MABEL, PiTone and Allstar for the Yaesu Fusion DR-1X Repeater

MABEL is a program designed to run on a Raspberry Pi 3 (rPi) in conjunction with Allstar/app-rpt controlling a Yaesu Fusion DR-1X repeater. PiTone is a program that can also run on the same Raspberry Pi as MABEL and produces a high fidelity sinewave CTCSS tone to be transmitted by the repeater so that FM only stations do not hear C4FM digital transmissions.

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MABEL Summary

MABEL is a program designed to run on a Raspberry Pi3 (rPi) in conjunction with Allstar/app-rpt controlling a Yaesu Fusion DR-1X repeater. Allstar provides the repeater control and linking capabilities when the repeater is operating in the analog FM mode. The DR-1X controller is used in the DIGITAL mode. MABEL supervises the switching of the repeater between Digital and FM.

MABEL functions by intercepting the CTCSS and PTT signals before they are sent to Allstar. A block diagram of the concept is shown below.

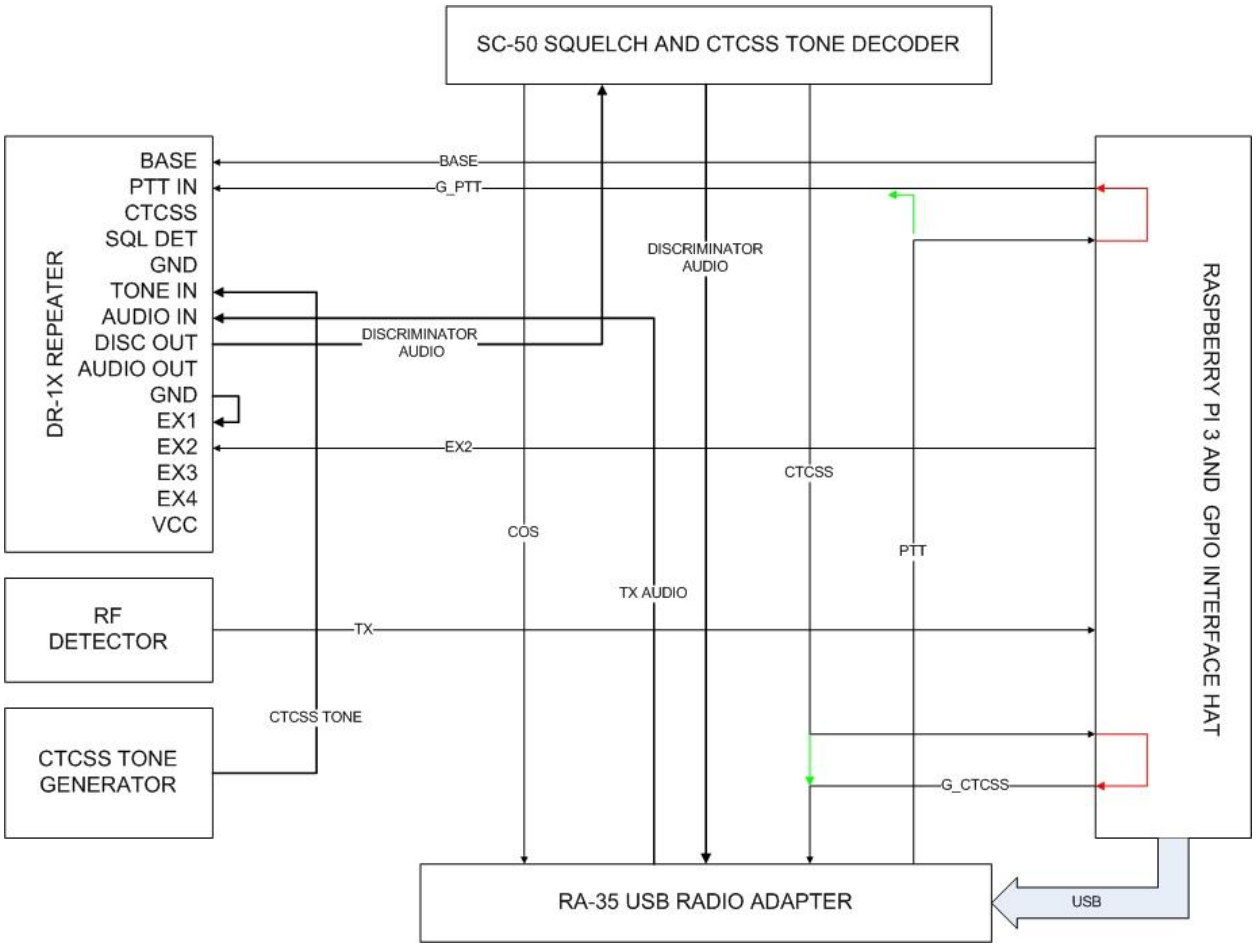


Figure 1 – Allstar with MABEL for the Yaesu DR-1X concept

As shown in Figure 1, the CTCSS signal from the SC-50 CTCSS decoder is routed to the MABEL rPi instead of directly to its normal destination, the RA-35 USB Radio Adapter. Likewise, the PTT signal from the USB Radio Adapter is routed to the MABEL rPi instead of the repeater. Substitute signals generated by MABEL (labeled G_CTCSS and G_PTT) are then routed to the USB Radio Adapter and the repeater. The routing change of the signals from the normal Allstar configuration (green lines) to the DR-1x with MABEL implementation (red lines) are shown in Figure 1.

In Allstar with MABEL operation, the DR-1X repeater controller is configured to operate in the AUTO-AUTO mode. The DR-1X internal repeater controller is configured to **not** activate on the assigned CTCSS tone by setting it to some unused tone. Instead, the desired CTCSS signal is decoded by the SC-50 decoder. MABEL monitors this CTCSS detected signal from the SC-50, as well as the PTT signal from Allstar via the USB Radio Adapter interface. Upon receiving a valid CTCSS signal or PTT signal, MABEL