Amplifier/Preamp Sequencer
Version 1.4
John Price – WA2FZW

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Introduction

This document describes a sequencer used to switch one or two linear amplifiers, an antenna mounted receive preamplifier and a switch box that allows simultaneous 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. This version will work with either the FT-891 or my Icom IC-9700. The original version wouldn't work when the Icom was being operated in satellite mode when transmitting on the 70cm band and receiving on 2 meters. When it transmitted on 70cm, the 2 meter preamp was being disabled. Since the whole idea of the full duplex operation is to be able to hear your own signal coming back from the satellite this was a problem!

Coming soon I will have both a 2 meter and a 70cm amplifier connected to the IC-9700, so the hardware was modified in Version 1.4 to provide the ability to key 2 amplifiers.

Also added in Version 1.4 is a provision to control an SDR switch that allows an SDR to be used as an alternate receiver.

The overall idea is to detect that the radio has been switched from receive mode to transmit mode and switch the preamplifier and SDR switch 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

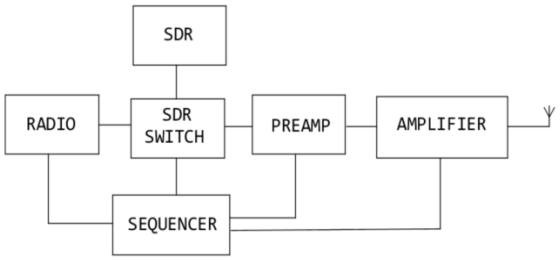
- The radio has a PTT line that goes to ground when the radio is put into transmit mode either manually or via CAT control.
- The preamplifier is put in receive mode by powering it from a +12V source. Removing the +12V power switches it to transmit mode (fail-safe operation).
- The SDR switcher is switched from receive mode to transmit mode by grounding a PTT input on the switcher. Not shown on the schematic is

an (optional) switch to ground the PTT line of the SDR switch to put it into permanent transmit (bypass) mode.

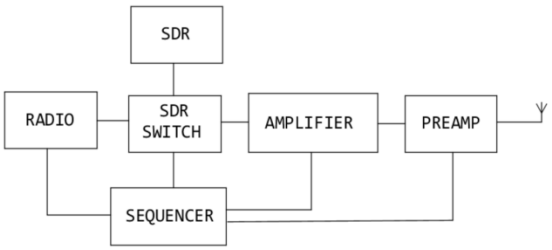
- The linear amplifiers are keyed by grounding their keying inputs. We use relay contacts for this so the amplifier's keying voltage can be anything. You could also install a switch to select which of the 2 amplifiers should be keyed; I didn't do this in my units however.
- This sequencer is designed primarily to be used when running the various digital modes. When used with the FT-891, it is fairly safe to operate SSB or CW, as the TX inhibit feature prevents RF output until everything has switched. This is not the case with other radios.

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

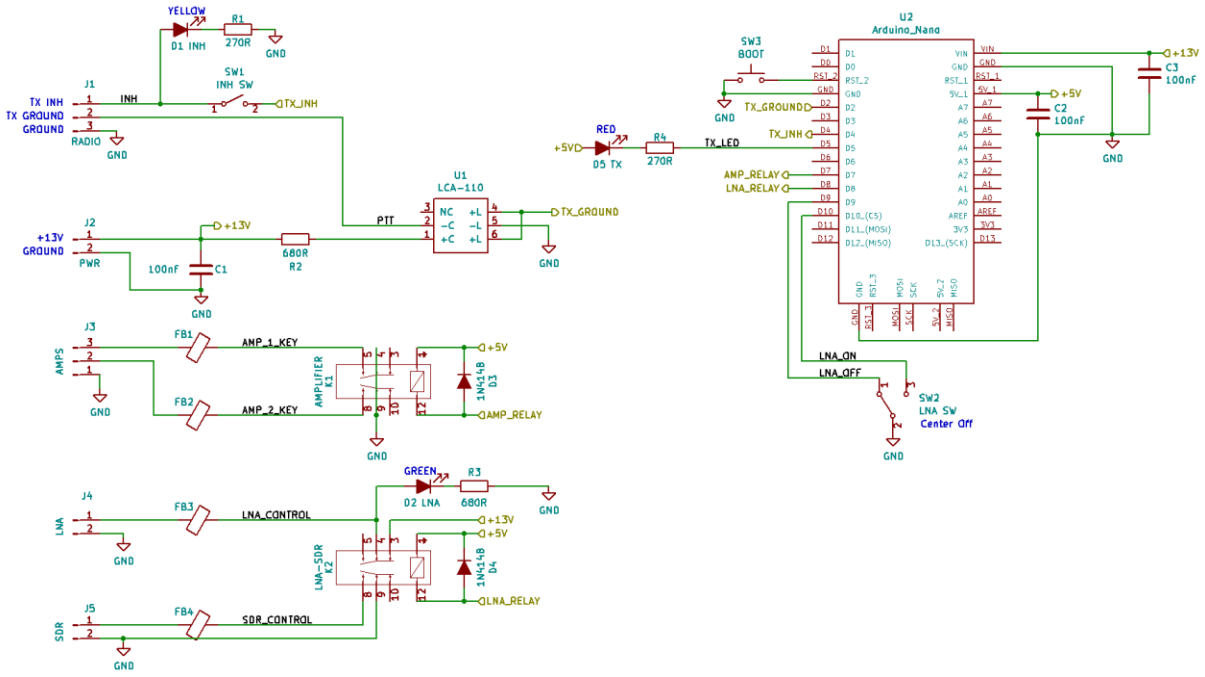
The primary difference is whether the preamp is ahead of or behind the amplifier. If you have a preamplifier that can handle the output power of the amplifier, it's better to put it between the antenna and the amplifier and as close to the antenna as possible.

