Ham Tips

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An In-Cabinet Repeater Controller for the MSR 2000 Station

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The MSR 2000 is a line of FM repeater/base stations offered from the early 1980s through the early 1990s by Motorola Communications. The one I acquired is a model C74KSB-3106BT. This unit has an ac power supply, receiver, 100-watt transmitter, 4-cavity duplexer, and several plug-in control modules all contained in a compact cabinet measuring 39 inches high by 22 inches wide by 10 inches deep and weighing about 125 pounds.

I wanted to convert this commercial repeater to one more suitable for amateur radio use. Since there was no rack space available inside the cabinet to mount a new controller, and I didn't want to use an externally mounted controller tethered by an umbilical cord, I needed to find a controller that would simply plug into the RF-Control Chassis. A thorough search of the internet did not turn up a project that met these requirements, so I decided to tackle the job myself. The main goals and objectives were:

- The conversion process should have minimal impact on the MSR 2000 station so that other factory plug-in modules could be used, if desired.
- The conversion should be a clean one, i.e., no cut traces on the backplane or in any of the modules; and no direct wiring between the modules and the controller.
- Indicators should show the status of the COR and PTT lines as well as the DTMF decoder, but there should be a way to disable them during periods of normal operation to minimize current drain.

Figure 1 — The YAP 2000 Repeater Controller module is designed to replace the factory Squelch Gate module in an MSR 2000 RF-Control Chassis.

- It should be possible to prevent the transmitter from being keyed, force the transmitter to be keyed, prevent receive audio from reaching the transmitter, and be able to monitor receive or transmit audio on a local speaker.

Although I have designed and built repeater controllers since the 1970s, this time I really didn't want to start from scratch. After researching the options available to me, I chose the kit version of the NHRC-4 Repeater Controller (www.nhrc.net) and here's why.

The NHRC-4 had all the features I needed and the size of the printed circuit board was a good fit for the MSR 2000 module form factor. The board draws less than 25 milliamperes of current and can be powered from the MSR 2000 power supply without the risk of overloading the regulator circuit. It has LEDs to indicate the status of COR and PTT lines and their position on the board was easy to incorporate into the front panel design. The overall design approach and layout of the printed circuit board is well thought out and all of the component locations are silk-screened on the board. The NHRC-4 is easy to assemble, easy to program, and easy to use. Starting with the NHRC-4 bare printed circuit board saved me a great deal of time and effort.

In a nutshell then, the overall concept was to piggyback an NHRC-4 repeater controller board onto a squelch gate board and mount both boards behind a double-wide front panel. The new module, designated the YAP 2000 Repeater Controller, would plug into the slot of the MSR 2000 RF-Control Chassis formerly occupied by the stock Squelch Gate module. YAP, by the way, stands for Yet Another Project. The remainder of this Ham Tip describes how I built this plug-in repeater controller for the MSR 2000.

Making the Front Panel

I made the new front panel from an MSR 2000 Line Driver module. While there are many variants of the MSR 2000 Line Driver module, they fall into two distinct groups: 1-line versions and 2-line versions. The 2-line version is preferred simply because it has two grommeted holes that align perfectly with the Squelch Key and Repeat Level controls on the squelch gate board. A 1-line version can be used if an additional 3/8-inch hole is drilled to provide access to the RPT LVL potentiometer. See Figure 2.

I added four toggle switches to the front panel that come in handy during setup and testing. The Transmitter Key switch is a locking style, center-off, miniature toggle switch. A deliberate pull-to-move action is required to select a position thereby eliminating accidental changes if bumped. When placed in the left-most position, the repeater controller can key the transmitter in response to a valid input signal. In the center position, the repeater controller is prevented from keying the transmitter. When placed in the right-most position, the transmitter is keyed manually. This position is convenient because it leaves both hands free for making adjustments or measurements.

The Transmitter Audio switch is a center-off, miniature toggle switch used to select a destination for the repeater controller’s audio output signal. When in the left-most position, audio is applied to the exciter. In the center position, repeater controller audio is disconnected. When placed in the right-most position, the repeater controller’s audio may be applied to the local speaker depending on the position of the Speaker switch.

