By Dwayne Kincaid, WD8OYG

A Repeater Controller Accessory: The RCA

Although designed initially for use with repeaters, this flexible controller can be adapted to many other applications. Let your imagination be your guide!

At 10:30 PM, the phone rang. It was Gene, one of our repeater-control operators. He said he was getting reports that our local repeater was hard to hear in the southern part of the county. I told him I would check it out.

Ordinarily, I would have had to stuff a bunch of test equipment into my car and drive about 30 minutes to the repeater site to analyze the problem. I would also have had to lug along a bunch of common replacement parts in case I could fix the problem on the spot. It could easily take two hours or more to check the system.

Tonight, however, would not be the norm. There would be no need to drive to the site to perform the check-up—we had just installed a Repeater Controller Accessory. I simply reached for my H-T, pushed a few keys on the pad and the repeater *told* me what the problem was! Tonight, the repeater's power amplifier had kicked itself off-line and the repeater was operating using only the exciter. With a few more keystrokes, I reset the power amplifier and the repeater was back up to full power.

How Did I Do That?

Necessity is the mother of invention—and that's how the Repeater Controller Accessory project began a few years ago when I got involved in building repeaters. I really enjoy repeaters—when they work—but *keeping* them working is another story! By the time I was caring for seven repeaters at three remote sites, I needed an easy way of keeping tabs on *all* of the equipment.

I researched some remote telemetry systems, but didn't find anything that met my needs. Many of the systems require phone lines and computers, and are way out of my price range. There are a few systems available that can be built around packet

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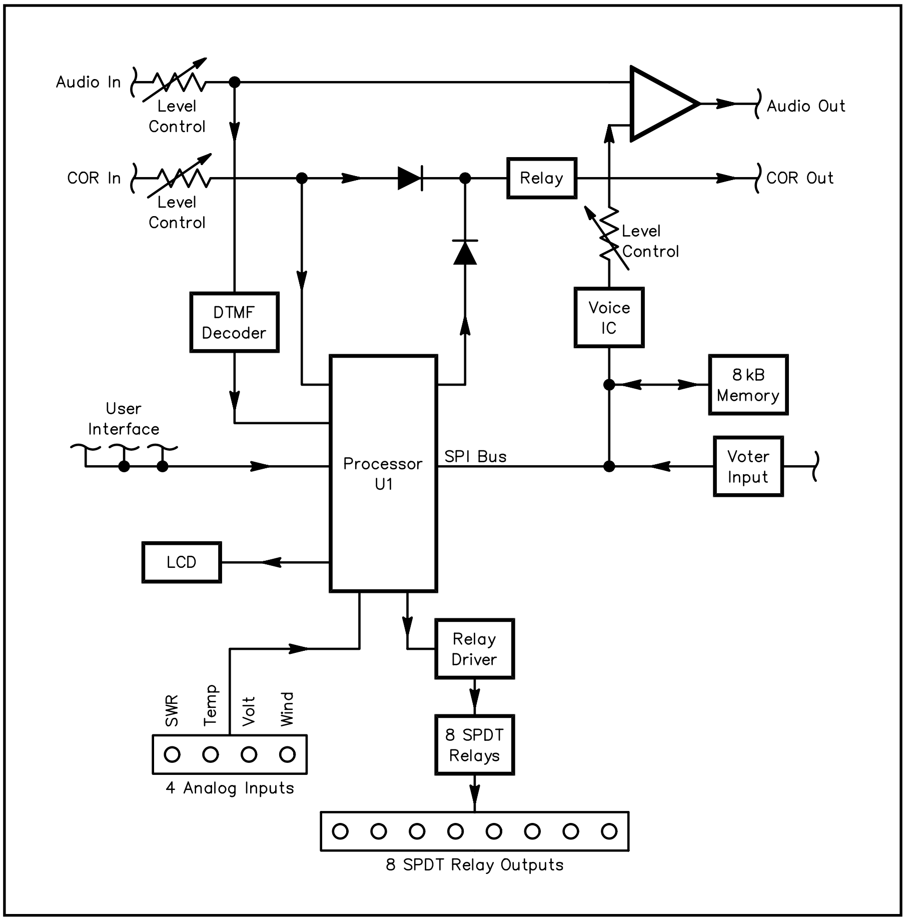


Figure 1—Block diagram of the Repeater Controller Accessory.