first checks the RF Detector signal to ensure the DR-1X transmitter is not active, then initiates a switch to the FM mode. Checking the RF Detector signal prevents the DR-1X from locking-up during the switch. (NOTE: Using the RF Detector output eliminates the need to splice into an internal cable in the DR-1X to verify the transmitter is not active.)

MABEL completes the switch to the FM mode in less than 200 milliseconds. The substitute CTCSS signal, now designated as the gated CTCSS signal (G_CTCSS) is applied to the USB Radio Adapter less than 1 millisecond later, allowing Allstar to perform its normal repeater controller and linking tasks. Similarly, the substitute PTT signal from MABEL is applied to the DR-1X transmitter as G_PTT.

Mabel continually monitors the CTCSS and PTT signals while the repeater is in FM mode. When valid CTCSS or PTT signals are not received for five seconds, MABEL automatically switches from FM mode back to the Digital mode.

Since MABEL works by intercepting the CTCSS and PTT signals and monitoring the transmitted RF signal, no modifications are required to the Allstar program. MABEL has been tested with several Allstar Distributions for the Raspberry Pi. The two distributions for the Raspberry Pi currently in wide use are:

1. DIAL for Raspberry Pi 2/3. It is available at http://wiki.allstarlink.org/wiki/Main_Page

2. RPi2-3 Image Version 1.5rc2. It is available at https://hamvoip.org/#image .

PiTone Summary

The Allstar distros for the rPi utilize the SimpleUSB channel driver which does not provide the capability to generate a CTCSS transmit tone. Especially in DR-1X applications, a CTCSS transmit tone is desired so that analog-only FM stations remain squelched without having to hear the “noise” during Yaesu Fusion digital transmissions.

PiTone is a program that runs on an rPi and produces a highly accurate CTCSS tone using a digital to analog converter (DAC) to generate a stepped sinewave approximation. Command line parameters set PiTone’s CTCSS frequency, the number of steps used to approximate the sinewave, and the amplitude of the sinewave. Example waveforms for 16, 32, 64 and 128 steps are shown below.