The Speaker switch is a 2-position miniature toggle switch used to select an audio source for the local speaker. When in the left-most position, audio from the repeater controller will be heard if the Transmitter Audio switch is in the SP position; and, when in the right-most position, audio from the receiver will be heard if the Transmitter Audio switch is in the RPT position.

Figure 2 — The new front panel was made from a Line Driver module because it is twice as wide as the Squelch Gate module’s front panel and can accommodate both the squelch gate board and the repeater controller board.

The LEDS switch is a 2-position miniature toggle switch used to select whether power is applied to the front panel indicators. Operation of the LED indicators is self-explanatory and is described in the NHRC manual. Very briefly though, the DTMF Decode LED turns on when the repeater controller has decoded a DTMF symbol; the MAIN COR LED turns on when the repeater controller's carrier operated relay line goes active low in response to a valid input signal; and the MAIN PTT LED turns on when the transmitter is being keyed by the repeater controller's push-to-talk line going active low. Note that this LED will not turn on when the transmitter is keyed with the TX KEY switch or the local microphone because those PTT signals are applied after the repeater controller board.

During normal repeater operation, all of the switches on the YAP 2000 Repeater Controller module should be in their left-most position. This is consistent with operation of the slide switches on the Station Control module.

Modifying the Squelch Gate Board

Modification of the squelch gate board consisted of removing jumpers JU11 and JU12 and lifting the end of R74 connected to JU11. After removing the jumpers, I cleaned out the solder from the vacated pads so wires from the repeater controller board could be soldered to them later.

The squelch gate board has fifteen jumpers that need to be set correctly. Most of them are either staple type wire jumpers or zero ohm resistors; however, jumpers 13, 14, and 15 are different. Each one of these consists of a short length of hookup wire terminated with a female socket. These three jumpers allow the user to choose field-selectable options. Unless, you have a specific reason not to do so, I suggest you set all of the jumpers as shown in Table 1.

Table 1
Jumpers on the Squelch Gate Board

Jumper	Status	Description or Function
JU1	OUT	Local control priority
JU2	OUT	Delayed keyed A+ to Q10
JU3	IN	Repeater PL indication
JU4	IN	PL indicator
JU5	IN	Keyed A+ for the F1 channel element switch
JU6	IN	F1 oscillator ground to enable exciter
JU7	IN	Line or remote push-to-talk
JU8	IN	Push-to-talk signal to option relay
JU9	IN	A+ to option relay
JU10	IN	R1 unsquelch indication for the audio gate driver
JU11	Remove	Audio to local speaker (see text)
JU12	Remove	Transmitter push-to-talk (see text)
JU13	User	Transmit turn off delay (tail timer); set to 0 seconds
JU14	User	PL indicator; put it on the PL pin if using PL; otherwise, put it on the CS pin
JU15	User	OR gate; put it on the PL pin if using PL; otherwise, put it on the CS pin

Modifying the NHRC-4 Repeater Controller Board

When building the NHRC-4 repeater controller board, I customized it for this application by substituting a few parts and making minor changes to the audio mute gate circuit and the CAS/COR isolation circuit.

Instead of using the recommended plug and socket at J1, I used a right angle solder-tail connector with color coded lead wires. The wire colors had a one-to-one correspondence with the pin numbers, i.e. brown wire for pin 1, red wire for pin 2, and so on.

For interstage coupling applications I prefer to use electrolytic rather than tantalum capacitors. Tantalum capacitors have a lower equivalent series resistance than electrolytics and work really well in dc bypass applications, but I learned a long time ago that they aren't suitable for audio coupling applications.

When a positive voltage is applied to both leads of a tantalum capacitor it often becomes noisy and randomly distorts the audio waveform. Therefore, instead of using tantalum capacitors for interstage coupling, I used 1 microfarad 25 volt radial lead electrolytic capacitors. The lead spacing was the same as the tantalums, so they were drop in replacements.

Instead of using the specified T1-3/4 LEDs, I used T1 size LEDs in right-angle packages. The ones I used had two LEDs mounted one above the other and I removed the lower LED from each package before installation. I positioned the repeater controller board behind the front panel in such a way that the LINK COR LED aligned with the hole previously occupied by the screw that secured the Line Driver module's support bracket to the front panel.

The optional audio delay modules weren't needed for this application, so I installed U-shaped wire jumpers between pads 2 and 3 of J4 and J5. These jumpers not only complete the audio paths, they also provide convenient test points for connecting an oscilloscope or ac voltmeter.