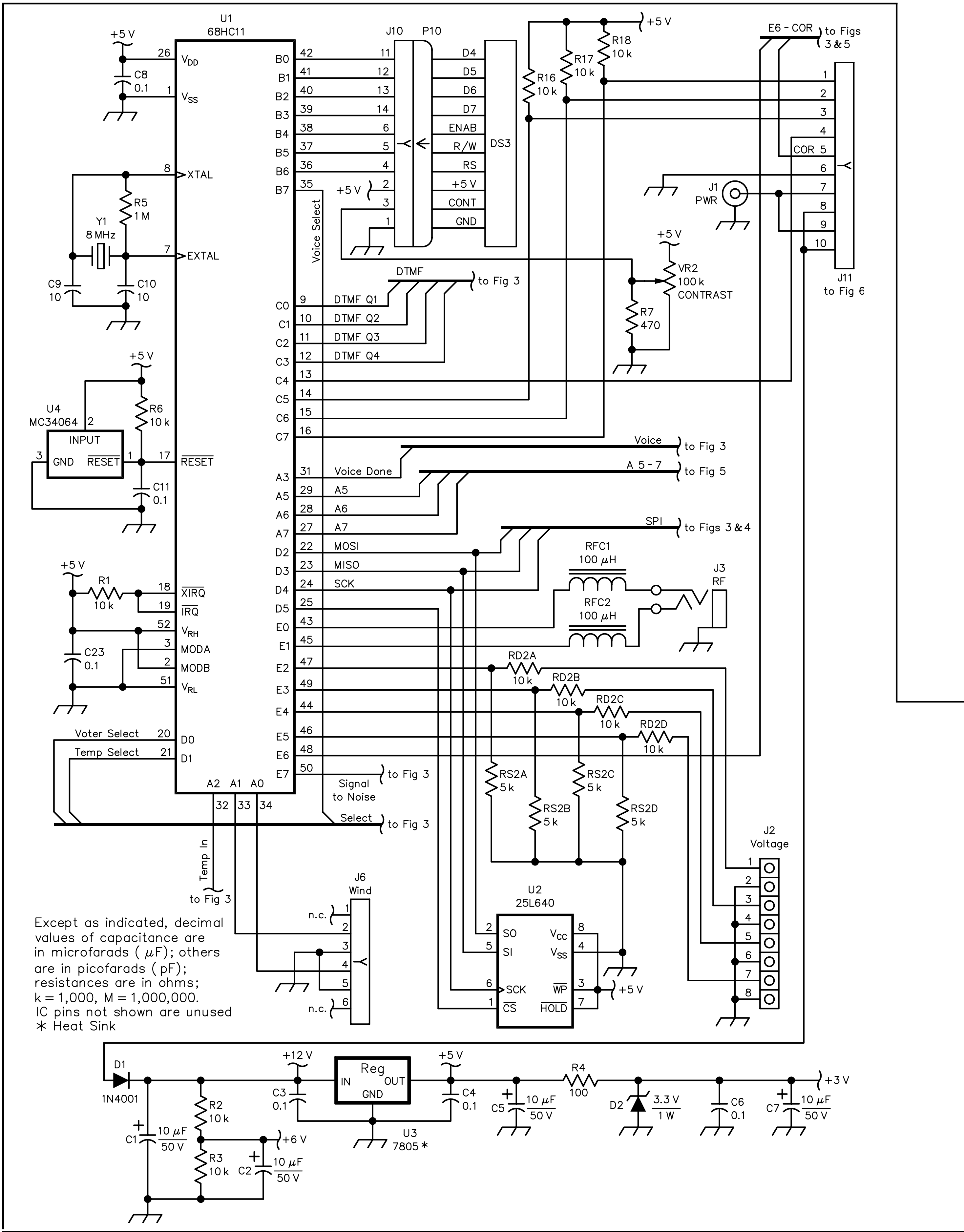
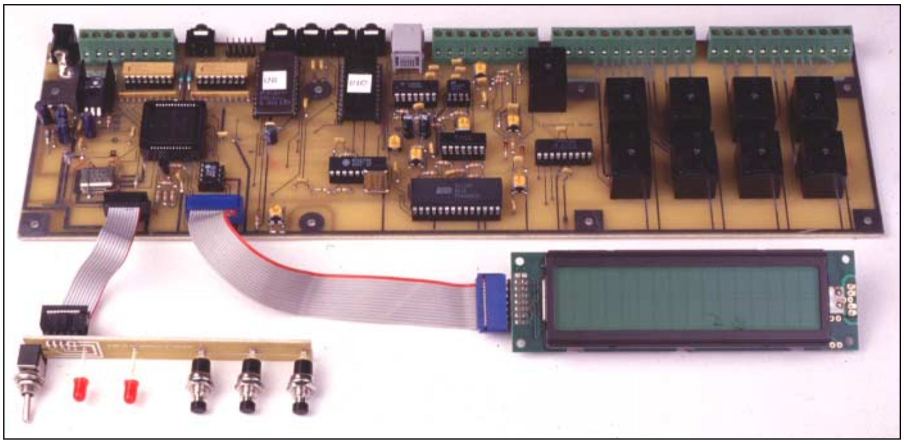

U1
68HC11
VDD
VSS
XTAL
EXTAL
RESET
XIRQ
IRQ
VRH
MODA
MODB
VRL
D0
D1
A2 A1 A0
C8 0.1
R5 1 M
Y1 8 MHz
C9 10
C10 10
U4 MC34064
INPUT
GND
RESET
R6 10 k
C11 0.1
R1 10 k
C23 0.1
Voter Select
Temp Select
J10
P10
DS3
D4
D5
D6
D7
ENAB
R/W
RS
CONT
GND
Voice Select
DTMF
to Fig 3
DTMF Q1
DTMF Q2
DTMF Q3
DTMF Q4
R16 10 k
R17 10 k
R18 10 k
E6 - COR
to Figs 3 & 5
COR
J1 PWR
J11 to Fig 6
VR2 100 k CONTRAST
R7 470
Voice
to Fig 3
Voice Done
A 5 - 7
to Fig 5
A5
A6
A7
SPI
to Figs 3 & 4
MOSI
MISO
SCK
RFC1 100 μH
RFC2 100 μH
J3 RF
RD2A 10 k
RD2B 10 k
RD2C 10 k
RD2D 10 k
RS2A 5 k
RS2B 5 k
RS2C 5 k
RS2D 5 k
Signal to Noise
Select
Temp In
to Fig 3
J6 Wind
n.c.
J2 Voltage
U2 25L640
SO
SI
SCK
CS
VCC
VSS
WP
HOLD
+5 V
Except as indicated, decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); resistances are in ohms; k = 1,000, M = 1,000,000.
IC pins not shown are unused
∗ Heat Sink
D1 1N4001
+12 V
Reg
IN
OUT
GND
U3 7805∗
C1 10 μF 50 V
R2 10 k
R3 10 k
+6 V
C2 10 μF 50 V
C3 0.1
C4 0.1
C5 10 μF 50 V
R4 100
D2 3.3 V 1 W
C6 0.1
C7 10 μF 50 V
+3 V

Figure 2

radio, but those approaches require considerable customization and the installation of *more* radios and antennas. Not for me…

The system I had in mind had to be very flexible—flexible enough to work with all of the different repeaters and remote receivers that I cared for. I wanted something I could use without a computer and telephone lines. The ideal system would also provide me with the information about the status of transmitters, antennas, feed lines, power amplifiers, power supplies, air conditioners, heaters, back-up batteries and be able to control some of those things.

With nothing in the market available at a price that I could afford, I wound up designing what I needed: a tone-controlled *talking* telemetry system. The result is the Repeater Controller Accessory described here. The project's name derives from the three parts to which the unit interfaces. The first is pretty obvious: a repeater. There are definitely other applications for this project, but the repeater is the main target. Next is the Controller. This unit works with all of the controllers that are used with Amateur Radio repeaters. It accomplishes this by requiring only audio and COR signals. Finally, there's Accessory. I didn't want to design a repeater controller; a multitude of very good controllers is already available. There was no sense reinventing the wheel, so this unit is an *accessory* for existing repeater controllers and interfaces to the other accessories that repeaters need to operate.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The main board and user interface.

With a little thought, you're sure to find the RCA flexible enough to remotely control a number of things, including HF station equipment at home or at another location.

