Homebrew Satellite/Weak Signal T/R Timing Sequencer
by Gordon Gibby KX4Z

NOTE: Full documentation, including software, hardware, BOM, pcb Gerbers and STL files for enclosure are available at https://github.com/docvacuumtubes/Sequencer

The Problem

Transmit/Receive sequencing is very simple when there is only one transceiver and no other equipment other than transmission lines and antennas involved. But when you add **transmit amplifiers**, or **receive preamplifiers**, or any kind of RF switching relay, it gets a lot more complicated -- because even millisecond overlaps in timing of different equipment can result in:

- hot switching of relay contacts, leading to either immediate failure or reduced lifespan, even of expensive vacuum relays
- instantaneous damage, often catastrophic, to sensitive GaAs receiving preamplifiers
- potential damage to transmitter power amplifiers due to improper loads.

VHF/UHF small signal operators whether pursuing terrestrial or satellite communications, often utilize amplifiers, additional receivers and remote (mast-mounted) preamplifiers. All of these bring the possibility of great damage if strong RF power shows up when it shouldn't. It isn't fun to lose an expensive GaAs preamplifier that was part of your satellite system, or was helping your distant tower-mounted system to overcome hundreds of feet of coax loss!

Commercial and Homebrew Existing Solutions

Traditionally, ham radio operators have utilized any of several commercial "sequencers" that take push-to-talk inputs and provide multiple different outputs to control transmitter output and operation of various amplifiers, preamps etc. These aren't cheap! And often the need was so unique that custom designs were needed.

- DX Engineering Time-Variable Sequencer Unit -- $319 https://www.dxengineering.com/parts/dxe-tvsu-1b
- M2 S3 Sequencer $248 https://www.m2inc.com/FGS3
- Homebrew Device: https://github.com/WA2FZW/Amplifier-Preamplifier-Sequencer-by-WA2FZW/tree/main
- MFJ 1708B-SDR / SDR RF Sensing TR/Switch (**no longer available**) https://mfjenterprises.com/products/mfj-1708b-sdr
- SDR Switch by N2EME - $179-$299 https://sdrswitch.com/ (appears to be RF sensing as well)

Lacking Any Internal Delay

My used ICOM-820H not only lacked the ability to delay the production of RF output after the closure of the PTT contacts, it further lacked an adjustable power level. The improved IC-910 provides adjustable power output, but still no ability to delay RF output -- in fact, even the IC-9700 does not appear to offer the feature. However, for HF operation, the IC-7300 does!

Lacking Ability To Delay RF Output
ICOM 820H
ICOM 910
ICOM 9700
and therefore possible to damage downstream devices

My reading suggests that Yaesu full duplex satellite type transceivers may also lack a transmission delay option. The FT-847 includes a "transmit inhibit" input on the TUNER jack that has been used to inhibit transmission (see: https://www.kl7uw.com/TX-INHIBIT.htm) For such a radio, the "power level" can be set to 0% and the *positive*-voltage signal on C2 could likely be used for inhibit. In that case, the negative voltage supply and the op-amp inverter are not needed. (This suggestion has not been tested.)

FailSafe Topologies of Existing Solutions

- The DXEngineering Time Variable Sequencing Unit intercepts the CW key or other device, and itself controls the PTT input of the transceiver as well as controlling when DC power is sent to the PREAMP. This appears to provide a fail safe in the case that the +12 power fails.

- The DH8BQA sequencer works also by intercepting the CW key and Microphone PTT and itself delaying and controlling the closure of the PTT to the transceiver. Information on this design is limited: the best information that exists is a PDF of the printed circuit board unless you have a particular issue of a German magazine. (see https://www.dh8bqa.de/sequencer/)

- WA2EFZ's homebrew device is primarily oriented toward digital satellite efforts and derives its transmit signal directly from a USB output of the computer providing FT8, and then controls the transmitter PTT. I'm not clear on its fail-safing.

- I'm not completely clear on how the N2EME system works: it appears to involve the coaxial RF relays inside itself and presumably controls them adroitly to protect the external SDR used for receive. The information I read didn't make it clear how any delays were arranged.

None of these designs provide **adjustable power output** for my IC-820H. And they are either expensive, or require homebrew efforts, or difficult to perceive if they would properly protect as needed. Therefore I looked into how to work with the IC-820H.