Modifying the Audio Gate Circuit

Refer to the main receiver audio mute circuit on the NHRC-4 audio schematic diagram. Transistor Q4 is an audio gate that is controlled by the mute signal from the PIC. Since circuitry on the squelch gate board already provides audio muting, it was not necessary to do it again here. So, instead of installing resistors R15 and R39 and transistors Q4 and Q12, I installed a jumper wire from the source pad to the drain pad of Q4 to bypass this function.

Modifying the CAS/COR Circuit

Refer to the main CAS/COR isolation circuit on the NHRC-4 digital schematic diagram. Transistors Q3 and Q5 perform the "AND" squelch function. Circuitry on the squelch gate board already does this however, so it is not necessary to duplicate that function here. In addition, the repeater control board was designed for use with an active high CAS signal, but the squelch gate board provides an active low COR signal.

I addressed both of these issues by not installing resistors R1 and R3 nor transistors Q3 and Q5. Instead, I installed a jumper wire from the J1-2-side pad of R1 to the collector pad of Q5. Now, the active low COR signal from the squelch gate board activates the repeater controller's COR circuit directly.

Connecting the Boards

Refer to Figure 3 for the complete wiring diagram. Table 2 shows a comparison of the signals on the squelch gate board's backplane connector before and after the modification with the most significant signals appearing in boldface type. Figure 4 is a view of the YAP 2000 Repeater Controller module opened up to show how it was wired.

Wiring the Power Supply Circuit

I soldered a brown wire from J1 pin 1 on the repeater controller board to backplane pin 12 on the squelch gate board. This is the +12 volt dc supply line. Then I soldered a black wire from J1 pin 7 on the repeater controller board to backplane pin 1 on the squelch gate board. This is the ground line.

Wiring the COR Circuit

I soldered a red wire from J1 pin 2 on the repeater controller board to the Q17-side pad of jumper JU12 on the squelch gate board. This is the COR line. It lets the dc control signal from the squelch gate board be applied to the repeater controller board.