Features

My features list started out being pretty generic, but I quickly added some of the other things that I've wanted for our local repeaters. The main task remains: reporting telemetry. The repeater-site items I wanted to monitor include: transmitter and amplifier RF power (forward and reverse); SWR (to determine the state of the antenna and feed line); power supply and back-up battery input voltages, and temperature readouts of power supplies, heat sinks, air conditioners, heaters and the inside and outside air temperatures.

I also wanted *built-in* relay-contact interfacing. If there's one thing that I feel can be improved on in today's repeater controllers, it is the "outside-world" interface. Most controller interfaces have just an open-collector transistor or a TTL output. Both of those are just about useless when connecting to the outside world. With other controllers, you have to add a relay, a voltage source and connectors for each item you want to control. What a mess! I wanted to have the relay contacts available and have easy connections to them—an arrangement in which you could merely connect a pair of wires to a device and the controller would control it. The RCA has eight SPDT contacts, each capable of handling 10 A. The normally open and normally closed contacts are brought out to compression-screw terminal blocks for device interconnection.

Another feature accommodates repeaters that have voters. A few years ago, I designed a repeater voting system,[1] but omitted any way to distinguish which site was being polled. Because the RCA can speak, it can use the voter data to indicate which site is selected. Of course, this feature can be turned on and off remotely.

In addition, I added the ability to measure the signal-to-noise ratio (S/N) of an audio signal and present it as an analog voltage to the microprocessor. The S/N converter is similar in design to Mark (WB2WHC) Kolber's audio-noise-based voting circuit.[2] As in Kolber's design, the S/N converter uses an input buffer, a three-pole high-pass filter, a noise rectifier and a smoothing circuit for each channel. The RCA goes one step further by allowing the output of the converter to give a voltage representation of the S/N. This is a 0.5 to 4.0-V signal that is read by the microprocessor's ADC. More noise on the audio yields higher voltage to the ADC.

Almost as an afterthought, I included a weather-sensor interface. Some of the better repeater controllers have this feature; adding it here makes weather reporting much more affordable. A simple phone-line interface jack (an RJ11) and a Peet Brothers sensor[3] (about $100) easily adds wind speed and direction reporting. Peet Brothers also supplies a model equipped with a heater for use at the more-northern latitudes. Both units provide a wind-direction resolution of about 2°.

Controller Design

The block diagram (Figure 1) and schematic (Figures 2, 3, 4, 5, 6, 7, 8) detail the system layout. Six major subsystems neighbor the microcontroller in the RCA: the analog sensors, relay driver, DTMF decoder, voice chip, voter input and the user interface. The microcontroller uses inputs from the DTMF decoder, analog inputs, voter input and the user interface to drive the voice-chip and relay-driver outputs.

Analog Inputs

There are four analog sensor inputs: RF power, voltage, temperature and wind. U1's

Figure 2—The microprocessor section of the Repeater Controller Accessory schematic; the main-board schematic extends through Figure 6. Unless otherwise specified, resistors are 1/4-W, 5%-tolerance carbon-composition or film units. Equivalent parts can be substituted; n.c. indicates no connection.

C1, C2, C5, C7—10 μF, 50 V electrolytic
D1—1N4001
D2—3.3-V, 1-W Zener diode
DS3—2-line, 16-character LCD
J1—PC-mount coaxial power connector
J2—8-position screw-type PC-mount terminal block
J3—3-circuit phone jack
J6—6-conductor, PC-mount RJ-11 jack (connects to wind sensor)
J10—2-row, 7-position PC-mount header (mates with DS3).
J11—2-row, 5-position PC-mount header (mates with P11, Figure 7).
RFC1, RFC2—100 μH
RD2—10-kΩ DIP-16 resistor package
RS2—5-kΩ SIP-10 resistor package
U1—*Programmed* 68HC11 microcontroller (see Note 5)
U2—25L640 SPI serial EEPROM
U3—7805 5-V, 1-A positive regulator with heat sink
U4—MC34064 undervoltage sensor
VR2—100-kΩ PC-mount pot
Y1—8-MHz crystal, HC-33/U holder

[1]Notes appear on page 45.