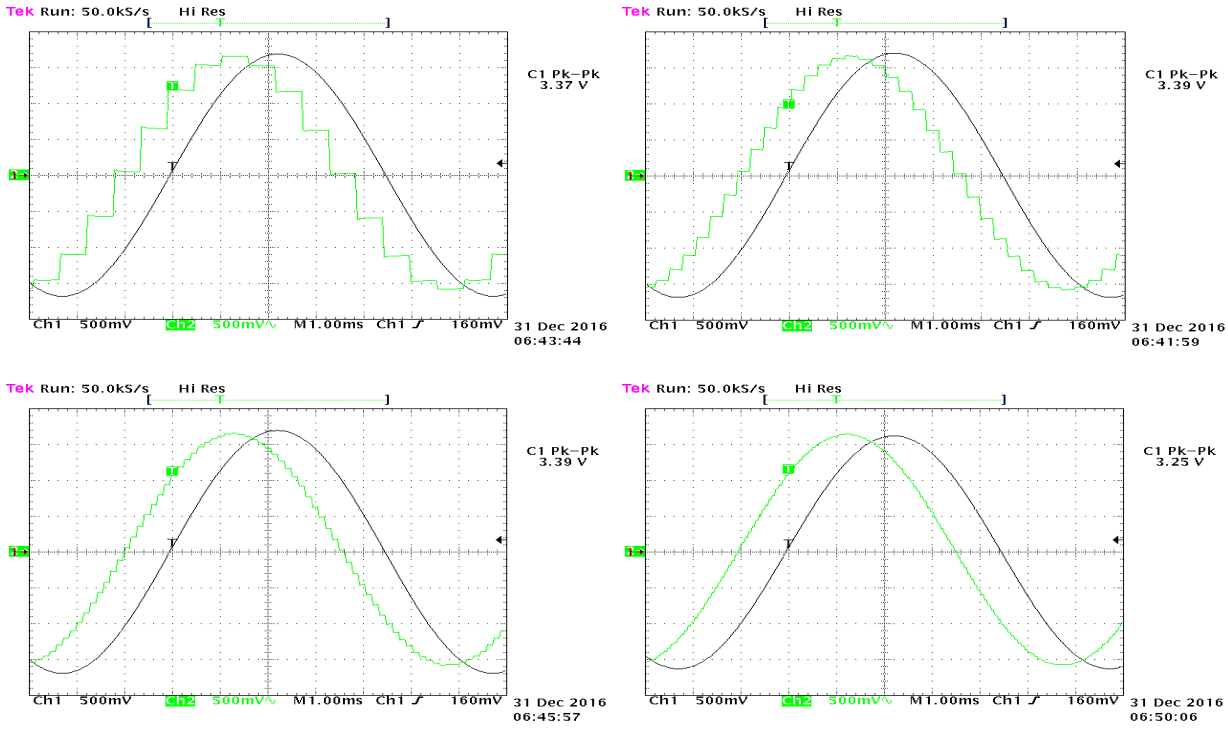


Figure 2 – PiTone output raw (green) and low pass filtered (black) for 16, 32, 64, 128 steps

MABEL/Allstar for the DR-1X Electronics Implementation

As shown in Figure 1, implementation of the MABEL/Allstar configuration requires a number of functions including:

- CTCSS encoder and decoder
- Squelch detector
- USB Radio Adapter
- GPIO interface electronics
- RF detector

A custom printed circuit board called the MABEL/DR-1X Interface Board has been designed to simplify the Allstar / MABEL / PiTone implementation. Figure 3 shows how this board is used with other commercially available modules.