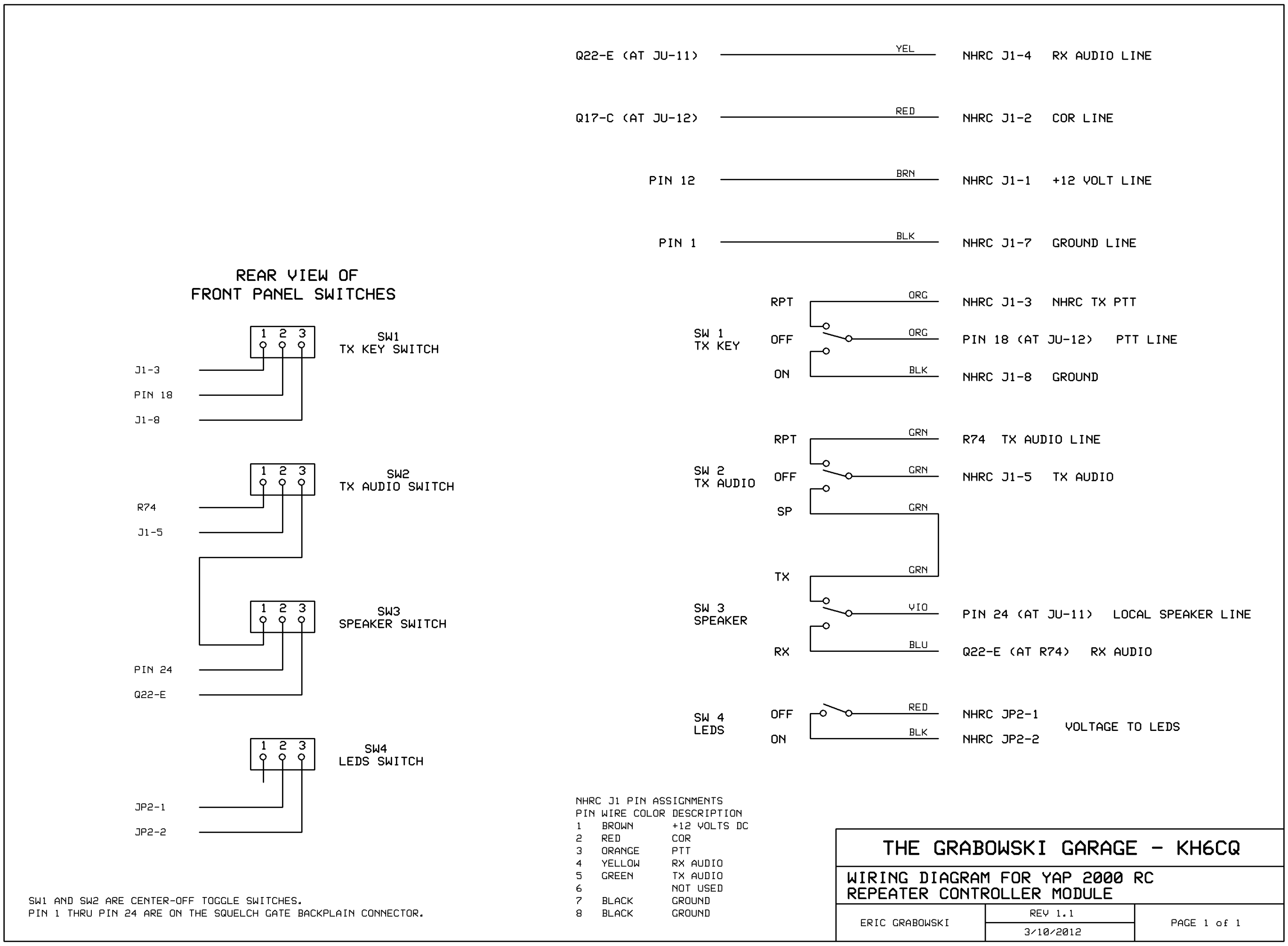

Figure 3 — Wiring diagram for the YAP 2000 Repeater Controller module.

Wiring the PTT Circuit

I soldered an orange wire from J1 pin 3 on the repeater controller board to one side of the TX KEY switch. Next, I soldered a black wire from J1 pin 8 on the repeater controller board to the other side of the TX KEY switch. Then, I soldered a wire from the backplane pin 18-side pad of jumper JU12 on the squelch gate board to the pole of the TX KEY switch. This is the PTT line. It lets the dc control signal from the repeater controller board key the transmitter via the Station Control module.

Wiring the Audio Input Circuit

I soldered a yellow wire from J1 pin 4 on the repeater controller board to the pad previously occupied by a lead of R74. This is the receive audio line. It lets the gated low-level audio signal from the squelch gate board be applied to the repeater controller board.

Wiring the Audio Output Circuit

I soldered a green wire from J1 pin 5 on the repeater controller board to the pole of the TX AUDIO switch. Then, I soldered a wire from the free end of resistor R74 on the squelch gate board to one side of the TX AUDIO switch. I used heat shrink tubing to insulate the connection at R74. This is the transmit audio line. It lets the low-level audio signal from the repeater controller board be applied to the MSR 2000 exciter.

Wiring the Local Speaker Circuit

I soldered a wire from the other side of the TX AUDIO switch to one side of the SPEAKER switch. Next, I soldered a wire from the other side of the SPEAKER switch to the R74-side pad of jumper JU11 on the squelch gate board. Then, I soldered a wire from the backplane pin 24-side pad of jumper JU11 on the squelch gate board to the pole of the SPEAKER switch. This is the local speaker line. It lets the low-level audio signal from either the receiver or repeater controller be applied to the local speaker via an amplifier in the R1 Audio and Squelch module.

Wiring the LEDS Switch

I soldered red and black wires from the LEDS switch to the pads of JP2 on the repeater controller board instead of using the recommended 2-pin header and removable jumper at that location. The wires need to be long enough so the repeater controller board could be opened up as shown in Figure 4.