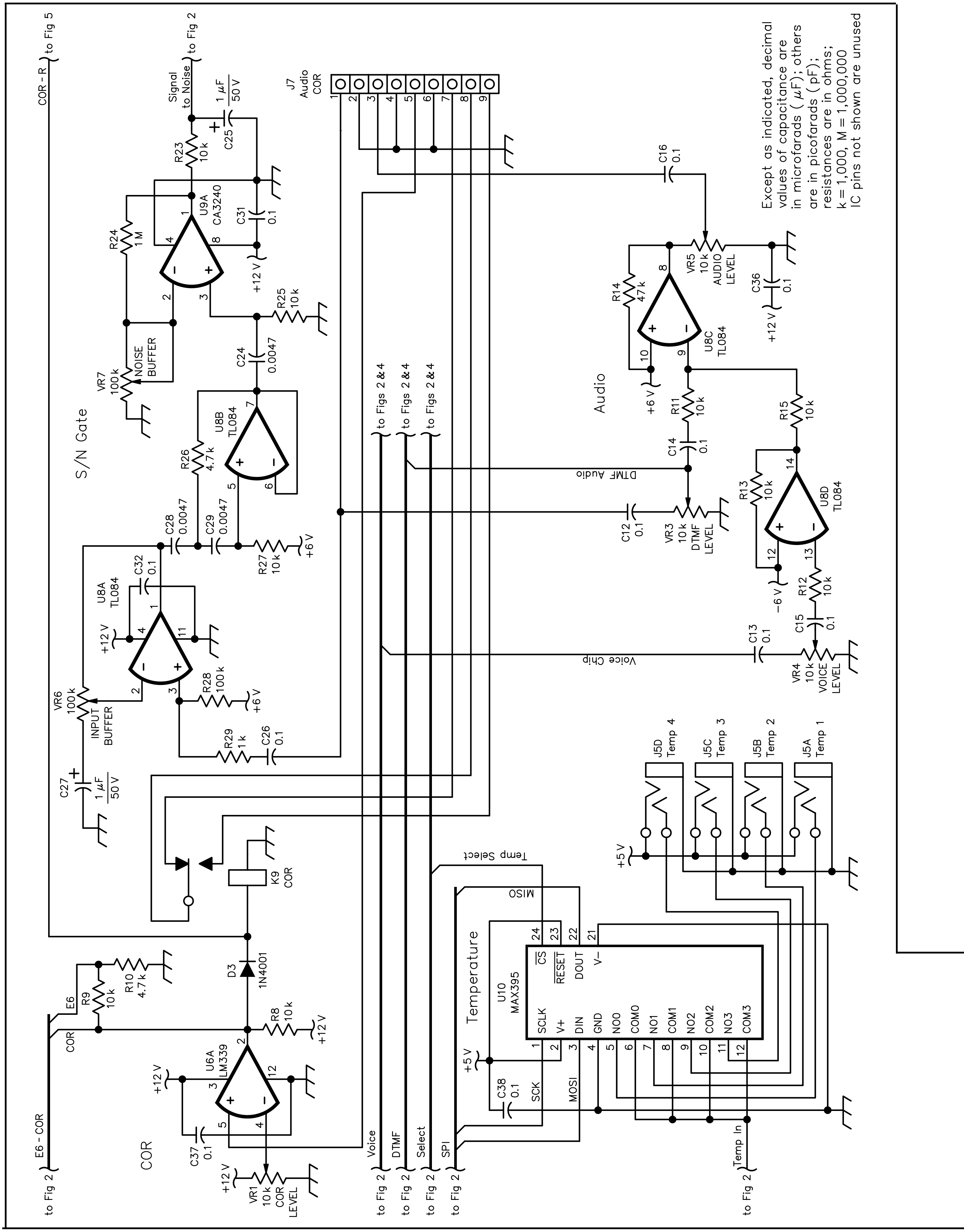
Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms; k = 1,000, M = 1,000,000
IC pins not shown are unused
S/N Gate
Audio
COR
Temperature
J7 Audio COR
U10 MAX395
U9A CA3240
U8A TL084
U8B TL084
U8C TL084
U8D TL084
U6A LM339
K9 COR
D3 1N4001
VR1 10 k COR LEVEL
VR3 10 k DTMF LEVEL
VR4 10 k VOICE LEVEL
VR5 10 k AUDIO LEVEL
VR6 100 k INPUT BUFFER
VR7 100 k NOISE BUFFER
J5A Temp 1
J5B Temp 2
J5C Temp 3
J5D Temp 4
DTMF Audio
Voice Chip
Temp Select
MISO
MOSI
SCK
to Fig 2
to Fig 5
to Figs 2 & 4
Signal to Noise
COR - R
E6 - COR
Voice
DTMF
Select
SPI
Temp In

Figure 3

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An inside view of the HF and VHF/UHF remote SWR sensors

ADCs read the first two after they're filtered on the main board. U1's timer inputs read the temperature and wind-sensor outputs.

The RF SWR sensors include HF and VHF types that handle power levels up to 200 W. The HF sensor (used on 10 and 6 meters) is a common toroidal bridge.[4] The single-lead primary passes through the center of T1 providing RF current sampling to the secondary. D1 and D2 rectify the forward and reverse currents. Bypass capacitors and chokes filter out RF and provide a smoother dc signal. The potentiometers provide voltage-level reading adjustment and allow calibration.

For VHF (used on 144, 220 and 440 MHz), the RF sensor uses stripline sampling. Striplines above and below the main line provide the forward and reverse voltage sampling. D1 and D2 rectify the forward and reverse currents. Again, bypass capacitors, and chokes smooth the signal and potentiometers provide adjustable voltage levels to U1's ADCs.

The voltage sensor is set to read a range of 0 to 15 V dc. A simple resistive voltage divider lowers the input voltage to a level U1 can handle.

An external temperature sensor connects to the circuit via J5. The sensor is a unique device (an SMT-160-30 from Smartec) that provides a pulse-width modulated (PWM) signal proportional to temperature. U1's timer port reads these pulses and converts them to a digital number corresponding to the temperature. The temperature-sensor's range is –50° to +200° F.

The Peet Brothers wind sensor is a little more complicated. It provides a pulsed signal that represents the wind speed; another pulsed signal represents the wind direction. These pulses are filtered and sent to U1's timer port. There, an internal timer measures the pulses and the software correlates the measurements to wind speed and direction. The anemometer speed is directly proportional to the number of pulses per second received. Wind direction is found by comparing the relative timing between the anemometer and vane pulses.

The HF and VHF/UHF remote SWR sensors

Figure 3—Temperature section and level controls for audio, DTMF, COR and S/N gate.

C25, C27—1 µF, 50 V electrolytic
D3—1N4001
J5A-J5D—3-circuit phone jacks
J7—9-position screw-type PC-mount terminal block
K9—SPDT relay, 12-V, 30-mA coil, 10-A contacts (Aromat JS1-12V)
U6—LM339 quad comparator
U8—TL084 quad op amp
U9—CA3240 dual op amp
U10—MAX395CNG serially controlled, low-voltage, 8-channel SPST switch
VR1, VR3-VR5—10-kΩ PC-mount pot
VR6, VR7—100-kΩ PC-mount pot

Relay Driver

U7, the relay driver, is an Allegro '5810 IC. It is specially made to handle several relays and other high-current devices. The '5810 operates as a four-line serial device (there is one line each for the enable, clock, data and strobe signals) that gets its information from U1. The '5810 can drive a maximum of 10 relays. The RCA uses eight lines for the eight relay outputs and one line to drive the COR output.

DTMF Decoder

U5, the DTMF decoder, is an MT-8870 IC. The MT-8870 uses the Bell System standards for DTMF decoding. The chip has a 30-dB dynamic range that allows for wide audio-level variation. For the signal to be recognized by U5, it must have a 40-ms tone duration and a 40-ms pause between tones. The audio input is noise filtered before it is sent to the decoder. U5 then looks for an audio-signal input that has a valid DTMF signal. When a valid DTMF signal is received, the chip raises the valid bit and the data lines contain the proper signals corresponding to one of the 16 DTMF tones it can decode.

Voice Chip

An ISD33000 ChipCorder, U12, provides the voice for the RCA. This record/audio playback IC can store up to two minutes of audio data and retain it in nonvolatile memory for 100 years. The '33000 has an on-chip 3.4-kHz band-pass filter that provides a natural voice playback. Audio data is stored in 128 different segments, one for each word. (The RCA has only about 80 words in its vocabulary.) To play the selected word or words, U1 sends a read command to U12.