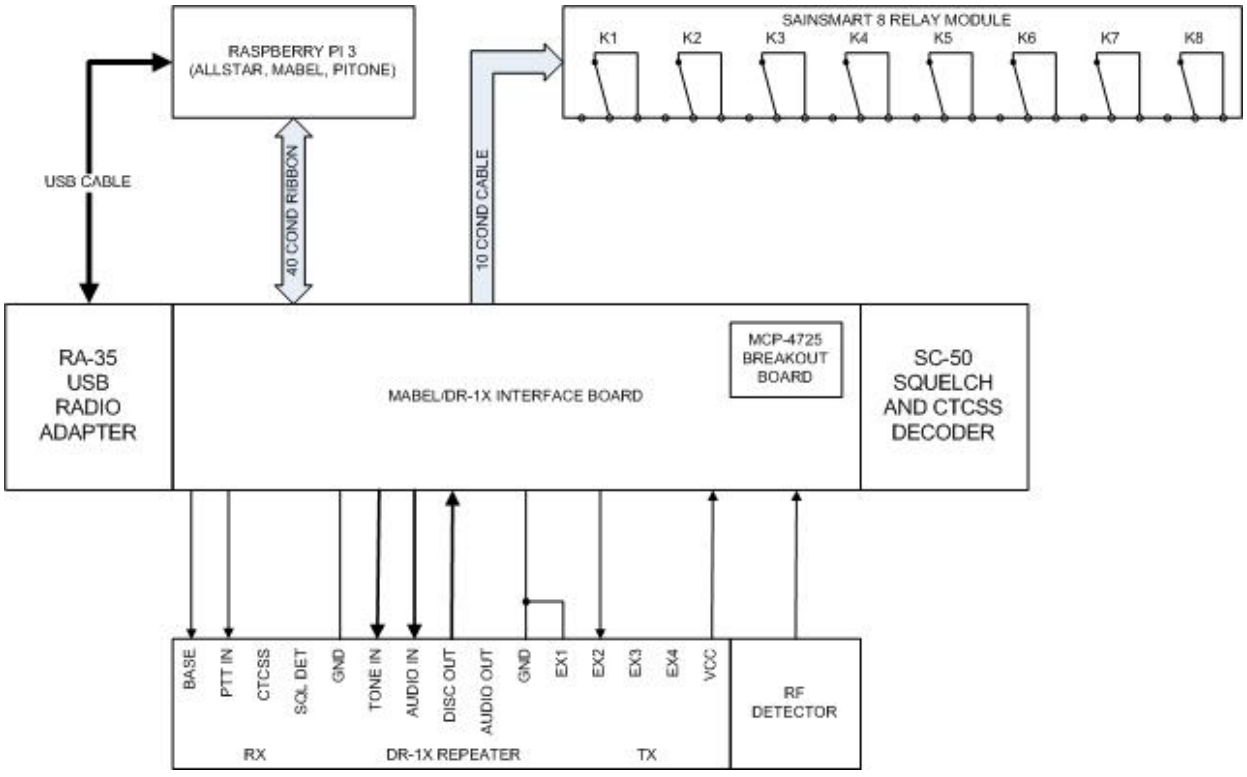


Figure 3 – MABEL/DR-1X Interface Board used to simplify connecting to the DR-1X Repeater

As shown in Figure 3, the SC-50 Squelch/CTCSS Decoder board and the RA-35 USB Radio Adapter (available from www.masterscommunications.com) plug directly into the interface board via their 25 pin and 9 pin d-sub connectors. The MABEL rPi connects to the board via a 40 pin ribbon cable. The Allstar rPi connects to the RA-35 USB Radio Adapter via a USB cable. The DR-1X control connector (15 pin HD DE-9) and RF Detector are connected to screw terminal headers on the board. The board has a 6 pin header to accept an MCP-4725 DAC breakout board used to generate transmit CTCSS via the PiTone program. A three pole low pass filter is also included to filter the stepped sine wave PiTone output. Finally, a 10 pin header is available to connect an optional SainSmart 8 relay board for controlling other external circuits.