IC820 Adjustable Power Hack

The traditional method for adjusting IC-820H output is a 9V battery and a potentiometer producing an adjustable *negative* voltage to the accessory back panel socket pin 8, configured as ALC (automatic level control). It seemed to me that this same feature could be utilized the delay the production of RF -- by just making the ALC signal strong enough to squelch any output. It turns out, this works!

<u>Putting all this together to make a working unit</u>
An Arduino Nano analog input can easily sense when the SEND output of any of those Icom transceivers goes to ground and then provide any desired delay to the ALC adjustment, and also provide adjustable ALC; it can also control additional outputs, such as a relay.

So I decided to use this technique to create just such a sequencer.

The state diagram is simple, as there are only about 3 important states: Receiving, Transitioning to Transmitting (followed by steady transmitting), and Transitioning to Receiving

SEND OUTPUT is High ==> Receive state; set ALC to -4 volts

|

SEND OUTPUT transitions to LOW ==> transitioning to TRANSMIT State -- delay for an adjustable time, and then reduce ALC negative voltage to an adjustable negative voltage suitable for the desired power output

|

SEND OUTPUT transitions to High ==> Transmitter is turning OFF, going to RECEIVE; change ALC to -4 volts

<u>Both Positive and Negative Power Required</u>
In other to power the Arduino, measure SEND voltages that are positive, and create ALC voltages that are negative, the resulting system needs both a positive and negative supply of modest current. In my case, I used a powerpole connector to grab nominal +12 from station supply, and a wall wart to produce -10V from AC power. (This could be replaced by other technology.)

<u>Connections Required</u>
At a minimum, the system requires connection to the

1) SEND output and to the
2) ALC input of the ICOM transceiver.

Both of these are available on the back panel 8-pin DIN accessory connector on the ICOM transceivers. Beyond that, an optional relay output can be provided and contacts wired however the user needs; in particular, it can be wired in series with the +12 supply to the downstream preamps if desired (see below). Control for the relay comes from a different output of the Arduino Nano, so it can even be delayed by a different amount if necessary.

<u>FailSafe Possibilities Of This Design During U/V or V/U Satellite Operation</u>

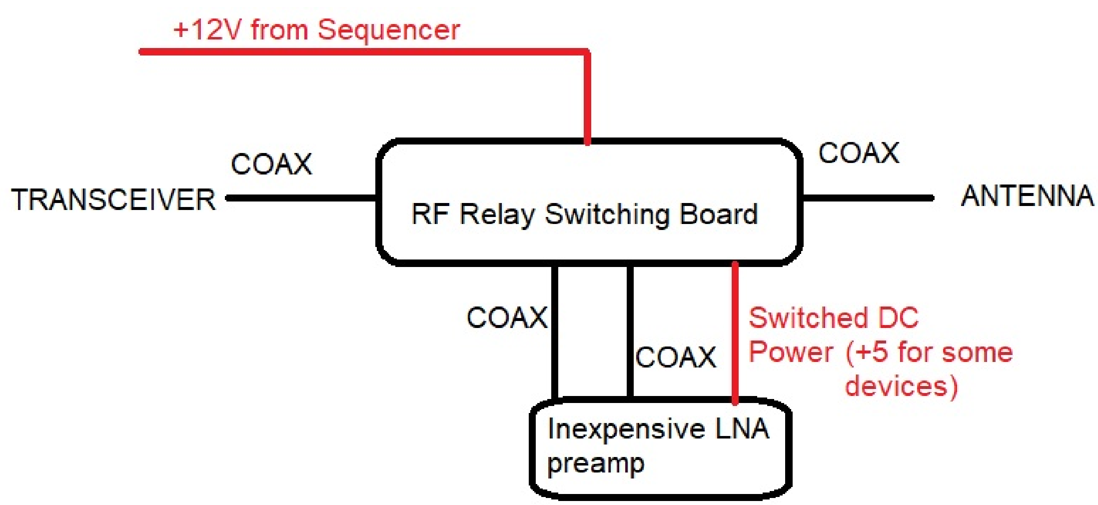
The failure [in my case, damage to downstream preamp] possibilities depend on whether you are using your station for

- duplex on two bands (e.g. for satellite communication) or
- simplex only on one station.

