IC-9700 Amplifier/Preamp Sequencer
Version 1.5
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Introduction

This document describes a sequencer used to switch one or two linear amplifiers, antenna mounted receive preamplifiers and switch boxes that allow receiving on an SDR when the radio status changes from transmit to receive and vice-versa.

Version 1.0 of the device was specifically designed to work with the Yaesu FT-891. Version 1.5 is designed specifically for the Icom IC-9700 on any 2 of the 3 bands it can operate on. In my case, I'm only operating on 2 meters and 70 centimeters and thus you'll see that the panel labels on my unit reflect that.

In Version 1.4 I added the capability to key one or two amplifiers, but it only supported one preamp and one SDR switch box. Version 1.5 supports two of everything, but eliminates the transmit inhibit capability used in the unit for the Yaesu FT-891.

The overall idea is to detect that when the radio has been switched from receive mode to transmit mode and switch the preamplifiers and SDR switches to transmit (bypass) mode before keying one of the linear amplifiers. When the radio is switched from transmit to receive the process is reversed.

The Hardware

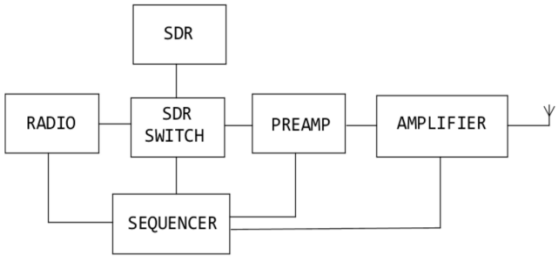
Some Assumptions

- The radio has a *PTT* line that goes to ground when the radio is put into transmit mode either manually or via CAT control.
- The preamplifiers are put in receive mode by powering them from a +12V source. Removing the +12V power switches them to transmit (bypass) mode (fail-safe operation).
- The SDR switch boxes are switched from receive mode to transmit mode by grounding a *PTT* input on the switcher. SW5 and SW6 on the schematic are optional switches to ground the *PTT* line of the SDR switchers to put one or both into permanent transmit (bypass) mode.
- The linear amplifiers are keyed by grounding their keying inputs. We use relay contacts for this so the amplifier's keying voltage can be pretty much anything. A SPDT switch (SW4 on the schematic) selects which of the two amplifiers is actually keyed. I used a center-off switch which allows amplifier to be keyed.

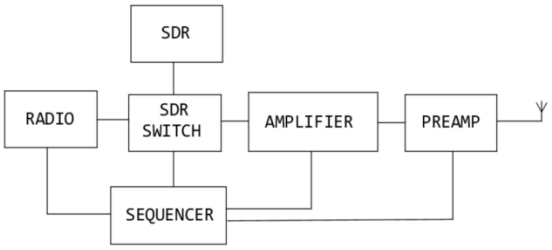
- This sequencer is designed primarily to be used when running the various digital modes. The preamps should be turned off when operating CW or SSB (I already toasted one expensive preamp).

Equipment Configurations

There are two possible configurations one might use when using an external preamplifier, linear amplifier and/or SDR switch:



