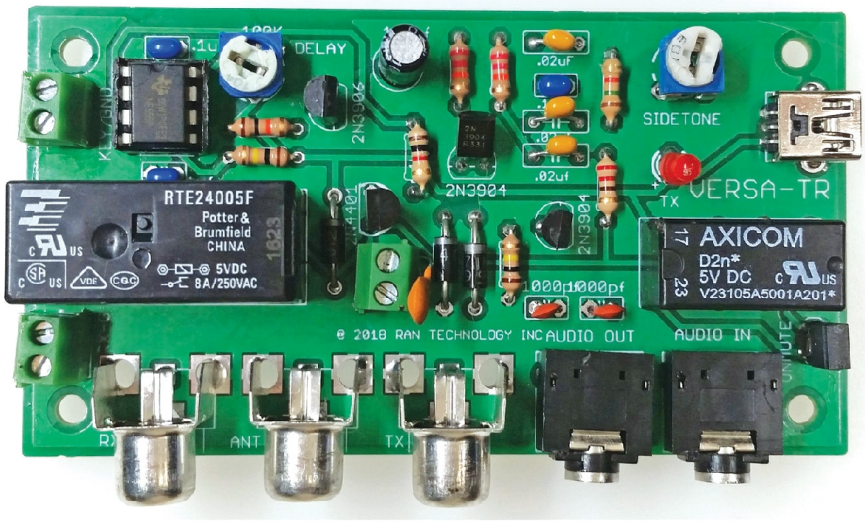
A Versatile T/R Switch for SDRs and Vintage Radios

This RF-actuated switch can be used with any transmitter and receiver combination, but it is especially well suited for software-defined radios.



Robert Nickels, W9RAN

In my January 2013 *QST* article, "Cheap and Easy SDR," I introduced many hams to the world of software-defined radio (SDR) through inexpensive DVB-T (RTL-SDR) dongles and other SDR receivers like Airspy, SpyVerter, HF+, SDRplay RSPs, HackRF One, and more that have since become part of many ham shacks.

Adding an upconverter like my RANVerter (available at **www.hayseedhamfest.com**) turns inexpensive dongles intended for digital TV reception into usable HF receivers when operated with PC-based software such as *SDR#*. But after some initial fun, many SDR receivers end up in a drawer, because they lack several key communications receiver features needed for use on the air.

I designed my versatile T/R switch with these needed features:

- A provision for muting the speakers when transmitting
- Sidetone to monitor CW keying
- A convenient means of switching the antenna between the transmitter and the SDR receiver
- Protection for the receiver input during transmit
- A way to overcome digital signal processing latency, which makes it impossible to monitor one's own signal, as can be done with a conventional receiver.

With these features, any SDR receiver can be conveniently used as part of a ham station, either as a primary receiver or as a panadapter or DSP second receiver connected to the IF of an existing receiver. Even an inexpensive RTL-SDR can become a very usable receiver when the needed functions are properly integrated. Versa-TR puts everything onto a compact PC board (see the lead photo) using all through-hole construction.

The Versa-TR also works with conventional analog transmitters and receivers or transceivers. Some possible station configurations include a conventional transmitter with an SDR receiver, a conventional transmitter and receiver, a conventional transceiver with an SDR panadapter (or second receiver), and a conventional transmitter with multiple receivers.

The Versa-TR incorporates a versatile RF-sensing relay that can also be used for keying a linear amplifier or lighting an "on air" sign.

Circuit Description

The Versa-TR schematic diagram is shown in Figure 1. It includes four major circuit functions: an RF-actuated switch, antenna relay, muting relay, and sidetone oscillator. A Versa-TR hookup is illustrated in Figure 2. The board requires 5 V at 200 mA, provided by the 5 V USB power supply via a USB Mini-B (five-pin) connector.

RF-Actuated Switch

The RF switch detects RF energy at the transmitter connector and triggers a 555 timer, activating the antenna relay K1 and the muting relay K2.

> *"Even an inexpensive RTL-SDR can become a very usable receiver when the needed functions are properly integrated."*

An adjustable time delay accommodates semi break-in operation. Both relays energize instantly, but the timer provides a delayed release time determined by the setting of the delay trim potentiometer (trimpot). The delay can be up to several seconds to provide VOX-like operation on voice or semi break-in operation in CW.