When operating duplex, you only need a working preamp on the RECEIVE transmission line, not on the TRANSMIT transmission line.   For operating simplex, you must have the preamp on the single transmission line you are using for both transmit and receive on these radios -- and hence more FailSafe effort is required.

Duplex (Satellite) Operation

Normally you transmit only on one band (satellite uplink) and receive on a different band (satellite downlink).   You must receive on the 2nd band simultaneously with transmission on the first band (full duplex) to find your signal on the satellite downlink band.   My KX4Z relay-switching system to insert low-cost LNA preamps uses coaxial-cable bias T provided + DC power **by the transceiver itself** to turn on a preamp in the transmission line (at a much lower price than commercial designs).



Block Diagram of RF Preamp Switching System (future article)

What this means is that even though the Sequencer has certain fail-safing when operated in the simplex mode, all of that becomes completely superfluous when operating in DUPLEX mode and taking advantage of the transceiver-controlled activation of ONLY THE PREAMP IN THE RECEIVE-ONLY TRANSMISSION LINE.   This is a huge advantage for the duplex operator, and should be fully leveraged, as follow:

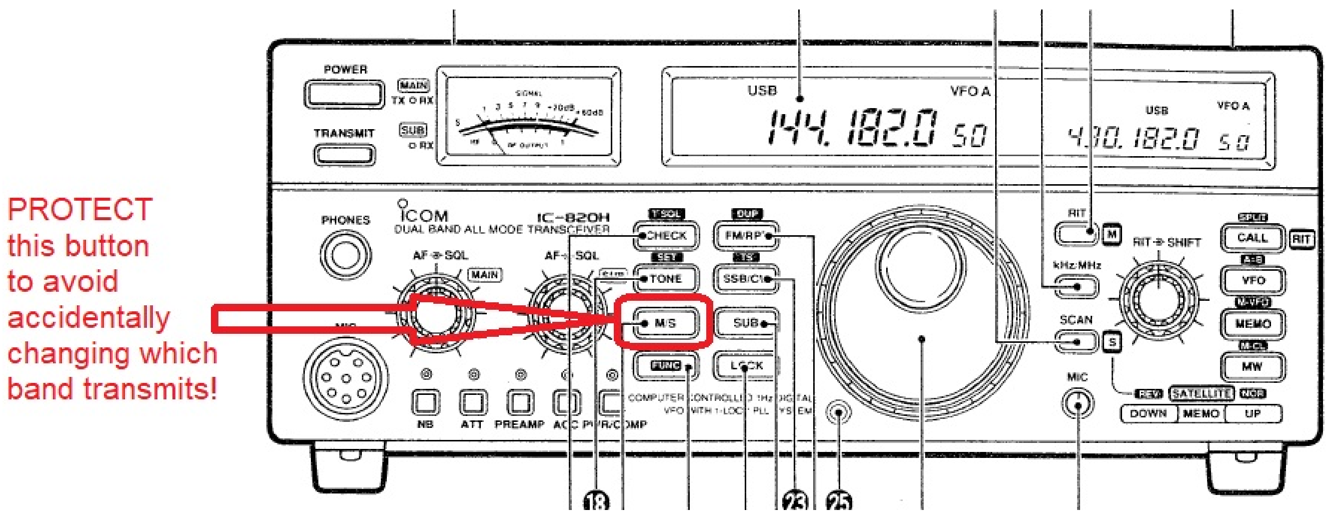
DUPLEX OPERATION ULTIMATE FAILSAFE:

1. **When operating DUPLEX (satellite operation) you should ONLY enable the coaxial cable +DC power for the band you will use for RECEIVE.**

- *On the IC-820H this requires adjusting a transceiver "F-set mode" option. (Hold FUNC pressed while turning on power to access.)*
- *On the IC-910 and IC-9700 there are front panel buttons or menu choices to choose which line should have PREAMP enabled.*
- *Before initiating a satellite contact, configure these options so that ONLY the receive band gets preamp drive on its coaxial line.*

Impact of MAIN versus SUB BAND: The IC-820H is only able to TRANSMIT on the "Main" band, not the "SUB" band. You use the SUB band for RECEIVE. But either ham band can become the Main Band -- a hazard -- by touching the M/S switch button. The IC-910 has a similar button. *You must not accidentally change the RECEIVE band (which through the F-Set you have enabled preamp power) to become the MAIN.*

2. **Therefore you might wish to place a protective cover over the front panel M/S button so that you cannot accidentally switch which band is MAIN.**



On the IC-820H, protect the M/S switch against accidental change in transmit band.

