

**FT-891 Amplifier/Preamp Sequencer**  
**Version 1.1**  
**John Price - WA2FZW**

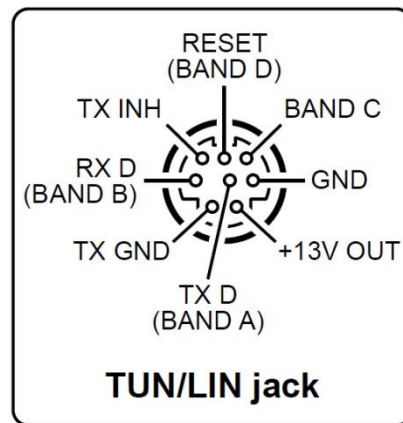
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## Introduction

This document describes a sequencer used to switch a Heathkit SB-200 linear (or pretty much any other) amplifier and an antenna mounted receive preamplifier that I use with my [Yaesu FT-891](#) radio. My SB-200 has been converted for 6 meter operation only and the [particular preamp I'm using](#) is also for 6 meters.

Although designed specifically for the FT-891, it should work with any Yaesu radio which has the same *TUN/LIN* mini-DIN connector arrangement:



Additionally, it will probably work with any linear amplifier and with any preamp that relies on being switched based on whether or not it is receiving power (13 volts in this device).

Why would one need such a device you might ask? The preamplifier I'm using is the [EME220-6M from Mini-Kits in Australia](#)<sup>1</sup>. It has an RF sensing circuit built in that can switch it from receive mode to transmit (bypass) mode however, that circuit can only handle 100 watts; my SB-200 puts out about 400 watts, thus it is necessary to switch the preamp into transmit mode before sending all that power through it. Also note that this specific preamp is only rated to 500 watts even when sequencing is used.

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<sup>1</sup>As Mini-Kits does not provide the schematic or manual for the preamp online, I can't provide a link to that, and for copyright reasons, can't insert it here.

If your radio doesn't have this capability, this device probably won't work as designed.

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 (which could be mounted on or off the PCB).

The diagram illustrates a portable radio receiver circuit. Key components and their connections include:

- Radio Tuner (U1):** Labeled "Radio TUN/LIN", it has pins for TX INH, BAND D, BAND C, BAND B, RX / BAND B, TX / BAND A, GROUND, TX GROUND, and +13V OUT. It is connected to a 5V supply and ground.
- LCA-110 (U2):** An audio amplifier with pins for NC, +L, -L, and +C. It is connected to the radio tuner and the Arduino Nano.
- Arduino Nano (U3):** A microcontroller with pins for VIN, GND, RST, TX, RX, and various digital pins. It is connected to a 5V supply and ground.
- Pre-amplifier (K2):** Labeled "K2 PREAMP", it is connected to the LCA-110 and the Arduino Nano.
- Speaker (K1):** Labeled "K1 AMPLIFIER", it is connected to the pre-amplifier and the Arduino Nano.
- Power Supply:** A 5V supply is connected to the circuit, with a 10K resistor (R2) and a 680R resistor (R1) used for voltage regulation.
- Other Components:** The circuit includes a switch (SW2), a speaker (K1), and various resistors (R1, R2, R3, R4, R5) and capacitors (C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C31, C32, C33, C34, C35, C36, C37, C38, C39, C40, C41, C42, C43, C44, C45, C46, C47, C48, C49, C50, C51, C52, C53, C54, C55, C56, C57, C58, C59, C60, C61, C62, C63, C64, C65, C66, C67, C68, C69, C70, C71, C72, C73, C74, C75, C76, C77, C78, C79, C80, C81, C82, C83, C84, C85, C86, C87, C88, C89, C90, C91, C92, C93, C94, C95, C96, C97, C98, C99, C100, C101, C102, C103, C104, C105, C106, C107, C108, C109, C110, C111, C112, C113, C114, C115, C116, C117, C118, C119, C120, C121, C122, C123, C124, C125, C126, C127, C128, C129, C130, C131, C132, C133, C134, C135, C136, C137, C138, C139, C140, C141, C142, C143, C144, C145, C146, C147, C148, C149, C150, C151, C152, C153, C154, C155, C156, C157, C158, C159, C160, C161, C162, C163, C164, C165, C166, C167, C168, C169, C170, C171, C172, C173, C174, C175, C176, C177, C178, C179, C180, C181, C182, C183, C184, C185, C186, C187, C188, C189, C190, C191, C192, C193, C194, C195, C196, C197, C198, C199, C200, C201, C202, C203, C204, C205, C206, C207, C208, C209, C210, C211, C212, C213, C214, C215, C216, C217, C218, C219, C220, C221, C222, C223, C224, C225, C226, C227, C228, C229, C230, C231, C232, C233, C234, C235, C236, C237, C238, C239, C240, C241, C242, C243, C244, C245, C246, C247, C248, C249, C250, C251, C252, C253, C254, C255, C256, C257, C258, C259, C260, C261, C262, C263, C264, C265, C266, C267, C268, C269, C270, C271, C272, C273, C274, C275, C276, C277, C278, C279, C280, C281, C282, C283, C284, C285, C286, C287, C288, C289, C290, C291, C292, C293, C294, C295, C296, C297, C298, C299, C300, C301, C302, C303, C304, C305, C306, C307, C308, C309, C310, C311, C312, C313, C314, C315, C316, C317, C318, C319, C320, C321, C322, C323, C324, C325, C326, C327, C328, C329, C330, C331, C332, C333, C334, C335, C336, C337, C338, C339, C340, C341, C342, C343, C344, C345, C346, C347, C348, C349, C350, C351, C352, C353, C354, C355, C356, C357, C358, C359, C360, C361, C362, C363, C364, C365, C366, C367, C368, C369, C370, C371, C372, C373, C374, C375, C376, C377, C378, C379, C380, C381, C382, C383, C384, C385, C386, C387, C388, C389, C390, C391, C392, C393, C394, C395, C396, C397, C398, C399, C400, C401, C402, C403, C404, C405, C406, C407, C408, C409, C410, C411, C412, C413, C414, C415, C416, C417, C418, C419, C420, C421, C422, C423, C424, C425, C426, C427, C428, C429, C430, C431, C432, C433, C434, C435, C436, C437, C438, C439, C440, C441, C442, C443, C444, C445, C446, C447, C448, C449, C450, C451, C452, C453, C454, C455, C456, C457, C458, C459, C460, C461, C462, C463, C464, C465, C466, C467, C468, C469, C470, C471, C472, C473, C474, C475, C476, C477, C478, C479, C480, C481, C482, C483, C484, C485, C486, C487, C488, C489, C490, C491, C492, C493, C494, C495, C496, C497, C498, C499, C500, C501, C502, C503, C504, C505, C506, C507, C508, C509, C510, C511, C512, C513, C514, C515, C516, C517, C518, C519, C520, C521, C522, C523, C524, C525, C526, C527, C528, C529, C530, C531, C532, C533, C534, C535, C536, C537, C538, C539, C540, C541, C542, C543, C544, C545, C546, C547, C548, C549, C550, C551, C552, C553, C554, C555, C556, C557, C558, C559, C560, C561, C562, C563, C564, C565, C566, C567, C568, C569, C570, C571, C572, C573, C574, C575, C576, C577, C578, C579, C580, C581, C582, C583, C584, C585, C586, C587, C588, C589, C590, C591, C592, C593, C594, C595, C596, C597, C598, C599, C600, C601, C602, C603, C604, C605, C606, C607, C608, C609, C610, C611, C612, C613, C614, C615, C616, C617, C618, C619, C620, C621, C622, C623, C624, C625, C626, C627, C628, C629, C630, C631, C632, C633, C634, C635, C636, C637, C638, C639, C640, C641, C642, C643, C644, C645, C646, C647, C648, C649, C650, C651, C652, C653, C654, C655, C656, C657, C658, C659, C660, C661, C662, C663, C664, C665, C666, C667, C668, C669, C670, C671, C672, C673, C674, C675, C676, C677, C678, C679, C680, C681, C682, C683, C684, C685, C686, C687, C688, C689, C690, C691, C692, C693, C694, C695, C696, C697, C698, C699, C700, C701, C702, C703, C704, C705, C706, C707, C708, C709, C710, C711, C712, C713, C714, C715, C716, C717, C718, C719, C720, C721, C722, C723, C724, C725, C726, C727, C728, C729, C730, C731, C7

Relays K1 and K2 are used to key the amplifier (my SB-200 has been modified to have a low voltage keying input as opposed to the original 110V arrangement) and provide power to the preamp respectively.