Configuration 1



Configuration 2

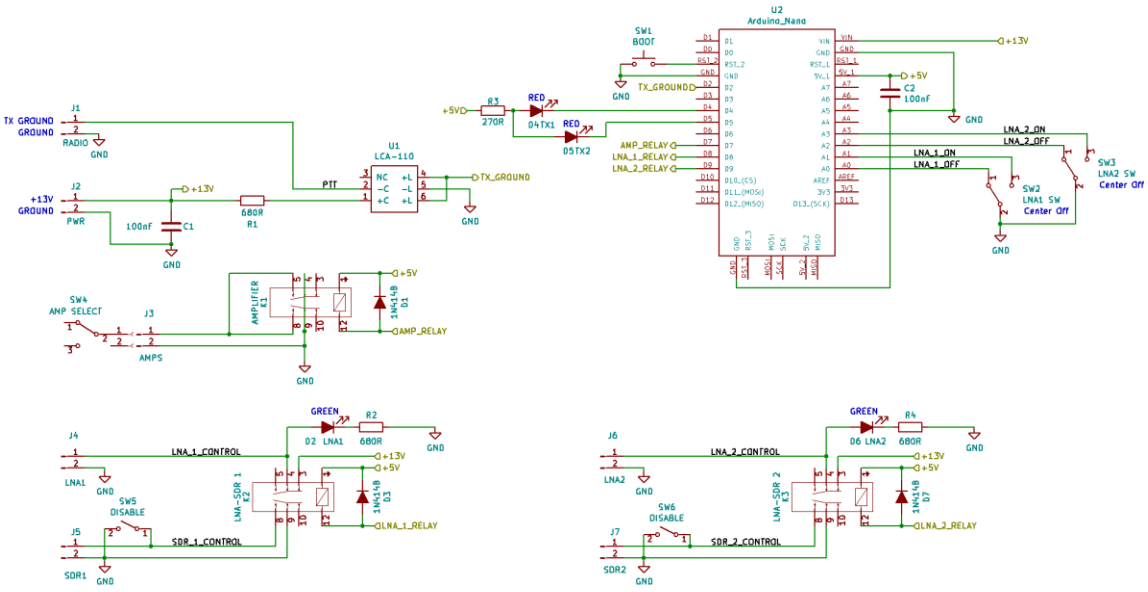
The primary difference is whether the preamp is ahead of or behind the amplifier. If you have preamplifiers that can handle the output power of the amplifier, it's better to put it between the antenna and the amplifier and as close to the antenna as possible.

Any of the major components (except the radio and antenna) are optional. If all you have is a radio and an antenna, you can stop reading because you have no need for this sequencer!

Which configuration you have and what specific equipment will determine how to set the various delay values in the software.

Theory of Operation

Here's the schematic:



Note that there is no provision on the PCB for switches SW5 and SW6. These two switches should be connected across the connectors for the SDR switchers.

When the various pieces of equipment are switched between receive and transmit mode is controlled by the software in the Arduino Nano processor. We'll get to setting the timing later.

The switching process begins when the radio's *PTT* line goes active. We assume this is indicated by the *PTT* input going to ground. That causes U1 (LCA-110 solid state relay) to also put a *LOW* indication on the *TX_GROUND* output which will be seen by the processor almost immediately (interrupt enabled pin).

As soon as the processor sees the *TX_GROUND* go *LOW*, it immediately operates relays K2 and K3 which switch both preamps and SDR switchers to transmit mode unless switch SW2 and/or SW3 is in the 'ON' position; more on this later.

After a delay of *LNA_ON_DLY* (currently 25) milliseconds, relay K1 is operated which switches the selected amplifier on.

When the *PTT* line goes *HIGH*, the process is reversed. The selected amplifier is turned off and after *AMP_OFF_DLY* (currently 50) milliseconds, the preamps and SDR switchers are returned to the receive mode.

Preamp Always On or Off Switch Considerations

These switches (SW2 and SW3) were added in a previous version of the software when I started using the IC-9700 for satellite work. When working the satellites, the radio is transmitting on the 70cm band and receiving on 2 meters (or vice-versa). Without the switch, when transmitting on 70cm and listening on 2 meters, the 2 meter preamp would switch off when I transmitted causing me to no longer be able to hear myself.

Putting the switch in the 'ON' position cured the problem.

The Version 1.5 software and hardware has two such switches; one for each band.

VERY IMPORTANT: Be very careful when switching back to normal operations to put the switch back to the normal operating position or to the 'OFF' position. I already fried one rather expensive preamp!

When the switch is in the 'ON' position the red transmit indicator LED for that band will flash rapidly as an alert when the radio's *PTT* is not active. When the *PTT* goes active, both red LEDs will be on continuously.