> *"RF sensing eliminates the need for anything other than an RF connection to the transmitter."*

Antenna Relay

The antenna relay has 8 A contacts to handle antenna switching but should only be used with non-reactive 50 Ω loads. Applied power should not exceed 100 W, and a tuner or resonant antenna should always be used to ensure low SWR. One set of contacts transfers the antenna from receiver to transmitter, and a second set grounds the receiver input to protect against excessive signal levels during transmission.

You will need to provide RG-58/U coaxial cables with RCA connectors for the Versa-TR end, and suitable connectors for the transmitter, receiver, and antenna.

RF sensing eliminates the need for anything other than an RF connection to the transmitter. However, external normally open contacts may be connected to the **KEY** terminals to directly control the Versa-TR, like a conventional T/R relay. No ac or dc voltage should be applied to these terminals.

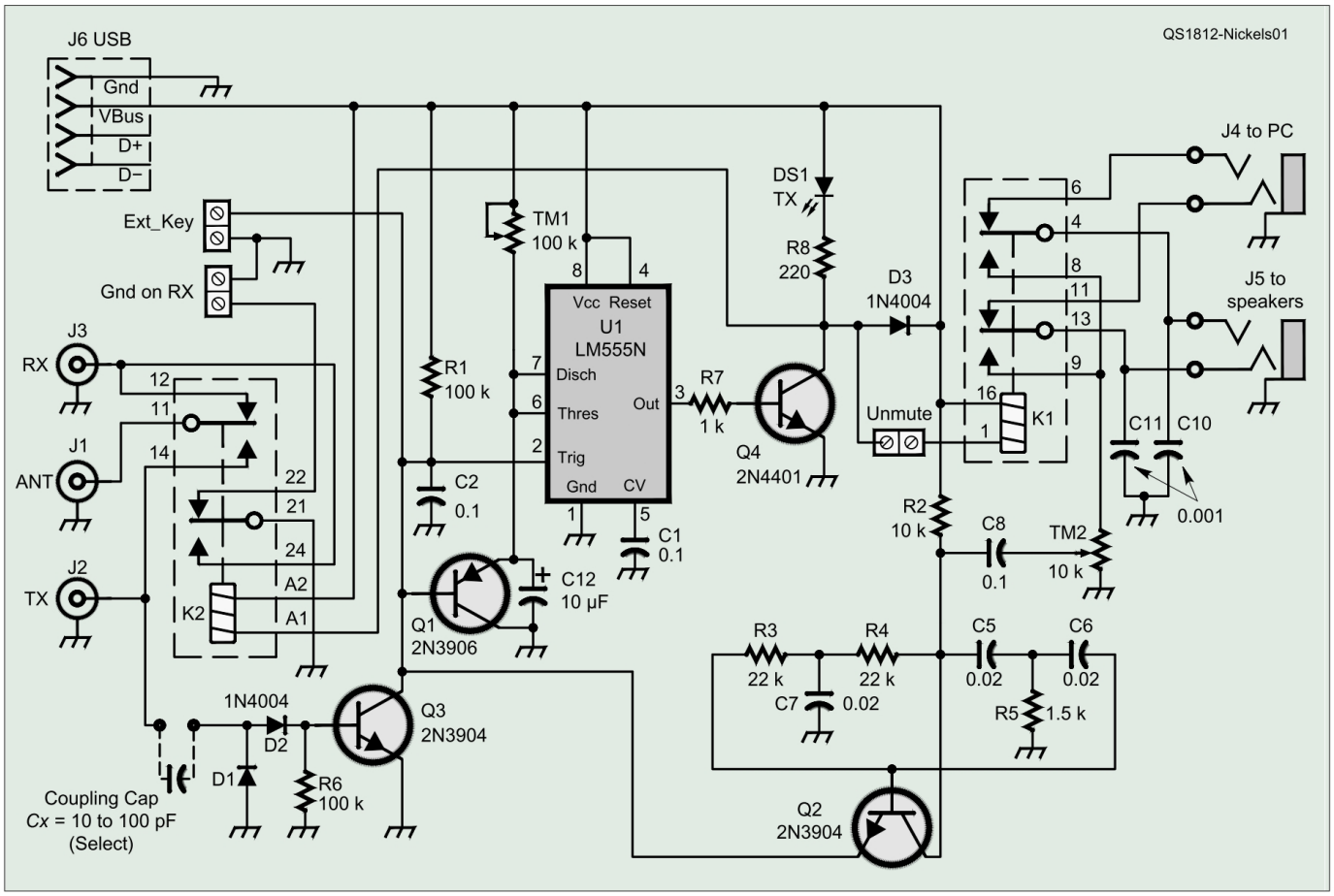


Figure 1 — Schematic of T/R switch. A kit is available at **https://hayseedhamfest.com/products/ran-technology-versa-tr-switch**.