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:



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 relay K2 which switches both the preamp and SDR switch to transmit mode unless switch SW2 is in the 'Preamp Always On' position; more on this later.

After a delay of *LNA_ON_DLY* milliseconds, relay K1 is operated which switches the amplifier(s) on. After another delay of *AMP_ON_DLY* milliseconds, the *TX_INH* pin is set to *LOW* which allows the FT-891 to actually produce power. The TX inhibit is a feature unique to the Yaesu radios and does not apply to other makes.

When the *PTT* line goes *HIGH*, the process is reversed. The *TX_INH* line is set to *HIGH* (again only applies to Yaesu radios) to stop any RF output and the amplifier(s) are turned off. After *AMP_OFF_DLY* milliseconds, the preamp and SDR switch are returned to the receive mode.

Preamp Always On or Off Switch Considerations

This switch was 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 LNA would switch off when I transmitted causing me to no longer be able to hear myself.

Putting the switch in the 'Always On' position cured the problem.

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

When the switch is in the 'Always On' position the red transmit indicator LED will flash rapidly as an alert.

Also when the switch is in the 'Always On' position, the SDR switch will be stuck in receive mode. It should be put into permanent transmit mode by powering it off or putting the (optional) SDR Disable 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, a couple of relays, a solid state relay (SSR), a few resistors and three LEDs.

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 have powered everything from both the FT-891 and the IC-9700 without any problems however I am now powering both my sequencers from an external 12 volt power supply.

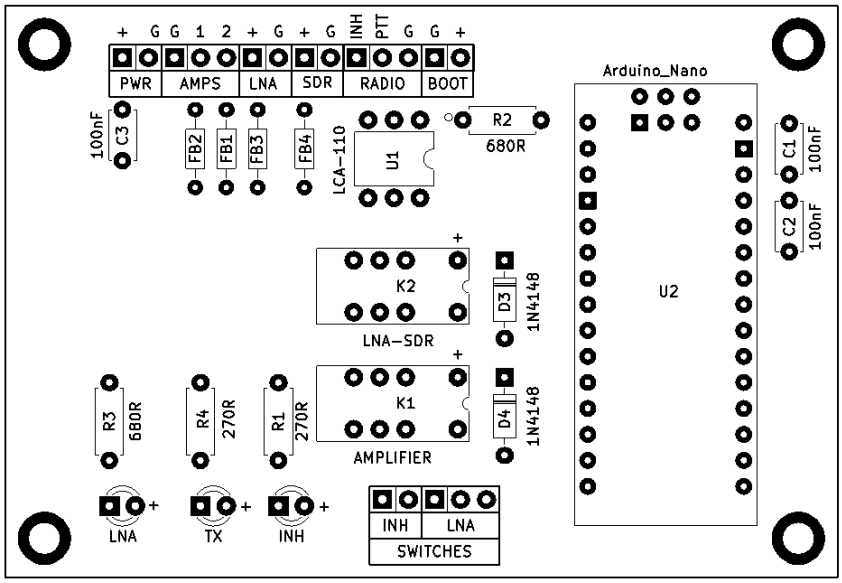
U1 is an LCA-110 solid state relay (SSR) which provides isolation between the radio's *PTT* line and the processor. It is required as the normal voltage on the *PTT* line is 12V and the Arduino pins can only handle 5V.