Also when the switch is in the 'ON' position, the SDR switch will be stuck in receive mode. You can put them into permanent transmit mode by powering them off or putting the (optional) SDR Disable switch (SW5 and SW6) into the 'DISABLE' position. Of course you won't be able to receive on the SDR in this mode.

The Printed Circuit Board

The hardware consists of a printed circuit board (PCB) containing an Arduino Nano (or clone) processor, three mechanical relays, a solid state relay (SSR), a few resistors, a couple of capacitors and four LEDs (which can be mounted externally).

The board can be powered from the radio if it can conveniently provide 12 to 13 volts and enough amperage; however one must be careful not to exceed any current limitations the radio might have. I powered earlier versions of the sequencer (with a single preamp and no SDR switcher) from the radio with no problems but now use a separate power supply (A wall-wart is fine).

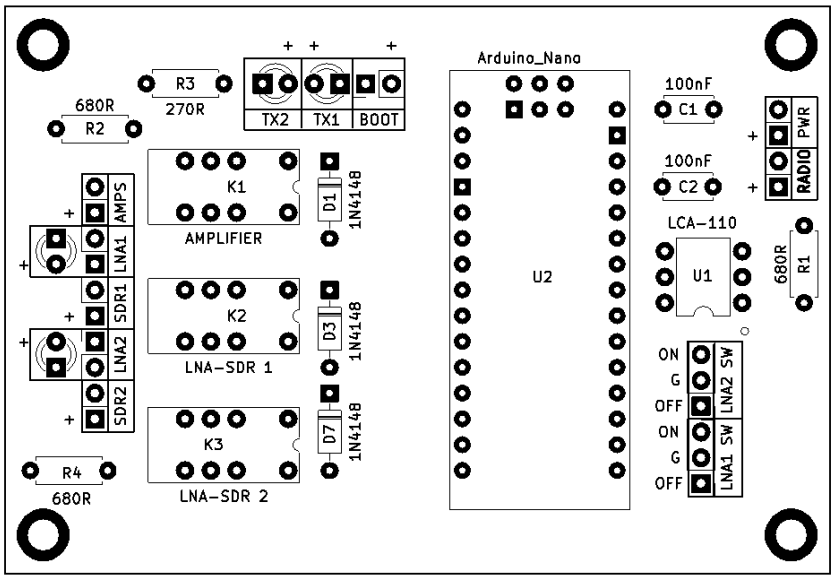
U1 is an LCA-110 solid state relay (SSR) which provides isolation between the radio's *PTT* line and the processor. It is required as the normal voltage on the *PTT* line is 12V and the Arduino pins can only handle 5V.

Relay K1 keys the amplifier(s). Relays K2 and K3 provide power to the preamps and ground the *PTT* inputs on the SDR switches in transmit mode.

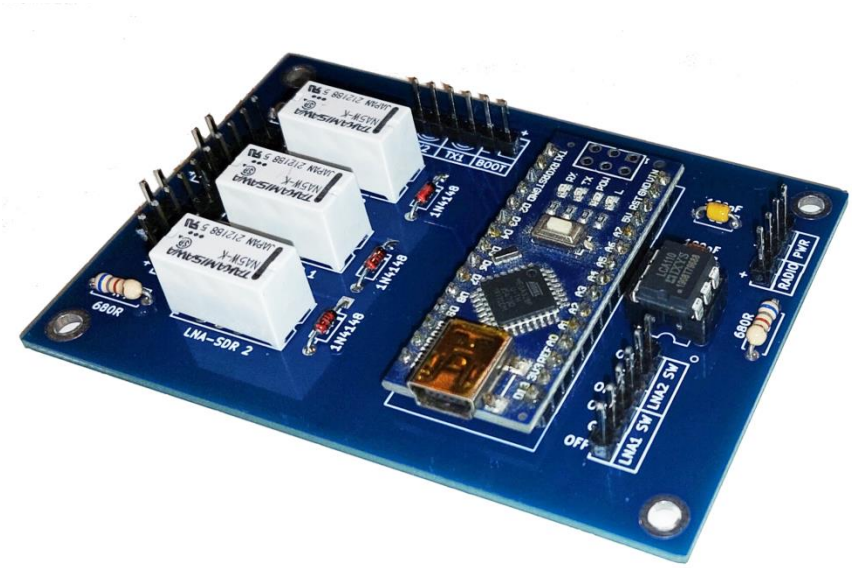
The LEDs indicate when the radio's *PTT* line is active (red), and when the preamp is in receive mode (green). The preamp LED is operated by the relay which supplies power to the preamp in receive mode providing a positive indication that power is actually being sent to the preamp (or at least to the connector).