The RCA's vocabulary is recorded into U12 using an ISD programmer. A professional announcer in a sound studio recorded the words. The recordings were then transferred to a CD-ROM used as the master for the ISD programmer.

U12 communicates with U1 via a three-wire bus called a *serial peripheral interface* (SPI) bus. This high-speed (1 Mb/s) serial bus is controlled by U1. U1 also controls other devices on the SPI bus: voter input, temperature multiplexer and external EEPROM, U2.

Voter Input

The repeater's voter sends up to eight discrete inputs to the RCA to indicate which channel or site the voter selected as the best. The RCA monitors the COR line to determine when the COR becomes inactive and sends the command to U12 to announce the site number. If no voter is connected (or you

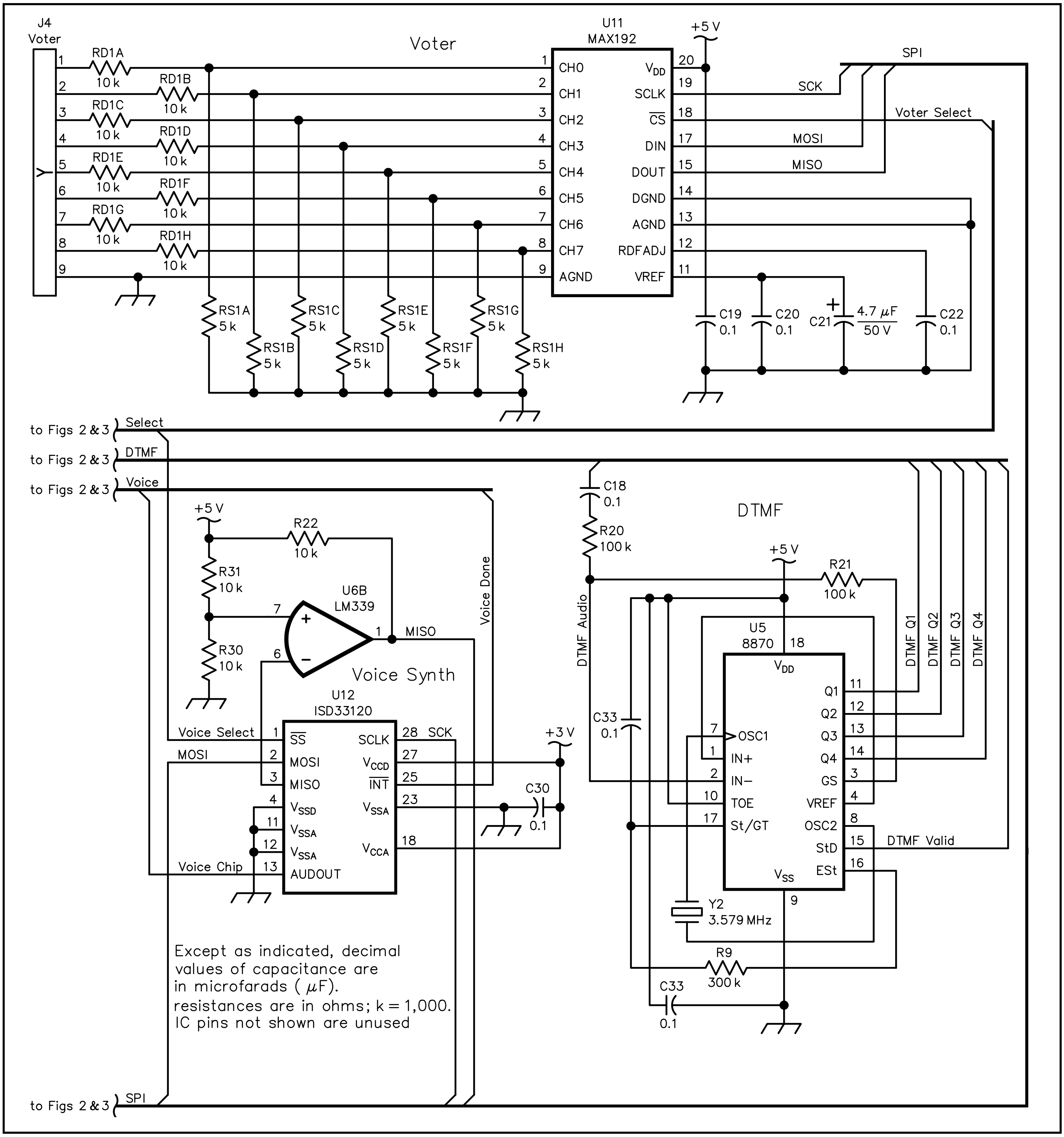

Figure 4—Voice synthesizer and DTMF receiver.

C21—4.7 μF, 50 V electrolytic
J4—2-row, 5-pin PC-mount header
RD1—10-kΩ DIP-16 resistor package
RS1—5-kΩ SIP-10 resistor package
U5—MT8870DE-1 DTMF receiver
U6—LM339 quad comparator (sections C and D unused).
U11—MAX192ACPP 8-channel, serial 10-bit ADC
U12—ISD33120 ChipCorder
Y2—3.579-MHz crystal, HC-33/U holder

find the announcement annoying) it can be deselected in the menu system.

User Interface

The user interface consists of an LCD (DS3, the main display), three pushbuttons (S1-S3), one toggle switch (S4) and two LEDs (DS1 and DS2). The LCD displays a series of menus. Each menu offers information about the setup and programming of the RCA.

There are two controller modes: setup and operate. During setup, you can scroll through the menu system to view or change the operating parameters. In operation, the RCA simply waits for a COR signal and DTMF tones, then performs the appropriate action.