Table 2
YAP 2000 Repeater Controller Pin Assignments

PIN	YAP 2000 RC SIGNAL	ORIGINAL SIGNAL
1	Power Ground (input)	Power Ground (input)
2	TX Oscillator Ground (input)	TX Oscillator Ground (input)
3	F1 Oscillator Ground (output)	F1 Oscillator Ground (output)
4	RPTR PL Indication (input)	RPTR PL Indication (input)
5	R1 Unsquelch Indication (input)	R1 Unsquelch Indication (input)
6	Keyed A+ (input)	Keyed A+ (input)
7	Delayed Keyed A+ (input)	Delayed Keyed A+ (input)
8	Single Tone Reset (output)	Single Tone Reset (output)
9	Quieting Indicator (output)	Quieting Indicator (output)
10	**R1 Disc Audio** (input)	**R1 Disc** (input)
11	**MN TX Audio** (output)	**RPT Audio to Exciter** (output)
12	A+ (input)	A+ (input)
13	Local PTT (input)	Local PTT (input)
14	**PL Decode** (input)	**PL Indicator** (input)
15	Remote RPTR PTT (output)	Remote RPTR PTT (output)
16	Line/Remote PTT (input)	Line/Remote PTT (input)
17	**MN RX Audio** (input)	**Unnotched R1 Audio** (input)
18	**RPTR PTT** (output)	**RPTR PTT** (output)
19	Squelch Gate Inhibit (input)	Squelch Gate Inhibit (input)
20	RPTR A+ (output)	RPTR A+ (output)
21	RPTR Turn Off (input)	RPTR Turn Off (input)
22	Time-Out Timer Reset (output)	Time-Out Timer Reset (output)
23	Audio Ground (input)	Line Driver Ground (input)
24	**Audio to Speaker** (output)	**RPTR Audio to Speaker** (output)

Setting the Levels

Squelch crashes can be virtually eliminated by setting up the system so that a slightly higher input signal is required to gate the audio than key the transmitter. And, when this is done, the audio signal applied to the repeater controller will remain muted when an input signal is strong enough to break the squelch but still extremely noisy. This provides an additional benefit by reducing the possibility of DTMF decoder falsing.

I installed a factory MSR 2000 Squelch Gate module and set the Repeat Level and Squelch Key controls according to the procedure in the MSR 2000 instruction manual. Then I used an oscilloscope to measure the audio signal present on the Mic Hi line and recorded that value. It was 680 millivolts peak-to-peak.

Next, I removed the Squelch Gate module and installed the YAP 2000 Repeater Controller module on the Squelch Gate module's backplane pins as shown in Figure 5. Then, I adjusted the levels on the squelch gate board and repeater controller board until they matched those of the factory Squelch Gate module.

Now, as a bonus, if it ever becomes necessary to remove the YAP 2000 Repeater Controller for any reason, I can keep the repeater on the air by simply re-installing the factory Squelch Gate module — no additional tweaking required.

Here's how I went about setting the levels.

Setting the Receiver-to-Controller Input Level

This level must be set correctly otherwise the DTMF decoder will not properly decode DTMF symbols. I preset the RPT LVL potentiometer to 75 percent clockwise (this control may not require further adjustment) and disabled the transmitter by placing the TX KEY switch in the Off position. Then I sent DTMF 5 tones from a low power HT and adjusted the MN RX IN potentiometer (VR4) until the DTMF decoder worked properly. If the signal is too weak, increase the gain by advancing the RPT LVL control a little and try again. Likewise, if the signal is too strong, decrease the RPT LVL control a little and try again. Once the DTMF decoder is working properly, do not readjust the RPT LVL or the MN RX IN controls.

Setting the Controller-to-Exciter Output Level

I preset the MN RX LVL potentiometer (VR3) to midrange. It may not be necessary to adjust this control any further. Then I injected a test signal (a 1000 microvolt, on-channel rf signal frequency modulated with a 1-kHz sine wave audio signal that had been adjusted to produce a deviation of 3 kHz) at the input of the receiver and, with the transmitter still disabled, adjusted the MN TX LVL potentiometer (VR5) so that the audio signal on the Mic Hi line was the same level as it was for the factory Squelch Gate module (680 mVp-p). Note that the MN TX LVL control works backwards from what you might expect. If this signal is too weak or too strong, adjust the MN RX LVL control one way or the other as necessary and try again. Once the level is set correctly, do not readjust the MN RX LVL or MN TX LVL controls.