SW2 and SW3 are connected to the PCB. The optional switches to disable the SDRs and the switch to select are not connected to the PCB, but are simply SPST switches that ground the *PTT* lines to the SDR switchers. The SPDT switch to select which amplifier should be keyed is connected to J3 (AMPS).

Here's what the printed circuit board layout looks like:

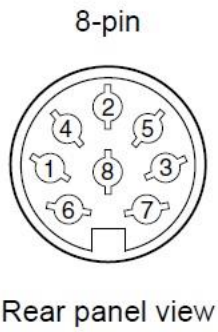


And here's the assembled board:



Icom IC-9700 Connections

The Icom uses a large size 8 pin DIN connector for the external connections:



The full description of the pinout can be found on page 94 the *IC-9700 Basic Operating Manual*. On the original version for the IC-9700, I cut one end off of a DIN cable and hardwired the cable to the PCB; this time I used a DIN jack. The DIN Cable I used to make the connection came from Amazon.

The following table gives the pin usage and color codes in the cable I used to connect the radio to the sequencer:

Pin	Color	IC-9700 Nomenclature
1	White	RTTY Keying
2	Yellow	Ground
3	Blue	PTT Ground
4	Green	Modulator input
5	Brown	AF/IF Output
6	Pink	Squelch
7	Red	+13.8V @ 1 Amp
8	Black	ALC Output

Only pins 2, 3 and possibly 7 are used for the IC-9700 implementation.

Some Construction Notes

I built the unit into an enclosure from Circuit Specialists. Here's what the final assembly looks like:

Notice I also added a USB jack so I can reprogram the processor without having to take it all apart.

The Software

GPIO Pin and Other Symbols Defined

The following are the GPIO pin assignments; for the most part, the symbols used match the net names on the schematic:

TX_GROUND	2	*PTT* Indication (interrupt capable)
TX1_LED	4	Band #1 transmit indicator LED
TX2_LED	5	Band #2 transmit indicator LED
AMP_RELAY	7	Operates the linear amplifier relay
LNA1_RELAY	8	Operates the band #1 preamp/SDR relay
LNA1_RELAY	8	Operates the band #2 preamp/SDR relay
LNA1_OFF	A0	Preamp for band 1 always off when LOW
LNA1_ON	A1	Preamp for band 1 always on when LOW
LNA2_OFF	A2	Preamp for band 2 always off when LOW
LNA2_ON	A1	Preamp for band 2 always on when LOW

There are several definitions of states for the various GPIO pins, for example:

```
AMP_ON   LOW    // A LOW on the AMP_RELAY pin keys the linear
AMP_OFF  HIGH
```

There are only eight global variables:

txState	Current transmit/receive state
oldTxState	Previous transmit/receive state
lna_1_ForcedOff	true when switch SW2 is in the always off position
lna_1_ForcedOn	true when switch SW2 is in the always on position
lna_2_ForcedOff	true when switch SW3 is in the always off position
lna_2_ForcedOn	true when switch SW3 is in the always on position
tx_1_LedState	Used in *CheckBlink* to toggle the LED state
tx_2_LedState	Used in *CheckBlink* to toggle the LED state

Timing Settings

There are two symbols in the software that define the timing for the sequencer:

AMP_OFF_DLY	50mS	Delay between turning the amplifier(s) off and returning the preamp and SDR switch to receive mode.
LNA_ON_DLY	25mS	Delay time between switching the preamp and SDR switch to transmit mode and keying the amplifier.