Other Hardware

There are also a few miscellaneous hardware functions in the RCA. The COR input is buffered by U6, an LM339 compara-

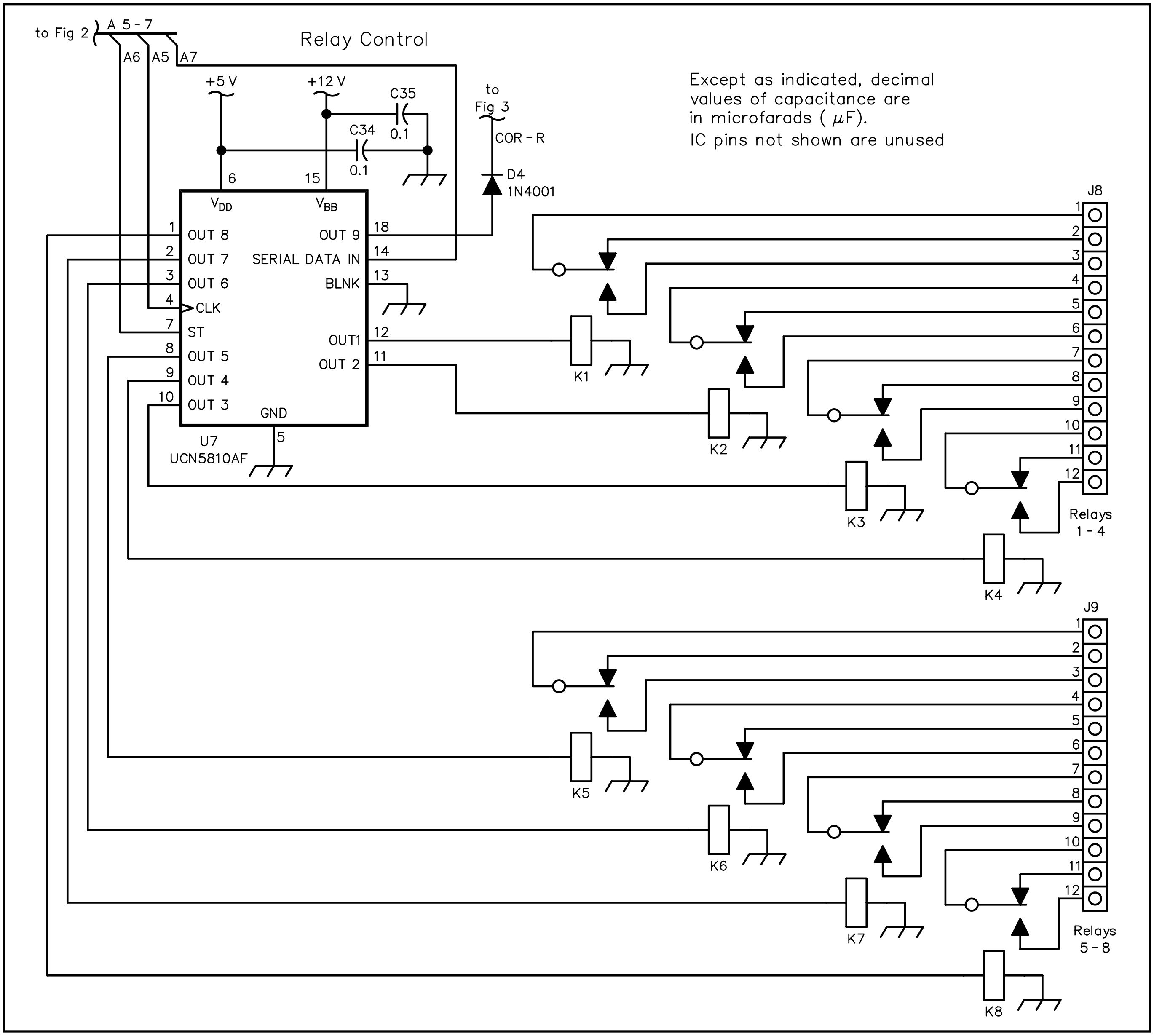

Figure 5—Relay control section

D4—1N4001 switching diode
J8, J9—12-position screw-type PC-mount terminal block

K1-K8—SPDT relay, 12-V, 30-mA coil, 10-A contacts (Aromat JS1-12V)

U7—UCN5810AF 10-bit serial-input latched-source drivers with active pull-downs

tor. Its variable COR level output can be set to match any COR input level between 1 and 11 V. The COR input is **OR**ed with U1's COR so that either can drive the COR output. This provides fast COR switching (about a 5-ms delay).

A pair of TL084 op-amp sections (U8A and U8B) buffer the audio input and output. They isolate the RCA from external devices and ensure the audio level is in the proper range for the DTMF decoder. These IC sections operate in their linear region by floating a voltage divider between the 12-V input and ground.

Processor

U1, an MC68HC11E9FN microcontroller, contains 12 kB of one-time programmable EPROM (for assembly language program space), 256 bytes of RAM for data storage, 512 bytes of EEPROM, an 8-bit output port, an 8-bit input port, an 8-channel, 8-bit ADC input port, an 8-bit timer port and a 6-bit communications port.

U1's eight ADC-input ports read the analog data; its 8-bit input port reads the DTMF and user interface and its 8-bit output port drives the main display, LCD module DS3. The wind sensor is read by U1's timer port; SPI-bus control is handled by U1's communication port. (Part of the communication port can be used for RS-232 communication, but that is not implemented here.)

U1 also uses external memory provided by U2, a 25LC640 serial EEPROM. This IC holds 8 kB of look-up tables used by U1 to convert the analog-input data to calibrated information used by the voice chip, U12. U1 also stores the user preferences.

U3, an on-board 7805 regulator equipped with a heat sink, delivers 5 V dc to the ICs. With no relays energized, the total current consumption is about 200 mA. Each relay draws an additional 30 mA, so depending on how many relays are used, the total current drawn can be as high as 500 mA.

Software

The RCA's program is written in 68HC11 assembly language.[5] The main routine monitors the COR and DTMF valid

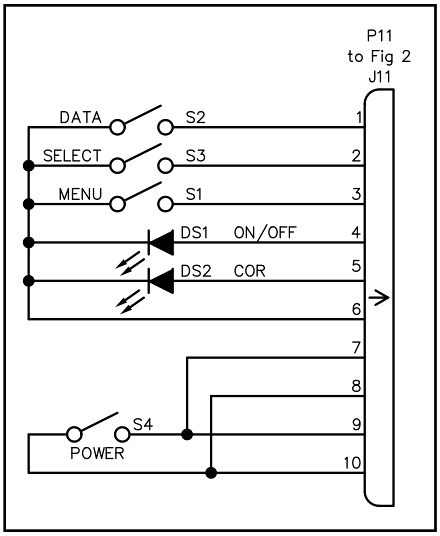

Figure 6—Front-panel switch and LED interconnect
DS1, DS2—LED
P11—2-row, 5-position header (mates with J11, Figure 2).
S1-S3—Normally open pushbutton
S4—SPST toggle