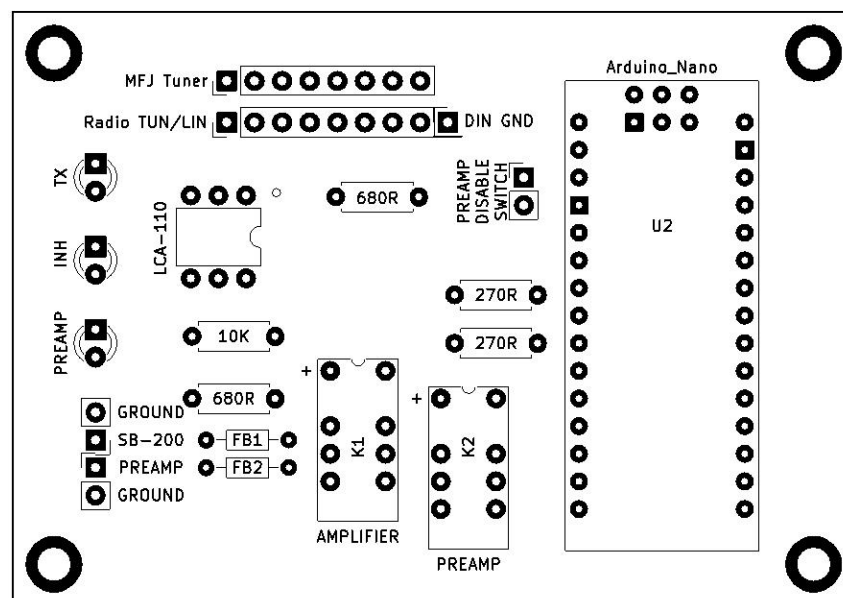
The LEDs indicate when the radio's PTT line is active (red), when the *TX INH* is active (yellow) and when the preamp is in receive mode (green). The transmit and inhibit LEDs are operated by the software in the processor but the preamp LED is operated by the relay which supplies power to the preamp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

SW2 allows the preamp to be disabled (always in bypass mode).

J1 and J4 provide a means to connect 8 pin mini-DIN jacks like the one on the back of the radio. This allows the radio to also work with the Yaesu tuners or the [MFJ-969Y tuner](#) which I use on HF. If you don't need the capability to operate an automatic tuner, you need only connect the radio. Also note that even though the pads on the PCB are labeled as being for the radio and the tuner, there is no difference; in other words, either device can be connected to either pad.

The *DIN GND* pad on the PCB provides a convenient place to connect a ground wire that goes to the shell grounds on the mini-DIN connectors, the connectors for the amplifier and preamplifier (I used RCA jacks) and the ground side of the preamp enable/disable switch.

Here's what the printed circuit board looks like:



If you use the same [mini-DIN jacks](#) as I used, here's the color codes and pin names used by Yaesu and MFJ for the various pins:

| Pin | Color  | FT-891 Nomenclature | MFJ-939Y Nomenclature |
|-----|--------|---------------------|-----------------------|
| 1   | Red    | TX INH              |                       |
| 2   | Orange | RESET (BAND D)      |                       |
| 3   | Yellow | BAND C              |                       |
| 4   | Green  | RX D (BAND B)       | TT/KY/TX              |
| 5   | Blue   | TX D (BAND A)       | TS/ST/RX              |
| 6   | Black  | GROUND              | GROUND                |
| 7   | White  | TX GROUND           |                       |
| 8   | Brown  | +13V OUT            | Power In              |

## 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               |
| TX_INH_LED    | 6 | Transmit inhibit LED                 |
| AMP_RELAY     | 7 | Operates the SB-200 relay            |
| PREAMP_RELAY  | 8 | Operates the preamp relay            |
| PREAMP_SWITCH | 9 | Preamp enable/disable switch         |

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

|         |      |   |
|---------|------|---|
| AMP_ON  | LOW  | A LOW on the <i>AMP_RELAY</i> pin keys the SB-200 |
| AMP_OFF | HIGH |   |

Those definitions are followed by definitions for the time delays needed in the sequences to switch from receive to transmit and vice-versa; the numbers are microseconds and are based on actual measured switching times plus rather large fudge factors; for a different amplifier and/or preamp, these might need to be adjusted:

|                |     |  |
|----------------|-----|--|
| AMP_ON_DLY     | 50  | Delay between turning the amplifier on and releasing the transmit inhibit line.    |
| AMP_OFF_DLY    | 50  | Delay between turning the amplifier off and returning the preamp to receive mode.  |
| PREAMP_ON_DLY  | 25  | Delay time between switching the preamp to transmit mode and keying the amplifier. |
| PREAMP_OFF_DLY | 100 | Currently not used   |

There are only three global variables:

|               |  |
|---------------|--|
| txState       | Current transmit/receive state                 |
| oldTxState    | Previous transmit/receive state                |
| preampEnabled | True when the switch is in the enable position |

## 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 accidentally 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 13V 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 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 requested (*PREAMP\_RX* or *PREAMP\_TX*).