The values shown are those currently set in the software. The values may be adjusted to suit your needs based on the specifications of your particular equipment and the equipment configuration.

Note, the sequencer is designed for digital mode operations. It can be used for SSB operations provided you use manual *PTT* (not *VOX*) and pause slightly between keying the radio and speaking. Using it for CW operation should only be done if the radio is put into transmit manually before operating the CW key; in other words don't try using break-in modes (I fried a $250 LNA that way)!

Overall Functionality

The software is pretty trivial. The *setup* function sets up all the GPIO pins used and sets them to the proper initial states. Note that there is a specific order in which those are handled that should prevent accidently hitting the preamp with any power before the *setup* is complete.

The *loop* function really only does two things; it first calls the *SwitchPreamp* function which may or may not switch the preamps and SDR switches into receive mode. I'll explain that function in more detail momentarily.

Next, the *loop* function looks for changes in the transmit/receive state of the radio and if the state has changed, executes the appropriate sequence of operations to initiate the state change.

The *SetTransmit* and *SetReceive* functions perform the state change operations by turning things on or off with the appropriate delays between operations.

The *TxInterrupt* function is executed via a hardware interrupt anytime the transmit/receive state of the radio changes and simply sets the *txState* variable as appropriate.

The *SwitchPreamp* Function

This function perhaps deserves a bit more explanation than the other functions. It takes two arguments; the first being which band(s) should be switched (*BAND_1*, *BAND_2* or *BOTH_BANDS*). The second argument is the new preamp and SDR switch state requested (*LNA_RX* or *LNA_TX*).

When the argument is *LNA_TX*, the selected preamp(s) and SDR switch(es) will always be put into transmit (bypass) mode unless the associated LNA switch (SW2 and/or SW3) is in the 'ON' position. If the switch is in the 'ON' position, both the preamp and SDR switch will remain in receive mode (BE VERY CAREFUL).

However, if the argument is *LNA_RX*, the preamp(s) and SDR switch(es) will only be switched into receive (active) mode if the associated preamp enable switch is in the 'SEQ' position and the *PTT* is not currently active (*TX_OFF*).

The *Test_LNA* Function

You will see a call to this function commented out at the end of the *setup* function. When the function call is un-commented, it will be invoked. It allows testing of the preamp switch functions. It is a never-ending loop, so when it runs, none of the rest of the sequencer functions will be enabled.

When one of the 'LNA' switches is put in the 'ON' position, the associated LNA LED will flash. When the switch is in the 'OFF' position, the associated LED should go out. The LED should also remain on when the switch is in the 'SEQ' position.

You should also see the voltage on the associated ‘LNA’ connectors (if the unit isconnected to a 12V power source) following the LED and you should also see contact closure/opening following on the ‘SDR’ connectors provided the associated ‘SDR’ switch is in the ‘ENABLED’ position.