I will create a small hinged cover and 3D print it to protect that switch.

Those two protections will make it FailSafe that **you will not be able to place a preamp inline, at any time, on the TRANSMIT-enabled MAIN band of the IC-820H.** From that point, even if the Sequencer were to completely fail, power the sequencer were lost, or connection to the sequencer is lost -- it is impossible to damage a preamp.

If you do not employ those two protections, then you might accidentally configure the transceiver so that it is able to transmit on the transmission line that also has a preamp that is enabled by +DC on the coaxial cable. In that case, you are now operating as if you were attempting SIMPLEX operation. As long as your connections are proper and the Sequencer is functioning properly, you will still be protected even in that situation. The FailSafe review of simplex operation follows.

SIMPLEX OPERATION PREAMP SWITCHING & FAILSAFE

When pursuing DX contacts on single band SIMPLEX, both transmission and reception occur on the same transmission line, half-duplex (one at a time). This entails MORE RISK than the duplex 2-separate bands of satellite work discussed above! The KX4Z relay-switching / preamp systems (to be further detailed in a subsequent article) only place the preamp inline if both
(a) +12 power are provided to them, AND
(b) +12 is sent down the coaxial cable from the transceiver, indicating it is in RECEIVE mode.

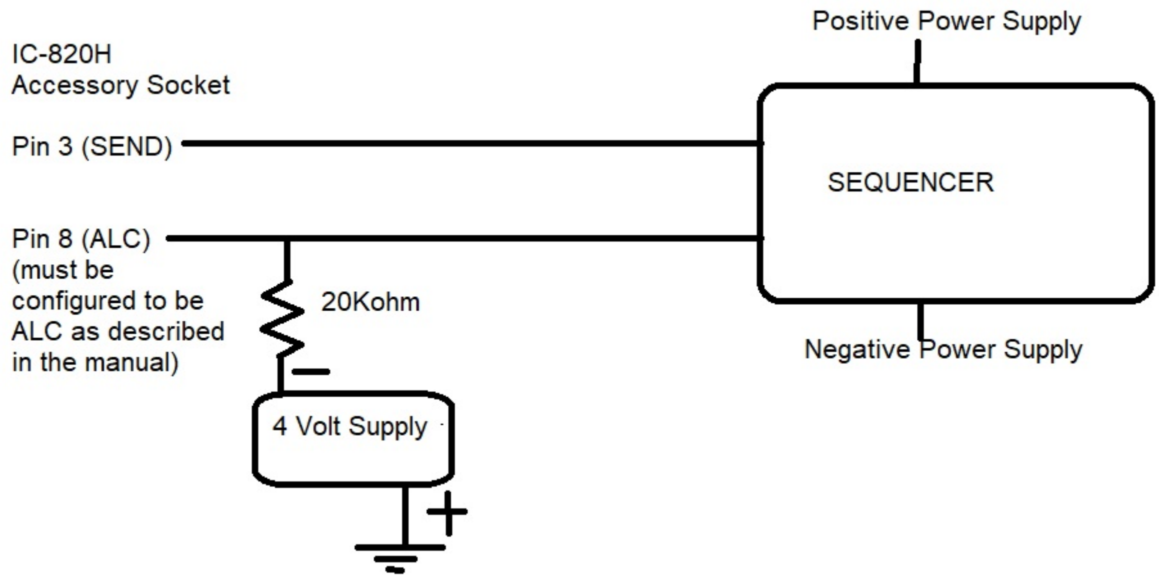
The danger period is the transition into TRANSMIT and beyond, when the preamp MUST be removed from the line prior to arrival of transmitter RF. This Sequencer circuit accomplishes that by creating a delay for relay operation by manipulating the ALC input of the transceiver to delay timing of real transmitter power.