C1, C2, C8 — 0.1 µF, 50 V, ceramic or film capacitor
C5, C6, C7 — 0.02 µF, 50 V, film capacitor
C10, C11 — 0.001 µF, 50 V, ceramic capacitor
C12 — 10 µF, 50 V, electrolytic capacitor
Cx — RF sense capacitor: 10, 47, or 100 pF; use smallest value for reliable keying.
D1, D2, D3 — 1N4004 (or 1N4007) diode
DS1 — T1 LED, red
J1, J2, J3 — RCJ-012, RCA jack, single, right angle, CUI
J4, J5 — 3.5-millimeter stereo jack, flat style
J6 — Mini-B USB connector
K1 — DPDT Signal Relay, V23105A5001A201 TE Connectivity P&B
K2 — DPDT Power Relay, RTE24005F TE Connectivity P&B
Q1 — 2N3906, PNP transistor, TO92 pkg
Q2, Q3 — 2N3904, NPN transistor, TO92 pkg
Q4 — 2N4401, NPN transistor, TO92 pkg
R1, R6 — 100 kΩ, ¼ W, carbon film resistor
R2 — 10 kΩ, ¼ W, carbon film resistor
R3, R4 — 22 kΩ, ¼ W, carbon film resistor
R5 — 1.5 kΩ, ¼ W, carbon film resistor
R7 — 1 kΩ, ¼ W, carbon film resistor
R8 — 220 Ω, ¼ W, carbon film resistor
TM1 — trimpot, 100 kΩ
TM2 — trimpot, 10 kΩ
Misc. — PC board, connector, screw terminal 3.5-millimeter spacing.
U1 — 555 timer IC, eight-pin mini-dip pkg

Muting Relay

A muting relay is designed for switching stereo audio channels to accommodate SDR operation where audio comes through the PC audio system. Both stereo channels are switched so the Versa-TR may be left connected at all times without affecting the quality of music or other PC audio. When no RF is present, PC audio passes through to the amplified PC speakers as usual. The muting relay switches the powered speakers from the line output connector during receive to the output of the sidetone oscillator in transmit.

Muting Disable

For normal muting, the pair of pads marked **UNMUTE** must be jumpered together. Optionally, an external switch can be connected to these pads to disable the muting feature. The **UNMUTE** jumper does not affect antenna relay operation.

Sidetone Oscillator

A sine-wave sidetone oscillator is keyed by the RF signal and sent to the audio output jack for CW monitoring. A volume control is provided to set a pleasant sidetone level.

Muting and Switching

Amplified speakers are required to hear the CW sidetone. The muting relay circuit can be used to mute the audio for any conventional receiver and speaker setup. The audio muting relay can also be wired to provide an SPST normally open or normally closed switching function for any desired purpose. A contact that is grounded on receive is also available.

Optimizing the RF-Sensing Level

A capacitive voltage divider provides a small amount of RF energy for the RF-switching circuit. This circuit works like a volume control to adjust the sensitivity of the RF-sensing circuit but varies with frequency and power level. To compensate for these combined effects, select a capacitor value *Cx* that reliably triggers the RF-switching circuit.

The RF sensing level is set by connecting a suitable capacitor at the **SENSE** screw terminal connector. For low RF power, 47 or 100 pF is needed, but 10 pF will suffice with higher power levels. Temporarily install the smallest value capacitor at the screw terminal location provided and verify that correct RF sensing occurs. Move to the larger values if needed for reliable operation.

Construction

The Versa-TR uses through-hole components to facilitate home construction. Be certain to install the transistors in the correct locations, and observe diode, LED, and capacitor polarity markings.