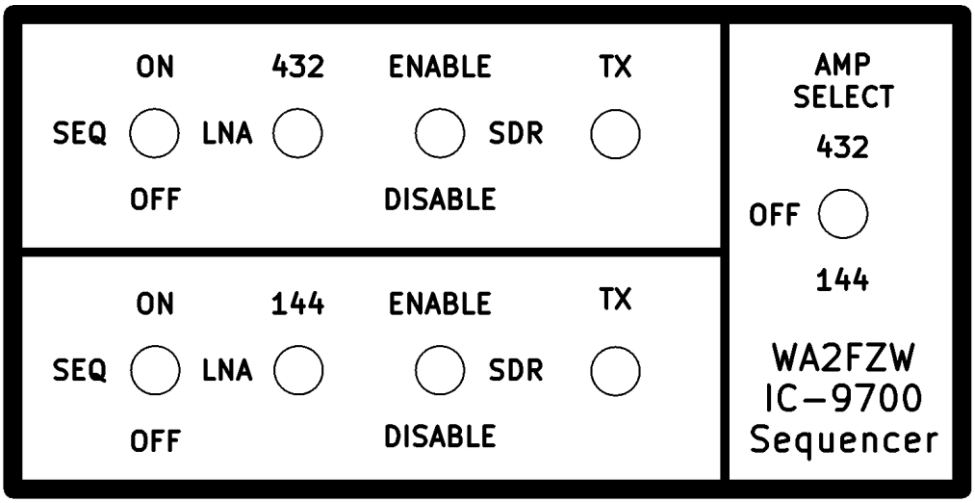
If the ‘SDR’ switch is in in the ‘DISABLED’ position you should see a constant contact closure on the associated ‘SDR’ connector.

It is critical to test everything before actually hooking the sequencer up to external equipment as you can easily destroy a preamp or SDR. The complete testing procedure is documented below.

Some Operational Notes

Front Panel Controls and Indicators

Here’s what the front panel looks like:



In the two areas on the left, from left to right are:

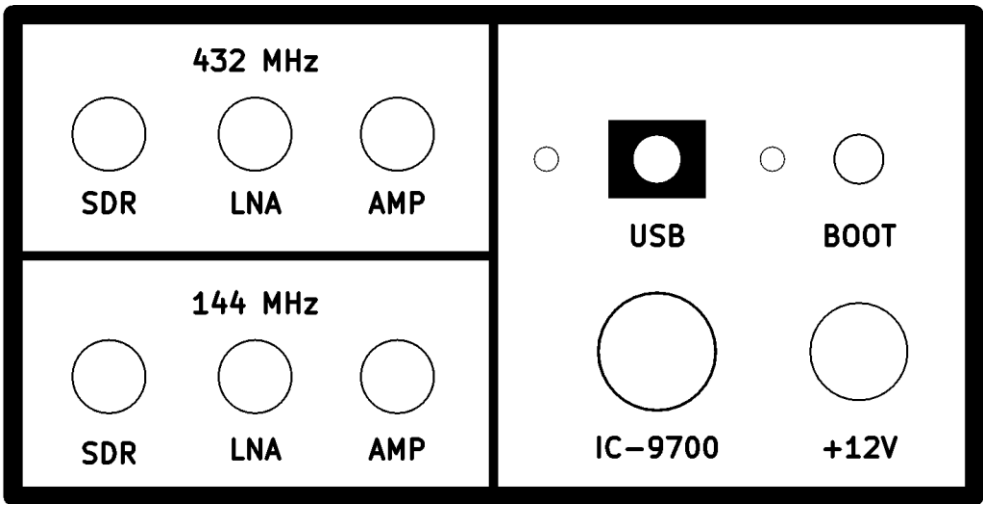
- LNA/SDR ‘ON’, ‘SEQ’, ‘OFF’ switches (SW3 & SW3).
- Green preamp power on (receive mode) LEDs.
- SDR ‘ENABLE’/’DISABLE’ switches (SW5 & SW6).
- Red transmit indicator LEDs.

In my build, the top section (labeled 432) is the *BAND_2* items and the bottom section (labeled 144) is the *BAND_1* items.

The section on the right side contains the amplifier select switch (SW4). I used the center-off option so that both amplifiers can be disabled.

Rear Panel Connections

Here's what my rear panel looks like:



In the sections to the left are the connectors for the SDR switcher, preamp and amplifier. I used RCA jacks. As on the front panel, the top part (labeled 432) are the connections for *BAND_2* and the bottom section (labeled 144) is for the *BAND_1* connections.