There are multiple different fault scenarios to be protected against:
1) Disconnection of the SEND line connection to the Sequencer
2) Disconnection of the ALC line connection to the Sequencer
3) Loss of the Positive Power Supply connection to the Sequencer
4) Loss of the Negative Power Supply connection to the Sequencer

These are considered in depth as follows:

1. SEND LINE DISCONNECTION: If the SEND line connection to the Sequencer is disconnected, the Sequencer will revert to RECEIVE state (due to the Nano pull-up resistors utilized) and as long as the connection to the ALCinput is maintained, it will forever **prevent any real transmitter power output, protecting the inline PREAMP**. FAILSAFE!

2. ALC LINE DISCONNECTION: **If the ALC control line connection to the Sequencer from the transceiver is broken, the Sequencer will lose the ability to silence the transmitter.** During RECEIVE, the preamp will be placed into the transmission line on command of the bias-T provided + voltage on the coaxial line. At transition to TRANSMIT, the impressed + voltage will be removed, but the transmitter power may arrive before the relays have moved the preamp to safety. The failure of the ALC control line connection is not automatically detected by this current design, and if no other steps are taken there is the distinct possibility of failure at the time of transition to TRANSMIT. However If the connector at the back of the transceiver remains intact, this can be fail-safed by a parallel connection of -4.0 volts from a separate or battery source to the ALC pin, through a resistor of approximately 20K. Loss of the connection to the Sequencer will leave this negative voltage to silence the transceiver. (Verify that it does by itself and adjust voltage or resistance until successful.) <u>FAILSAFE provided the additional negative supply remains connected to the transceiver ALC input. This is not a perfect solution.</u>



Possible FailSafe circuit for ALC input. 4V supply can be made with 3 AA Alkaline cells.

3. POSITIVE POWER SUPPLY FAILURE: If the positive power supply to the Sequencer fails, the circuitry will not function properly. **The builder can protection against this by using one set of the K1 relay to provide the + voltage to the power input of the KX4Z relay switching/preamps through the relay (use the Normally Closed contact as the relay ENERGIZES during transmit).** Thus if power is lost to the Sequencer, no power will be provided to the KX4Z relay switching to interpose the preamps, either. FAILSAFE if so wired.

4. NEGATIVE POWER SUPPLY FAILURE: **If the negative power supply to the Sequencer fails, it will be unable to generate a negative voltage to silence the transmitter appropriately. Some protection against this failure mode can be provided by a parallel connection of -4.0 volts from a separate or battery source right at the back panel DIN connector, through a resistor of 20K.** Check that this silences the transmit output (it should). The 1K output impedance of the 741 op amp in this circuit will be able to overwhelm that quiescent input and take over control of the ALC line when properly powered. FAILSAFE if the negative voltage remains connected to the ALC line.

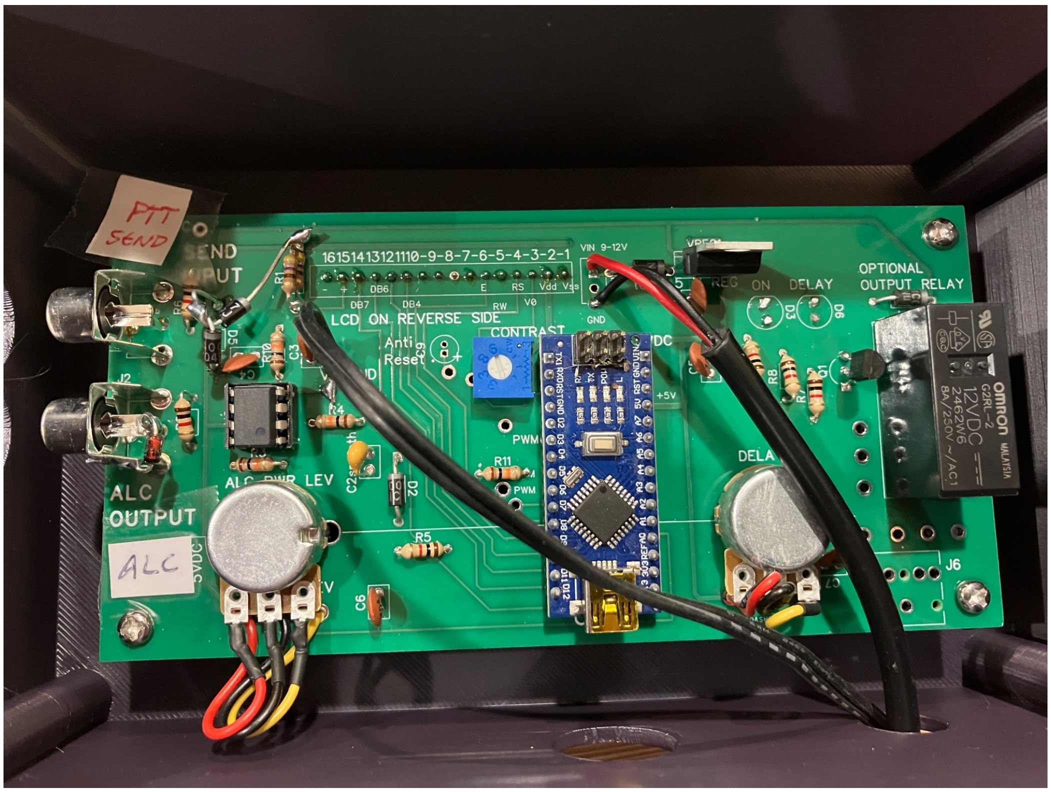
Because this design does not include closed loop monitoring of the effectiveness of its control, but instead relies on the ALC control to reduce transmitter output, it is not totally fal-safed in the SIMPLEX operation, but it can be quite close if the suggestions above are carried out.