Typical stereo cables with 3.5-millimeter (⅛-inch) three-circuit miniature phone plugs on each end are used for audio connections. The PC **LINE OUTPUT** goes to J4 and the powered speakers are plugged into J5. In most setups, a 3.5-millimeter stereo jumper cable would go from J4 to the PC **LINE OUTPUT** connector (green), and the speakers would plug direction into J5. Amplified PC speakers are required for SDR receiver use and may be left connected at all times, even without power to the Versa-TR, for normal PC audio operation.

Checkout

Attach a 5 V power supply to the mini-USB jack, temporarily connect short-wire jumpers to the external screw terminals, and touch them together. Both relays should pull in and the LED should light. Remove the short and the relays and the LED should drop out. Adjust the **DELAY** trimpot for the desired delay time consistent with the intended mode of operation. Delay can be set for up to several seconds for operation like semi break-in.

Connect the audio cable to the PC **LINE OUTPUT** connector on the PC, plug in amplified speakers, and verify normal PC sound operation. Insert a jumper plug or wire between the **UNMUTE** pads. Again, short the **KEY** terminals and a pure tone should be heard from the speakers. Adjust the sidetone trimpot for the desired audio

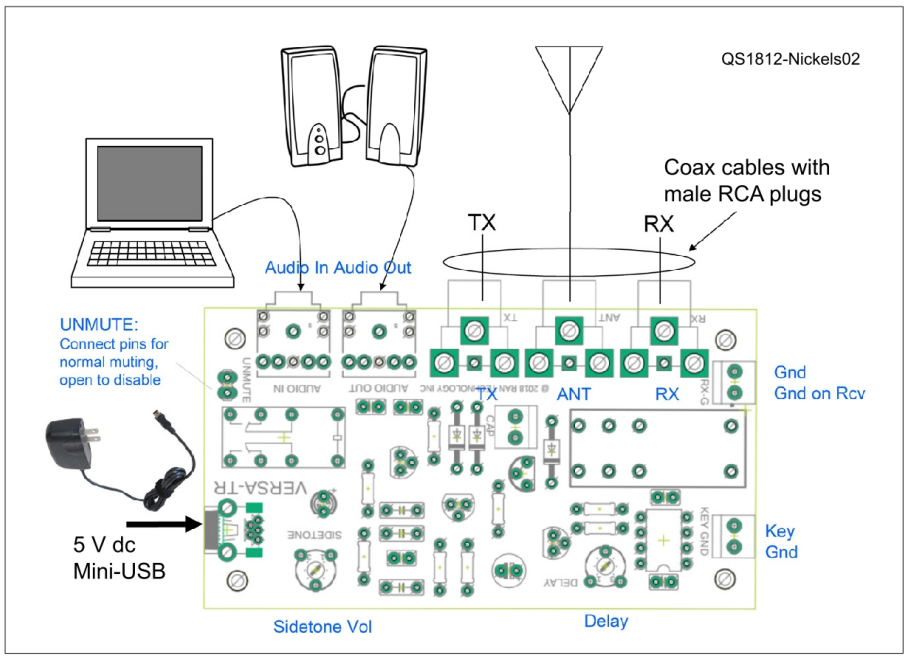


Figure 2 — Typical Versa-TR board connections.

level for CW. Removing the **UNMUTE** jumper will allow receive audio to be heard during transmit for spotting or testing.

Connect the Versa-TR to the station equipment and antenna or dummy load.

Connections

The connections for my board are shown in Figure 2 and in the file on the "*QST* in Depth" web page at **www.arrl.org/qst-in-depth**. Figure 1-QiD shows my PC board layout and location of connectors and controls. The Versa-TR is typically connected as shown in Figure 2-QiD when an SDR receiver is used with a transmitter. Power is provided by a 5 V USB power supply with a Mini-B USB connector. Note that this is not the micro USB used by many phones. PC line output (green) and powered speakers may be left connected for normal PC sound. Standard three-circuit TRS (tip-ring-sleeve) male plug wiring is shown in Figure 3-QiD.

Figure 4-QiD shows a hook-up for a conventional non-SDR receiver using 4 – 8 Ω speakers. Two 3.5-millimeter (⅛-inch) stereo phone plugs should be wired as shown. Connection is made to *either* tip or ring, and sleeve (ground). The unused pin should be left disconnected. Connected this way, audio from the receiver will normally be heard through the speaker and will be muted when RF is present. The CW sidetone will not be heard through a conventional unamplified speaker.