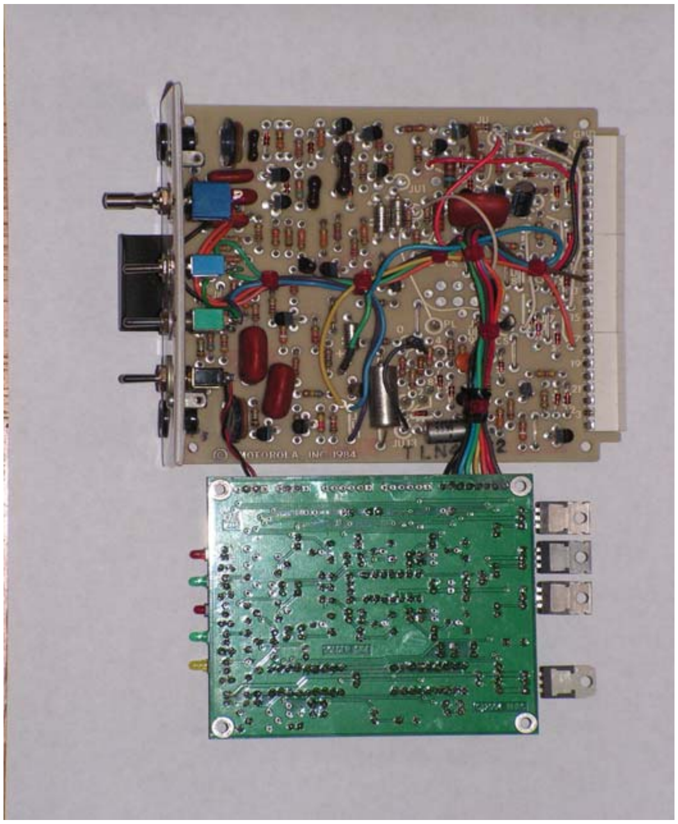

Figure 4 — The YAP 2000 Repeater Controller module "opened up" so you can see how the squelch gate and repeater controller boards are wired to each other and to the front panel switches. A few Ty-wraps keep the wires neatly bundled.

Setting the Squelch Key Threshold

I preset the SQL KEY potentiometer fully clockwise. Then, with the signal generator adjusted to provide a 0.5 microvolt signal, I turned the SQL KEY control counterclockwise until the MN PTT LED turned on. This is the threshold that an on-channel signal must exceed in order to key the transmitter.

Setting the Audio Squelch Gate Threshold

I preset the SQ potentiometer on the R1 Audio and Squelch module fully clockwise and increased the output of the signal generator to 0.7 microvolts. In order to hear transmit audio on the local speaker, I placed the TX AUDIO switch in the SP (speaker) position and the SPEAKER switch in the TX position.

Then, I turned the SQ potentiometer counterclockwise until I heard the test tone on the local speaker. This is the threshold that a valid input signal must exceed in order to open the audio gate so receiver audio can be passed to the repeater controller board. After making these adjustments, I disconnected the signal generator from the receiver.

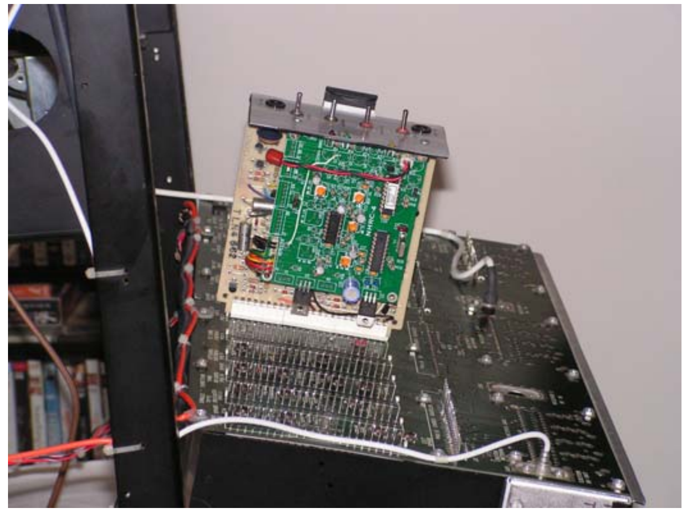

Figure 5 — An early version of the YAP 2000 Repeater Controller module plugged onto the rear of the backplane in the Squelch Gate module position. If you do this, there are two caveats you need to be aware of: First, you can only insert a module onto its own designated backplane connector; and second, you have to pay attention that you don't insert the module up-side-down, i.e., pin 1 to pin 24.