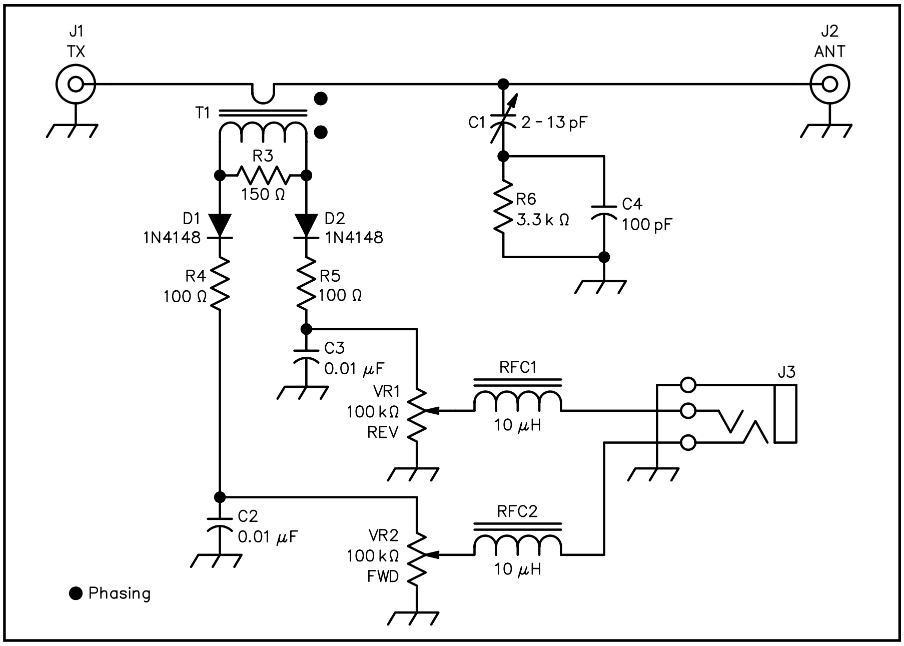

Figure 7—Schematic of the HF SWR sensor. Unless otherwise specified, resistors are 1/4-W, 5%-tolerance carbon-composition or film units. Equivalent parts can be substituted.

C1—2 to 13-pF air-variable trimmer
D1, D2—1N4148 silicon switching diode
J1, J2—SO-239 coax connector
J3—3-circuit 1/8-inch phone jack
RFC1, RFC2—10-µH RF choke
T1—14 bifilar turns #28 enameled wire on an FT-37-43 core.
VR1, VR2—100-kΩ PC-mount pot

lines to begin processing the DTMF tones. Once a valid tone is received, the software builds a string of DTMF tones. When the last tone is received— denoted by a two-second or longer pause—the string is compared to the command list. If a string matches a command, it is executed. If there is no command match, the software returns to monitoring tones.

When a command is executed, the related action takes place immediately. For example, if the command to read forward power is received, the forward power from the ADC input port is read. U1 then uses the look-up table in U2, the serial EEPROM, to convert the reading to watts. The watt number is formatted to a data string and sent via the SPI bus to be spoken by U12. When U12's message ends, the software returns to monitoring DTMF tones.

Menus

Eight menus control all of the RCA functions (see Table 1). You can scroll through the menus by pressing the **Menu** pushbutton. Under normal operating conditions, the **Status** menu is displayed. It shows when the COR is active and when valid DTMF tones are being received.

The second (**Command**) menu programs the codes for the commands. Pressing the **Select** button scrolls through the list of available commands. Pressing the **Data** button scrolls the cursor from one initial character to the next in the command-code sequence. Valid characters include: 0-9, A, B, C, D, *, and #. Pressing the **Select** button again cycles to the next command character. Pressing the **Menu** button enters the code in the display as the new command code. You can then use the **Select** button to scroll through the commands once more.

Table 1
Menu System

Menu	*Select*	*Data*
Status	-	-
Program	Command	Xxx
Program Call	Position	Xxxxxx
Band	10, 6, 2, 220, 440	-
COR Logic	hi, lo	-
Power Scale	1, 1/2, 1/4	-
Temp Report	F, C	-
Voter Report	ON, OFF	-
Signal Report	ON, OFF	-
Call	ON, OFF	-

The **Call Sign** menu works like the command-code menu. Valid characters include all letters and numbers and a blank. There are six character locations. The call sign can use any of the six as long as they are in sequence. Blanks do not equate to pauses.

The **Band** menu allows selection of 10, 6 and 2 meters and 440 MHz. This choice selects the proper look-up table to use for the forward and reverse SWR readings.

The **COR Logic** menu chooses between active-high and active-low COR logic. The input and output lines to the processor are matched to the COR logic.

Some repeater owners may not want to announce the repeater's transmitter power. The **Power Scale** menu keeps people other than the repeater owner from knowing the actual transmitted power. The scale can be selected to read back at full, half or one quarter of the real power. With the scaling, the repeater owner can easily convert the announced power reading to the real power reading.

The last two menus simply toggle the voter report and the call-sign status on or off. The call sign can be used if the RCA is connected to a radio that does not have a controller. This allows remotely monitoring weather conditions and reporting of other transmitters, such as remote packet radios. When activated, the call sign is voiced after the data is reported by the RCA.

Construction

Assembly is straightforward. Because there are so many ICs, it is best to use a ready-made PC board.[6] Use sockets for all ICs, as many repeater environments are prone to lightning strikes. When installing the ICs (especially U1), follow ESD safe-handling procedures and use a wrist strap to avoid damaging components. Once U1 is in its socket, it is well protected.

Place the RF sensor in a shielded enclosure to reduce the influence of RF fields. Ribbon cable connects the main board to the LCD and front-panel switches. Use a heat sink on U3, the 7805 regulator.