MABEL/DR_1X Interface Board

Photo 1 shows the MABEL/DR-1X Interface Board (with optional inputs populated).

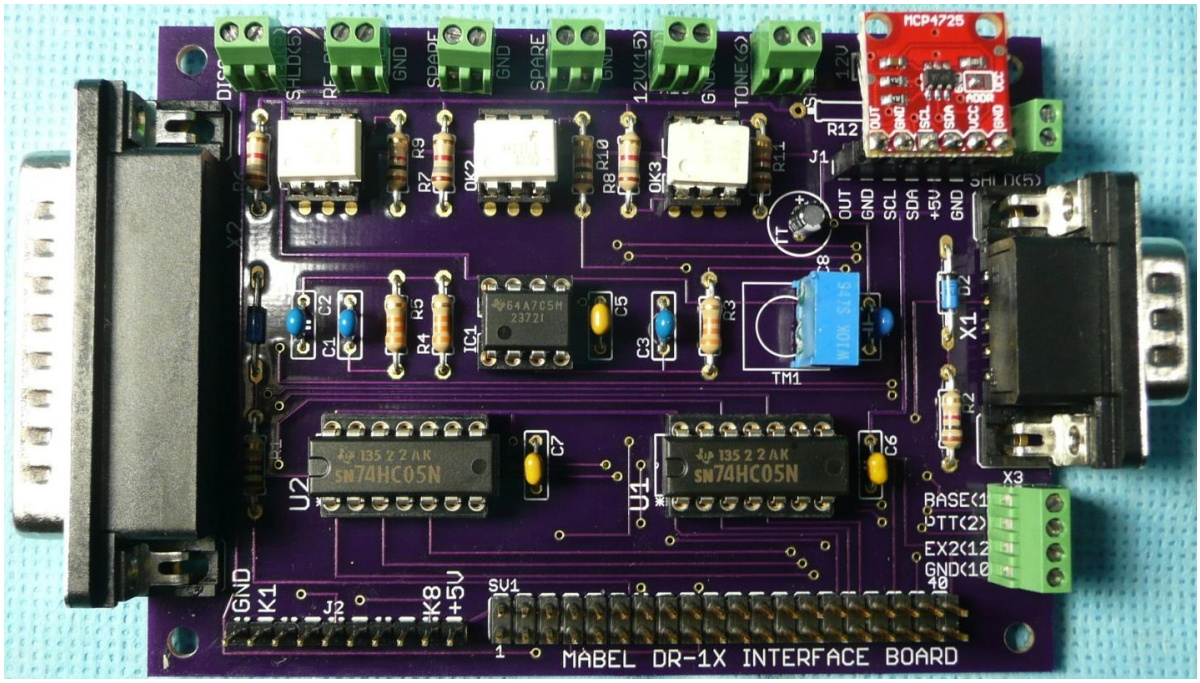


Photo 1 – MABEL/DR-1X Interface Board

As shown in Photo 1, the MABEL/DR-1X Interface Board has two right angle dsub connectors, a DB-25 and DE-9 on the left and right edges of the board. The SC-50 CTCSS/Squelch board plugs into the DB-25 connector (X2) and the RA-35 USB Radio Adapter plugs into the DE-9 connector (X1). A 40 pin header (SV1- bottom right edge of the board) is used to connect the MABEL rPi. The Sainsmart relay module plugs into

a 10 pin header (J2 - bottom left edge of the board). A six pin header (top right corner of the board) is used to install the MCP4725 DAC breakout board used for the PiTone CTCSS encoder. A three pole low pass filter (IC1 and associated components located across the middle of the board) is used to filter the PiTone output. TM1 (blue potentiometer) sets the coarse level of the CTCSS signal. Provision is made for three inputs via optoisolators (OK1 thru OK3 – white IC's). One of these is used for the RF Detector while the other two are spares for user inputs. Other connections to the board are made using screw terminal inputs (green connectors).

Photo 2 contains the Interface Board with all associated modules shown in the Figure 3 diagram.