Relay K1 keys the amplifier(s). Relay K2 provides power to the preamp and grounds the *PTT* input on the SDR switch in transmit mode.

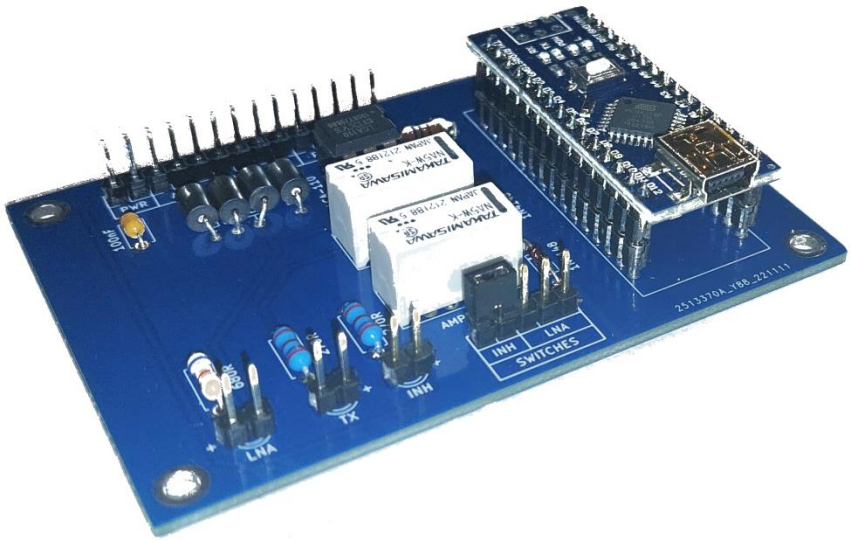
The LEDs indicate when the radio's *PTT* line is active (red), when the *TX INH* is active (yellow) and when the preamp is in receive mode (green). The transmit and inhibit LEDs are operated directly from GPIO pins by the software but the preamp LED is operated by the relay which supplies power to the preamp in receive mode providing a positive indication that power is actually being sent to the preamp.

There are provisions for two switches. One switch can turn the preamp on regardless of the radio's transmit status or force it to be always off regardless of the radio's status. The other switch can be used to disable the Yaesu's transmit inhibit line. If being used with a radio without the TX inhibit capability there is no need to add SW1. If a jumper is placed across the header for SW1, however the LED will operate.

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



And here’s the assembled board:



Notice, there’s a jumper plug on the connections for the inhibit disable switch. For the FT-891 version, I don’t want to be able to disable it.

SDR Enable/Disable Switch

If using an SDR switcher, you can also install a switch to enable or disable it as shown on the picture below. All that is needed is a SPST toggle switch that grounds the SDR switcher’s PTT input to disable it.

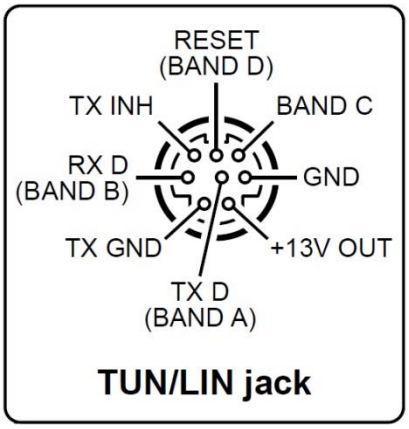
Oops!

There are a couple of errors on the original Version 1.4 PCBs (both are corrected in the Gerber files and in the PCB layout picture above).

- There is a silkscreen label on the back side of the PCB that says ‘Preamp Switch’; ignore it!
- The ‘+’ indication for the *INH* LED is on the wrong pin.

Yaesu FT-891 Connections

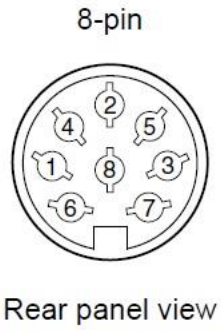
This shows the signals present on the FT-891 *TUN/LIN* mini-DIN jack, which is connected to the sequencer:



Only the *GND*, *TX GND*, *TX INH* and possibly the *+13V OUT* pins are used by the sequencer.

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*. 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.

I provided both types of DIN jacks on my units connected together so that either sequencer can be used with either radio. If you are building for only one radio, then just use the connection most appropriate for your situation.