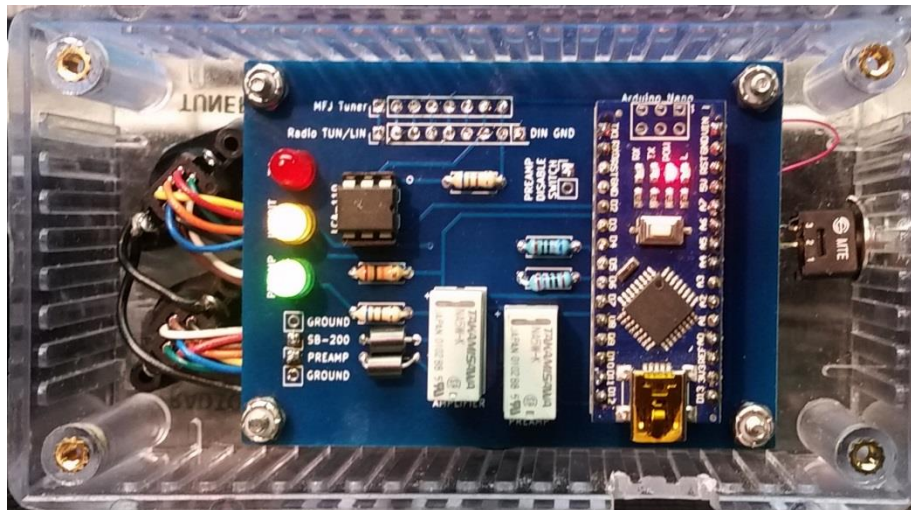
When the argument is *PREAMP\_TX*, the preamp will always be put into transmit (bypass) mode.

However, if the argument is *PREAMP\_RX*, the preamp will only be switched into receive (active) mode if the preamp enable switch is in the enabled position and the PTT is not currently active (*TX\_OFF*).

## Construction

I built the unit into a [Hammond 1951C plastic project box](#). These are not only available from Amazon, but most of the common component suppliers stock them as well. I actually got mine at a local electronics store (yes, a few of those still exist).

Here's the front view of the completed unit in receive mode:



You can see the mini-DIN connectors for the radio and the tuner mounted on the rear side of the box on the left and the preamp enable/disable switch on the right. Not visible under the circuit board are the two RCA jacks for the amplifier and preamp connections.

## Some Operational Notes

### Preamp Overload Protection

My preamp contains circuitry to protect it from strong nearby signals (in-band or off-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.

### Digital Mode Inhibit Workaround

As mentioned in the [Introduction](#), the usability of this device depends on the fact that the Yaesu FT-891 has the transmit inhibit capability. But if you are working digital modes using [WSJT-X](#), there is a way of using this without the inhibit capability.



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.

## 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:

|         |                                |   |
|---------|--------------------------------|---|
| R1,R5   | 680R 1/4W                      |   |
| R2      | 10K 1/4W                       |   |
| R3,R4   | 270R 1/4W                      |   |
| FB1,FB2 | BL01RN1A1D2B                   | <a href="#">Available from Mouser</a>   |
| U1      | LCA-110 SSR                    | 6-pin DIP package; available from <a href="#">Mouser</a> and other common suppliers                     |
| U2      | Arduino Nano                   | I used clones which are much cheaper than genuine Arduinos.   |
| D1-D3   | General purpose LEDs<br>– 20mA | Pick whatever colors you like!  |
| SW2     | SPST Toggle switch             |   |
| K1,K2   | Fujitsu<br>NA5W-K DPDT relay   | <a href="#">Available from Jameco</a>   |
| J1,J4   | 8-pin male header              | Optional – I hardwired the mini-DIN jacks to the PCB  |
|         | 2 mini-DIN jacks               | <a href="#">CUI Devices MD-80PL100 - Available from Mouser</a>  |
| J2,J2   | 2-pin male header              | Or you can use a single 4-pin male header; again, I hardwired the amplifier and preamplifier connectors |
| J5      | Just a pad really              | A place to connect a ground wire for the mini-DIN shields and the RCA jacks                             |
|         | 2 RCA Jacks                    | Or whatever you like as connectors for the amplifier and preamp   |

|  |     |   |
|--|-----|---|
|  | Box | I used a Hammond 1591C. They are available from <a href="#">Amazon</a> and some of the other usual suppliers. |
|--|-----|---|

## Suggestion Box

I welcome any suggestions for further improvements. Please feel free to email me at [WA2FZW@ARRL.net](mailto:WA2FZW@ARRL.net).