The section to the right contains:

- A type 'B' USB connector which allows me to re-program the unit without having to take it apart.
- The 'BOOT' momentary pushbutton (SW1 on the schematic).
- The 8-pin DIN jack for the connection to the IC-9700.
- The 12V power connector.

SDR ENABLE/DISABLE Switches

If you are using an SDR switcher and have installed the switch to disable the SDR switch as described above it is best to disable the SDR when not actually using it.

There are several such switchers available. The one I am using came from Paul (N2EME) and is kind of unique in that it allows one to listen on the radio and SDR simultaneously. It uses a splitter to achieve that. In this arrangement, when not actually using the SDR it is best to disable the switcher as the splitter causes a 3dB loss in the system. When this switcher is disabled, the radio is connected directly to the antenna with negligible insertion loss.

Another good switcher is available from Amazon. This one doesn't allow simultaneous reception on the transceiver and SDR however. When the SDR switch is in the 'ENABLE' position, you receive on the SDR; when in the 'DISABLE' position, you receive on the radio. This switcher has a very low insertion loss and no problems with SWR.

I recommend avoiding the use of the MFJ switcher as it has a 3dB insertion loss built in somehow.

LED Indications

Green LED – On indicates power is being supplied to the preamp for that band.

Red LED – Both on indicates the radio's *PTT* is active. Flashing is a warning that the preamp switch for the band is in the 'ON' mode and transmitting on that band could damage the preamp. This feature is primarily for the IC-9700 where in satellite mode, you are transmitting on one band and receiving on a different band; each band on the IC-9700 has its own antenna feed.

Note that putting one of the preamp switches into the 'ON' position will also put the associated SDR switch into permanent receive mode and transmitting could destroy the SDR. Whenever the preamp switch is in 'ON' you should 'DISABLE' the SDR switcher.

One could do this automatically by using DPDT switches for SW2 and SW2 and using the 2nd half of the switch to also put the SDR into bypass mode.

Preamp Overload Protection

Both my preamps contain circuitry to protect them from strong nearby signals (in-band or out-of-band). If you use a preamp without such protection, it is important that the 'ENABLE'/'DISABLE' switch be used to put yours into bypass mode before using a different nearby transmitter and/or antenna. I do this even though my preamp has the protection circuit.

There are front-end protection gimmicks available from DxEngineering, and there are cheaper ones on eBay.

Testing

I strongly suggest testing everything without any amplifiers, preamps or SDRs connected to the unit. It is ok to connect the unit to the radio for testing, or you could use a jumper wire to simulate the radio's *PTT*. The unit would have to be connected to a 12V source. The only test equipment needed is a volt/ohm meter.

Preamp 'ON'/'OFF'/'SEQ' Switches (SW2 & SW3)

With power applied to the unit and these switches in the 'SEQ' position, both green LEDs should be lit and you should measure +12V on the LNA connectors (if the *PTT* is not active). The SDR connectors should show an open condition.

With the radio's *PTT* active, and these switches in the 'SEQ' position, the green LEDs should go out there should be no voltage on the 'LNA' connectors. The 'SDR' connections should show a contact closure.

Moving the switches to the 'OFF' position should cause the green LEDs to go out and there should be no voltage on the 'LNA' connectors regardless of the *PTT* state. The 'SDR' connections should show a contact closure.

With the switches to the 'ON' position (*PTT* inactive) the green LEDs sill be illuminated and there should be +12V on the 'LNA' connectors. The red LEDs should be flashing. The 'LNA' connections should show an open condition.

The *Test LNA* function call at the end of the *setup* function in the software can be enabled to facilitate testing the 'LNA' switches.

SDR ‘ENABLE’/’DISABLE’ Switches

With these switches in the ‘DISABLE’ position, the SDR connectors should show a contact closure regardless of the state of the preamp switches or the radio’s *PTT*.