Adjustments

Because some repeater controllers do

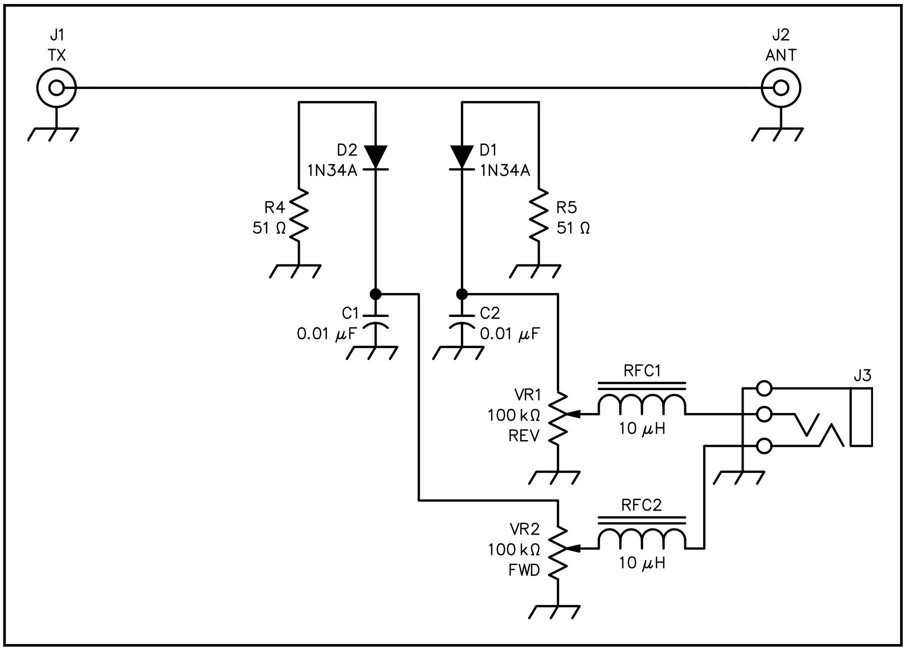

Figure 8—Schematic of the VHF/UHF SWR sensor. Unless otherwise specified, resistors are 1/4-W, 5%-tolerance carbon-composition or film units. Equivalent parts can be substituted. This sensor uses a stripline in lieu of the HF sensor's toroidal pickup.

D1, D2—1N34A germanium diode
J1, J2—SO-239 coax connector
J3—3-circuit, 1/8-inch phone jack
RFC1, RFC2—10-µH RF choke
VR1, VR2—100-kΩ PC-mount pot

not pass DTMF tones, it's probably best to install the RCA between the repeater's receiver and controller. The RCA's frequency response is 30 to 20,000 kHz, with a total distortion of less than 1%, so its presence does not affect the audio signals required by the repeater.

Few adjustments are needed. Start by adjusting VR1 so that your COR signal is read by U1. If you know your system's COR levels, you can monitor test point 1 (TP1) to set the COR level between the high- and low-voltage limits of your system. The COR LED (DS2) will light if the COR is being received.

VR3 adjusts the audio level fed to the DTMF decoder chip. While receiving a DTMF tone, watch the COR LED (DS2) to see if a tone is being received properly; it lights when the **DTMF Valid** signal is active. VR5 adjusts the voice level sent to the audio output. VR4 adjusts the overall audio-output level. Monitor your transmitter and another controller to ensure the voice is at an acceptable level. VR2 is the LCD's **CONTRAST** control.

The RF sensors have calibration adjustments. For the 10- and 6-meter sensor, first set VR1 and VR2 on the sensor PC board to midposition. Then, to calibrate the SWR-sensor reverse reading, connect the *transmitter* to the **ANTENNA** port and a *dummy antenna* to the **TRANSMITTER** port on the RF sensor. While transmitting at a level of 10 W, adjust C1 for a minimum voltage on the reverse line. A reading of 0.1 V or less is fine.

For all sensors: With the connections to the **ANTENNA** and **TRANSMITTER** ports still reversed, transmit a 10-W carrier and adjust the **REV** pot (on the RF board) for 1.2 V. Then, connect the transmitter and dummy antenna to their *proper ports*. Transmit a 10-W carrier and adjust the **FWD** pot on the RF board for a reading of 1.2 V. Once calibrated, the sensors offer an accuracy of 5% and a power resolution of 1 W over each band.

To adjust the signal-to-noise converter, transmit a 1-kHz tone with a 2.5-kHz deviation to your receiver. If you don't have a tone generator, a DTMF signal from your H-T will do. Adjust the **INPUT-BUFFER** pot (VR6) to read 0.5 V ac at the audio test point. Next, with the squelch open and no RF signal on the receiver, adjust the **NOISE-BUFFER** pot (VR7) to read 4.0 V dc at the noise test point.

The temperature and voltage sensors require no adjustment, neither does the wind sensor—it's calibrated at the factory.

Operation

After connecting the RCA to your repeater or remote base, you might want to program each code you intend to use rather than using the default values. Be sure that the codes you program don't conflict with codes used by your system controller. All codes are limited to three digits. The letters A, B, C and D, the pound key (#) and asterisk (*) may be used. This programming must be done from the front panel of the RCA, *not* over the air.

To operate the RCA, simply key your radio and use its DTMF pad to send the three-digit sequence corresponding to the function desired. (All remote-control operation must take place above 222.15 MHz.)The RCA will keep the repeater keyed; speak the words corresponding to that function, then unkey the repeater.

By being able to remotely monitor many sites, the RCA is certain to save repeater maintainers countless hours of valuable troubleshooting time. I've installed an RCA at each of our repeater's main sites and each remote site. I'm thankful for them every time I get a late-night phone call from someone with a repeater trouble report!

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Notes

[1]Dwayne Kincaid, WD8OYG, "A Microprocessor-Controlled Repeater Voting System: the RVS-8," *QST*, Apr 1996, pp 38-43.

[2]Mark Kolber, WB2WHC "An Audio-Noise-Based Voting Circuit," *QST*, Oct 1992, pp 24-26.

[3]Peet Bros Company, 1308 Doris Ave, Ocean, NJ 07712; tel 732-531-4615; **http://www.peetbros.com**; wind sensor: $89.

[4]John Grebenkemper, KI6WX, "The Tandem Match—An Accurate Directional Wattmeter," *QST*, Jan 1987, pp 18-26. See also John Grebenkemper, KI6WX, "An Updated Tandem Match," Technical Correspondence, *QST*, Jul 1993, p 50.

[5]The software for all three programmable ICs, including the source code, is available for download from the ARRL Web site: **http://www.arrl.org/files/qst-binaries/**.

[6]A complete kit of parts including all PC boards and all *preprogrammed* ICs is available for $199, plus $10 shipping from LDG Electronics, 1445 Parran Rd, St Leonard, MD 20685; tel 410-586-2177; **http://www.ldgelectronics.com**. Please specify which band (10, 6, 2, or 440 MHz). Matching enclosures (rack unit and RF sensor) are available for $85, plus $12 shipping. All major credit cards accepted. Maryland residents must add 5% sales tax.

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