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 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)
TX_INH	4	Transmit inhibit output to the radio
TX_LED	5	Transmit indicator LED
AMP_RELAY	7	Operates the linear amplifier relay
LNA_RELAY	8	Operates the preamp/SDR switch relay
LNA_OFF	9	Preamp always off (bypass) when LOW
LNA_ON	10	Preamp 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 five global variables:

txState	Current transmit/receive state
oldTxState	Previous transmit/receive state
lnaForcedOff	true when the switch is in the always off position
lnaForcedOn	true when the switch is in the always on position
txLedState	Used in *CheckBlink* to toggle the LED state

Timing Settings

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

AMP_ON_DLY	50mS	Delay between turning the amplifier(s) on and releasing the transmit inhibit line (FT-891 only).
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.
LNA_OFF_DLY	100mS	Currently not used

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)!

Digital Mode Transmit Inhibit Workaround

As mentioned in the *Introduction*, the fact that the Yaesu FT-891 has the transmit inhibit capability makes things very simple when the sequencer is being used with that radio. But if you are working digital modes using WSJT-X with a radio that doesn't have the transmit inhibit capability there is an alternate approach.

Under the *Settings* menu - *Advanced* tab in WSJT-X, there is a setting for “Tx delay”. The default setting for this is 0.2 seconds and what it does is delay the actual start of the transmitted output for that amount of time after the radio is keyed. 0.2 seconds is plenty of time for the preamp and amplifier to switch modes before any power is transmitted.

The IC-9700 has a menu setting for TX delay which can also be used for other modes.

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.

At the end of the *setup* function is a call to the *TestLEDs* function which is normally commented out. If the function call is un-commented, that function will cycle through all the possible states at 2 second intervals, which allows one to test the operation of the device. It must be connected to the radio or another source of 12V power in order for the preamp LED to light or for power to be provided to the preamp.

The *loop* function really only does two things; it first calls the *SwitchPreamp* function which may or may not switch the preamp and SDR switch 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 one argument which is the new preamp state and SDR switch requested (*LNA_RX* or *LNA_TX*).

When the argument is *LNA_TX*, the preamp and SDR switch will always be put into transmit (bypass) mode unless the LNA switch (SW2) is in the 'Always On' position. If the switch is in the 'Always 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 and SDR switch will only be switched into receive (active) mode if the preamp enable switch is in the 'SEQ' position and the PTT is not currently active (*TX_OFF*).

Some Operational Notes

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 cheaper ones on eBay.

LED Indications

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

Yellow LED – On indicates the transmit inhibit is on (FT-891 only)

Red LED – On indicates the radio's PTT is active. Flashing is a warning that the preamp switch is in the 'Always On' mode and transmitting 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 the preamp switch into the ‘Always On’ position will also put the SDR switch into permanent receive mode and transmitting could also destroy the SDR. Whenever the preamp switch is in ‘Always On’ you should ‘Disable’ the SDR switcher.

SDR Enable/Disable Switch

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 enabled position, you receive on the SDR; when disabled, 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.

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).

R1, R4	270R 1/4W	
R2, R3	680R 1/4W	
FB1 – FB4	Ferrite bead	The ones I used are no longer available. Pretty much anything will work.
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, D2, D5	General purpose LEDs – 20mA	Pick whatever colors you like. I used red, yellow and green.
SW1	SPST toggle switch	The switches themselves are not on the PCB, but rather mounted on the enclosure. SW1 is connected via a 2-pin male header. SW2 is connected via a 3-pin male header. The PCB is designed such that a single 5-pin header can be used.
SW2	SPDT center off toggle switch	
SW3	SPST Pushbutton	Reboot switch mounted on the rear panel and connected to the PCB via a 2-pin header
SW4	SPST Switch	Not shown on the schematic, but can be installed to ground the SDR switch *PTT* to place it in constant transmit mode.

K1,K2	Fujitsu NA5W-K DPDT relay	Available from Jameco
J1, J3	3-pin male header	The PCB is designed such that a single 14-pin header can be used (includes the 2-pin header for SW3).
J2, J4, J5	2-pin male header	
FT-891 Connection	mini-DIN female receptacle	CUI Devices MD-80PL100 – Available from Mouser. Only needed for the FT-891 implementation.
IC-9700 Connection	8-pin large female DIN receptacle	Available from Jameco. Only needed for the Icom version.
Amplifier, LNA, SDR Switch, etc. Connections	RCA and/or coaxial female receptacles	However many you need to connect all your equipment. Or 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”.