Setting the Beep Level

To insure a comfortable listening level for the CW ID message and the courtesy tones, I set the beep level much lower than the voice level so they would not sound too loud.

I adjusted the BEEP LVL potentiometer (VR6) so that the audio level of the CW ID message was 10% (68 mVp-p) of the test tone level.

Preparing for Normal Operation

After all the adjustments were made, I removed the YAP 2000 Repeater Controller from its test position, placed each front panel switch in its left-most position, and then inserted the module into the squelch gate slot of the fully-optionable RF-Control Chassis as shown in Figure 6.

Table 3 identifies the subassemblies used in this C74KSB-3106BT repeater cabinet and Table 4 identifies the jumpers needed for the fully-optionable backplane. The final steps involved programming the NHRC-4 repeater controller board as described in the NHRC instruction manual.

Table 3
Subassemblies in this MSR 2000 Station

Nomenclature	Name
TLN2475B	Fully Optional RF-Control Chassis
TLE5512A	Duplex Exciter Module
TRE6262A	Duplex Receiver Module
TRN5073A	Private-Line Encoder-Decoder Module
TRN9689A	R1 Audio and Squelch Module
TRN5324A	Squelch Gate Module (factory)
TRN5295A	Time-Out Timer Module
TRN5321A	Station Control Module
TLE 2283B	RF Power Amplifier
TRN1191A	AC Power Supply
TLE2363A	4-Cavity Duplexer

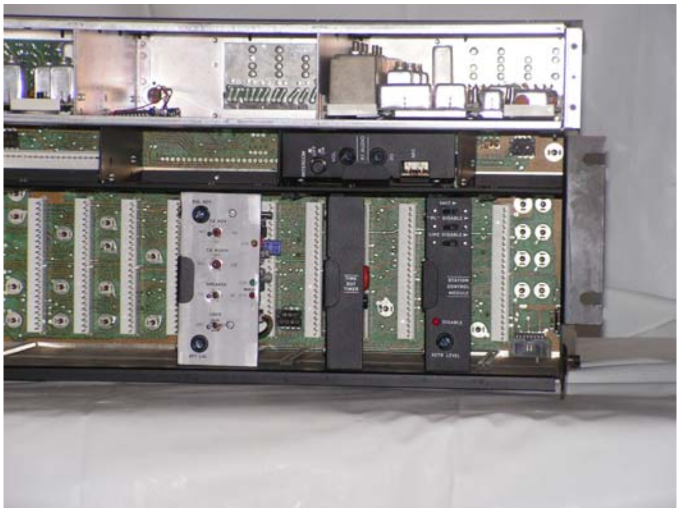

Figure 6 — An early version of the YAP 2000 Repeater Controller module plugged into the Squelch Gate module slot in the MSR 2000 station's fully optionable RF-Control Chassis.

Table 4
Jumpers Installed in the Fully-Optional Backplane

Jumper	Function
JU1	Permits audio from the local microphone to reach the exciter.
JU4	Permits the XMT switch on the Station Control module to key the transmitter for testing.
JU5	Permits the PL Disable switch on the Station Control module to disable PL Decode so the receiver can be used in carrier squelch mode for testing.

Summary

The MSR 2000 line of repeater and base stations came after the Micor line and before the MSF 5000 line. It was the last line of Motorola stations to use crystal controlled channel elements.

This Ham Tip described a way to build an in-cabinet repeater controller for the MSR 2000 station by piggy-backing an NHRC-4 repeater controller board onto a MSR 2000 squelch gate board and mounting both boards behind a double-wide front panel fashioned from a MSR 2000 Line Driver module. The indicators and switches on the front panel come in handy during initial setup and for routine maintenance.

Acknowledgements

Projects such as this one are built on the work of others who have gone before and shared their experiences with the rest of the amateur radio community. In particular, I would like to thank the following authors for their articles:

Richard D. Reese for his article "Micor Repeater Controller Interface" (http://wa8dbw.ifip.com/interface.html)

Skipp May for his article "A straight-forward modification to place an external controller into operation on a Motorola MSR 2000 (and Micor) repeater, connection via the squelch gate module" (www.radiowrench.com/sonic)

Mike Morris for his article "Information and Modifications for the MSR 2000 Station" (www.repeater-builder.com/msr2000/msr2000-index.html)

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