When these switches are in the ‘ENABLE’ position, the SDR connections should show open when the *PTT* is inactive and should show a contact closure when the *PTT* is active.

If you implemented the option to have the preamp switches also disable the SDRs when in the ‘ON’ position (as mentioned above), the SDR connections should show a contact closure when the preamp switches are in the ‘ON’ position.

PTT Tests

With the preamp switches in the ‘SEQ’ position and the SDR switches in the ‘ENABLE’ position, the green LEDs should be on and the red LEDs should be off when the radio’s *PTT* is inactive. There should be +12V on the ‘LNA’ connectors and open conditions on the ‘SDR’ connections.

With the switches still set as above, when the *PTT* is active, the green LEDs should go out and both red LEDs should light. There should be no voltage on the preamp connectors and the SDR connectors should indicate a contact closure.

One thing to be aware of; if one of the preamp switches is in the ‘ON’ position, the associated red LED should be flashing when the *PTT* is inactive. When the *PTT* goes active, however both red LEDs will be lit continuously.

This behavior could be changed in the software and I may do that.

With the *PTT* inactive the amplifier connections for both amplifiers should show an open condition. When the *PTT* goes active, the connection for the selected amplifier should show a contact closure. Make sure to check this for both amplifiers. As mentioned earlier, one could use a center-off SPDT switch so that neither amplifier is keyed.

Suggestion Box

I welcome any suggestions for further improvements. Please feel free to email me at WA2FZW@ARRL.net.

Bill of Materials

Here is a list of the parts you will need and in many cases, links to where you can get the less common parts.

There are hyperlinks to Mouser Electronics for some of the parts. Mouser has implemented a Captcha-like guard against robots. Thus, you can't simply click on the links, but if you copy the links and paste them into your browser they work (at least they did when I wrote this).

There are also hyperlinks for some items available from Jameco Electronics. Jameco has recently instituted a $25 minimum order policy, so if you order from them, find some other stuff you need!

The PCB		Gerber files are available on Github.
R1, R2 & R4	680R 1/4W	
R3	270R 1/4W	
C1, C2	100nF 25V	
U1	LCA-110 SSR	6-pin DIP package; available from Mouser and other common suppliers
U2	Arduino Nano	I used clones which are much cheaper than genuine Arduinos.
D1, D3 & D7	1N4148	
D2, D4 – D6	General purpose LEDs – 20mA	Pick whatever colors you like. I used red for the TX indicators and green for the preamp indicators. The documentation assumes these colors. The PCB is designed so that the LEDs can be installed on the PCB or connected externally.
SW1	Momentary push button	

SW2 & SW3	SPDT center off toggle switches	Or maybe DPDT center-off toggle switches; see the section on LED indications. These can be connected to the PCB using a single 6-pin header.
SW4	SPDT toggle switch	Not on the PCB, but connected between J3 (*AMPS*) and the amplifier connectors to select one of two amplifiers. A center-off switch can be used to select neither amplifier.
SW5 & SW6	SPST toggle switch	Not on the PCB. These are the SDR 'ENABLE/'DISABLE' switches. They should be wired to ground the SDR PTT connection when in the disable position.
K1 - K3	Fujitsu NA5W-K DPDT relay	Available from Jameco
J1 – J7	2-pin male header	The PCB is designed such that a single 4-pin header can be used for J1 & J2 and a single 10-pin header can be used for J3 – J7.
IC-9700 Connection	8-pin large female DIN receptacle	Available from Jameco.
Amplifier, LNA, SDR Switch, etc. Connections	RCA and/or coaxial female receptacles	However many you need to connect all your equipment. Use whatever you like as connectors for the amplifier, preamp, SDR switch and power connectors.
Enclosure		I used one from Circuit Specialists; 5.9" x 5.1" x 2.6".