Figure 1 is used to multiply the input frequency by a factor of four, spanning a range of 1 Hz to over 40 kHz, and it will track a step change anywhere in that range. There is one issue with this simple implementation, though. The constant delay at U2D (as seen at U3B output) tends to cause counting-by-twos in the lower decades *(Fig. 2)*.

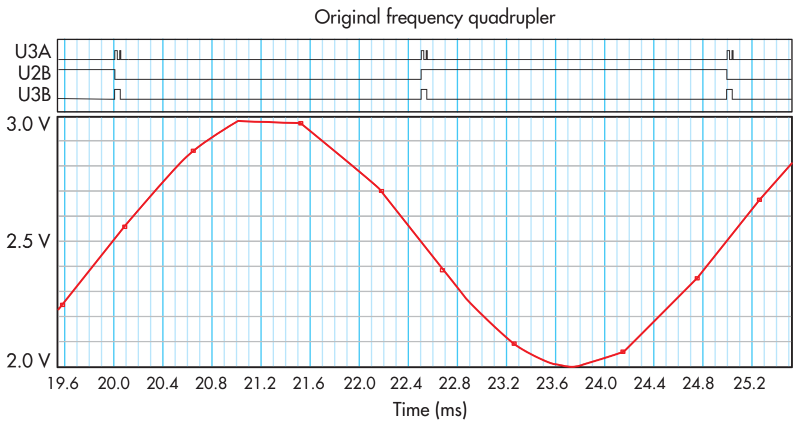
A circuit that eliminates this issue provides a quadrature output over the frequency range *(Fig. 3)*. Phase-lead and phase-lag circuits are used to create a constant 180° phase difference with respect to input frequency, at op-amp outputs (U5A and U5B).

Connecting the comparator inputs U6A and U6B to the op amps U5A and U5B reduces the phase difference to 90°, as measured from one comparator output to the other. Constant phase means variable delay, overcoming the issue with the circuit.

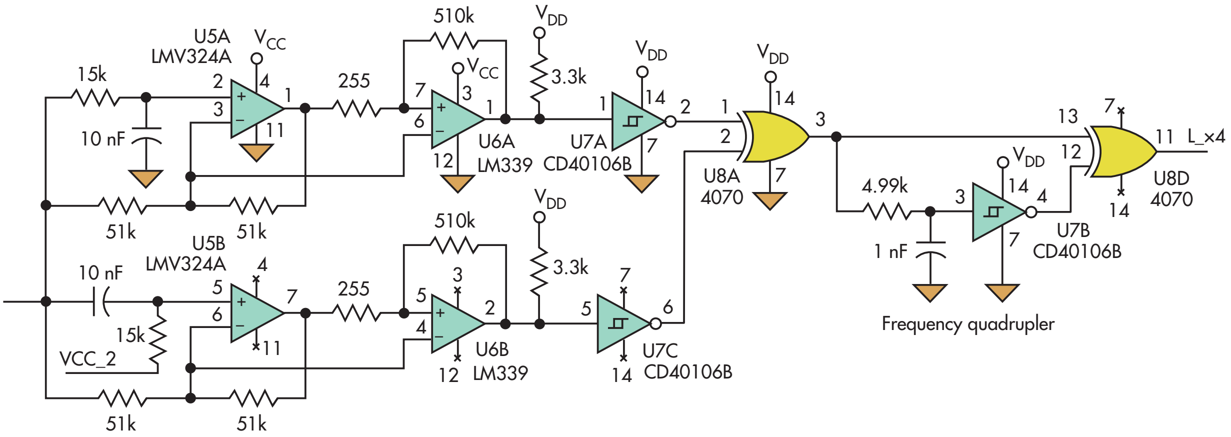
Figure 4 shows the benefits provided by the quadrature circuit. The first XOR gate, U8A, produces the exclusive OR of the two quadrature outputs, U7A and U7C. This multiplies the input frequency by two. The second XOR gate, U8D, produces a pulse for each positive and negative edge of the signal from U8A, again multiplying by two. The result is four equally spaced output pulses at U8D for each cycle at the input.

Quadrature maintains equal output pulse spacing as the frequency changes, so gating the pulse train will always count by ones. Quadrature is maintained within +0/–5° from 1 Hz to 49 kHz, but is lost above 49 kHz with the circuit values shown.

Accurate tracking speed may be limited by the time required to acquire four output pulses at the new frequency from a step change to an accurate count, effectively a



2. The circuit's shortcoming is a tendency to initiate counting-by-twos at the lower ranges, due to the fixed delay time of gate U2D.

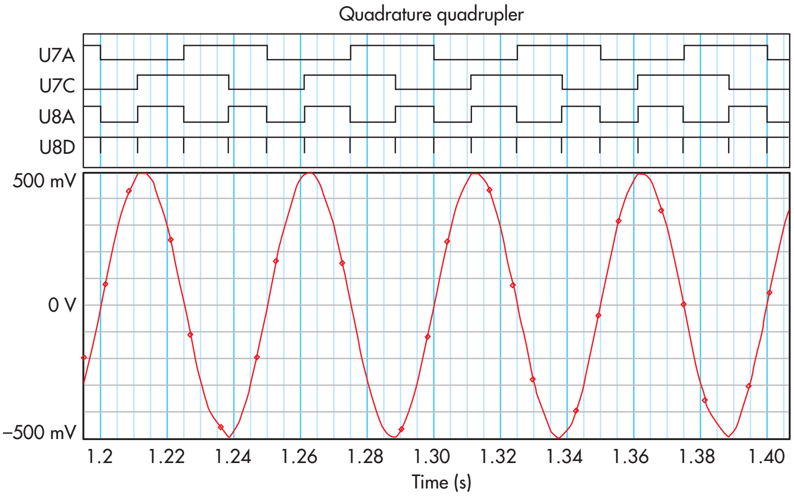


3. The addition of a quadrature function to the circuit changes the fixed delay time to a fixed phase difference, corresponding to variable time delay, overcoming the problem.

delay of 1/f seconds. This implies that accurate tracking is a function of the input frequency. Stepping from a higher to a lower frequency would require at least $1/f_{lower}$ seconds for the output to settle at four times the input frequency.

The output pulse is set wide enough to be reliably captured by the processor or other counter input. If it is too wide, it will limit the upper frequency at which multiplication can be achieved. Too narrow, and the microprocessor or counter will miss counts.

With the components shown, the output is a 5.6-µs pulse. This restricts the maximum theoretical multiplied output frequency to 89.3 kHz (input frequency less than or equal to 22.3 kHz). The quadrature circuit component values limit the maximum input frequency to 49 kHz or 196 kHz at the output of the multiplier. If the output pulse width could be made as short as 2.5 µs, the maximum multiplied output frequency would reach 196 kHz.



4. With quadrature and frequency multiplication by four at 20-Hz input frequency, the addition of the quadrature circuit clearly improves performance compared to the initial circuit.

Adjusting component values can move the usable range of multiplication higher or lower than that described here to fit the user's requirements. With faster op amps, comparators, and logic components, the design might be able to perform at RF frequencies.

DAVE CONRAD is a retired analog/digital hardware engineer who learned electronics by reading (starting at age 6) publications such as the *ARRL Radio Handbook*, *QST*, and *CQ* and later from various library books and *Popular Electronics* magazine. This was followed by a few courses in electronics in high school and junior colleges including TTL logic, along with learning on the job.