Construction

Detailed construction information is contained in a different article. A printed circuit board makes construction fast and easy. Parts for the unit are in the $20-$30 range; about $3 worth of filament builds the enclosure.

Does it work?

Testing of this system demonstrated that it works as desired. During RECEIVE, it has already shut down any possibility of transmitter output with a -4 V ALC output. When either the CW key or microphone is pressed, there is no initial RF that I can see (because the ALC negatively affects the gain at an IF amplifier level in the transceiver). After a chosen amount of delay, the ALC is slightly or totally released as determined by the user's choice of "power level" setting. If the transceiver has been set to send DC voltage down the coaxial cable during RECEIVE to enable preamplifier, and to remove that on TRANSMIT, this system can provide a chosen delay (from negligible to extreme) to allow the preamps or relays to assume a safe state before RF arrives.



Ver0.1 Board, working. Very slight differences from Ver0.2 Board

INITIAL TESTING PROTOCOL

1. Test the system with your transceiver with no preamp or other item at risk downstream, FIRST!
2. Verify that your SEND output is providing a small positive voltage (e.g. 2-5V) to the SEND input of this circuit. Be certain you have wired up the DIN connector properly! Verify that when the transceiver goes into transmit, the Sequencer detects the transition immediately. The DELAY LED should briefly flash and then the ON LED; screen display should show corresponding states.
3. Verify that with 0% power level requested, there is NO transmitter output. This is important to be sure that the ALC output is connected properly and that it has sufficient strength to completely suppress power output. In my IC-820H, power disappears below about 60% "power level"
4. Verify that with 100% power level requested, and the additional negative supply also wired to the ALC input, full power or nearly full power can be achieved.

5. Verify that when the negative supply to the Sequencer is temporarily disconnected, the transceiver does not produce any measurable output power due to the additional negative supply also wired to the ALC input.

<u>OPERATION</u>

1. Adjust desired power level as desired. (This is unnecessary for the IC-910 and IC-9700; set for "maximum" and adjust with radio controls.) On the IC-820H, this control will not be linear, just relative.
2. Adjust the delay as desired. Initially test with a very LONG delay so that you can visually confirm that the transmitter is initially suppressed and then power is allowed.
3. Some recommend a minimum of 29milliseconds if there are downstream relays that need to settle. The relays in my preamp design are smaller and faster so 29msec should be more than adequate.
4. The delay is open-loop; there is no confirmation that downstream units have switched, so don't try for excessively short delays. (Some excellent commercial units actually check downstream state changes!)
5. At 20wpm, the length of a CW "dit" is 60milliseconds. On CW, if you set the delay for 40-60milliseconds and send one "dit" at the beginning of your transmission, the following characters should be transmitted corrected. If you press the mic PTT and delay speaking just an instant, the transmitter should catch your first word.