The Versa-TR may be used as a general purpose RF-sensing switch by connecting to the audio output jack as shown in Figure 5-QiD. No connection is made to the audio input jack. The muting relay connects the tip and ring of this jack when RF is present. No connection is made to the sleeve or ground terminal. When using this circuit, the voltage should

Figure 3 — A 1950s vintage Multi-Elmac AF-67 is paired with an Airspy SDR with the SpyVerter for HF reception.

Figure 4 — A simple RTL-SDR is paired up with a Hallicrafters HT-37 transmitter for operation in AM, CW, and SSB modes.

Figure 5 — T/R switch used with an Ameco AC-1 two-tube 15 W CW transmitter and a National NC-98 receiver.

be less than 40 V dc. If control of an ac line powered circuit is needed, use these contacts to control an external slave relay. Under no circumstances should 120 V ac mains ever be wired to this board.

A short interval — I measured 5 ms — is needed for the T/R relay to switch the antenna from the receiver to the transmitter. At 20 WPM, a first "dit" will be shortened by about 10%.

Operation

The **DELAY** trimpot sets the variable drop-out time delay to hold the relays in transmit when a continuous carrier is not present. This provides for semi break-in CW operation, and can be set to mute the audio when using voice modes to mask the slightly delayed sound resulting from digital signal processing latency.

The **SIDETONE** trimpot adjusts the volume of the sine-wave sidetone oscillator for CW operation. First, set the SDR receiver volume to provide adequate volume through the powered speakers, and then adjust the **SIDETONE** trimpot for a comfortable level when transmitting. For voice modes, turn the volume to zero.

Typical Uses of the Versa-TR

Some examples of typical uses include those pictured here — let your imagination and radio inventory be your guide.

Figure 3 shows a 1950s vintage Multi-Elmac AF-67, a popular 60 W dc input power AM transmitter paired with an Airspy SDR with the Spy-Verter for HF reception. *SDR#* software on a Winbook Tablet provides DSP filtering and features like synchronous detection. A stereo patch cable connects between the tablet headphone jack with the input jack on the Versa-TR and the output jack into amplified computer speakers for audio and muting.

Figure 4 shows that even a simple RTL-SDR like my $50 RANVerter can be used to make contacts with the Hallicrafters HT-37 operating in AM, CW, and SSB modes. Wiring up antenna relays and muting the circuit can be tedious, but the Versa-TR makes it easy. For SSB, the sidetone level is turned to zero so no sidetone is heard and the laptop audio output is connected through the Versa-TR for muting on transmit with an amplified speaker. When no RF is present — such as during pauses between words — the Versa-TR will switch back to receive just like in VOX operation. The **DELAY** control can be adjusted to set the length of this delay.

Figure 5 shows the Versa-TR operating with a nostalgic Novice station that includes the classic Ameco AC-1 Novice rig. The AC-1 lacks features like a T/R relay, sidetone monitoring, and muting that make operating more fun. For CW, wiring is according to Figure 2. Audio from the headphone jack of the National NC-98 receiver is routed through the Versa-TR input, and from the output to an amplified speaker, which works for both receive audio and CW keying sidetone monitoring. Unplugging the headphone jack connection returns the NC-98 to normal speaker operation.

Conclusion

Because I like to mix and match various vintage transmitters and receivers, I've used the Versa-TR a lot in my own shack. Once you've wired up a few interconnecting cables, setting up a new station becomes truly a matter of plug and play.

All photos by the author.

ARRL member and Amateur Extra-class licensee Robert Nickels, W9RAN, was first licensed as WN0OHO in 1965 while in high school. He has a BS degree from Fort Hays State University in Kansas and credits Amateur Radio as a major influence during his 40-year-long career in electronics. Bob holds three US patents and is retired from Honeywell. He now heads up RAN Technologies, Inc., a business and technology consulting firm. Bob enjoys cycling, kayaking, and cross-country skiing as well as ham radio history and homebrewing. He also collects, restores, and operates vintage electronics and classic radios from the past 6 decades. You can contact Bob at **w9ran@arrl.net**.

For updates to this article, see the *QST* Feedback page at www.arrl.org/feedback.