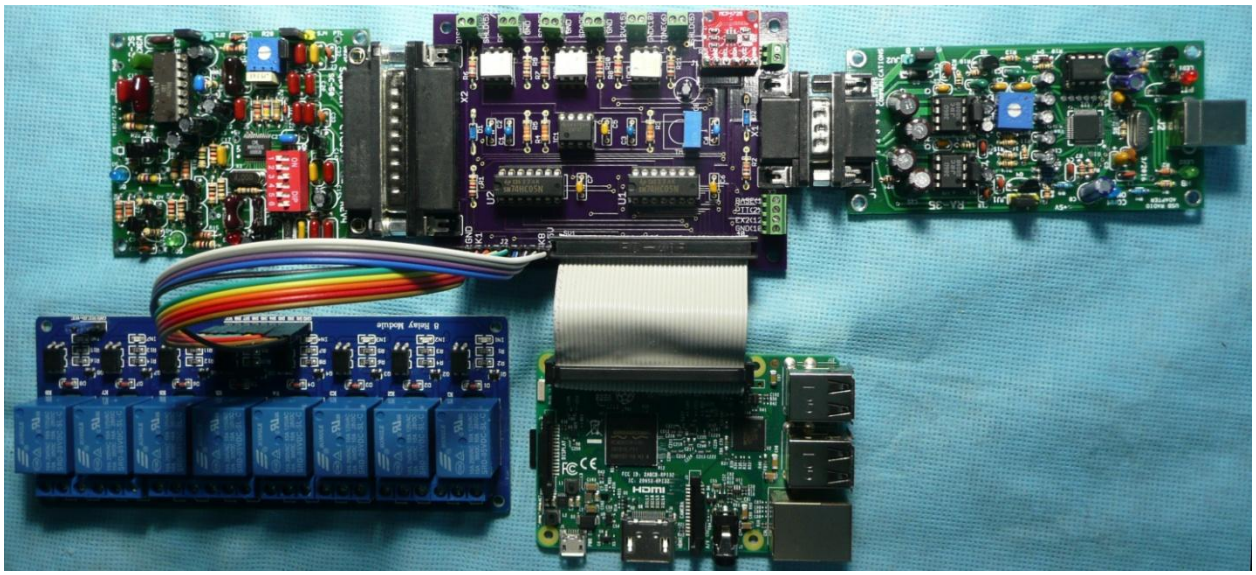


Photo 2 – MABEL/DR-1X Interface Board with other modules and rPi

RF Detector

To prevent the DR-1X repeater from “hanging up,” during switching between AUTO-AUTO and FM-FM the repeater controller must verify that the DR-1X is not transmitting before attempting to switch modes. In currently available controllers used with the DR-1X - such as the Arcom ADR board and the SCOM 7330 - this verification requires monitoring the PTT signal internal to the DR-1X. Access to that internal signal is accomplished by opening up the repeater, cutting open a cable and splicing to the wire carrying the PTT signal.

Instead, MABEL was designed to verify that the DR-1X is not transmitting by monitoring the RF output of the repeater. The RF monitor circuit uses an inexpensive 800 MHz to 2 GHz directional coupler (available on eBay for about $10 from US and Chinese vendors) and an RF Detector/Switch (easily fabricated)

Note: Directional couplers generally work well outside their specified frequency range. Coupled output just decreases in level. The directional coupler shown in Photo 3 is specified as a 15 dB coupler in the 800 MHz to 2 GHz range

Any RF detector which provides the capability to sink 2 mA of current from the optocoupler LED on the MABEL/DR-1X Interface Board is suitable. Figure 4 contains a schematic of one such RF Detector/Switch. Use it with a 20 dB nominal, 800 to 2 GHZ coupler if you are running your DR-1X at 20 watts. Use a 15 dB nominal coupler if you use the 5 watt output level.

Photos 3, 4, 5 and 6 show a prototype coupler and RF detector.

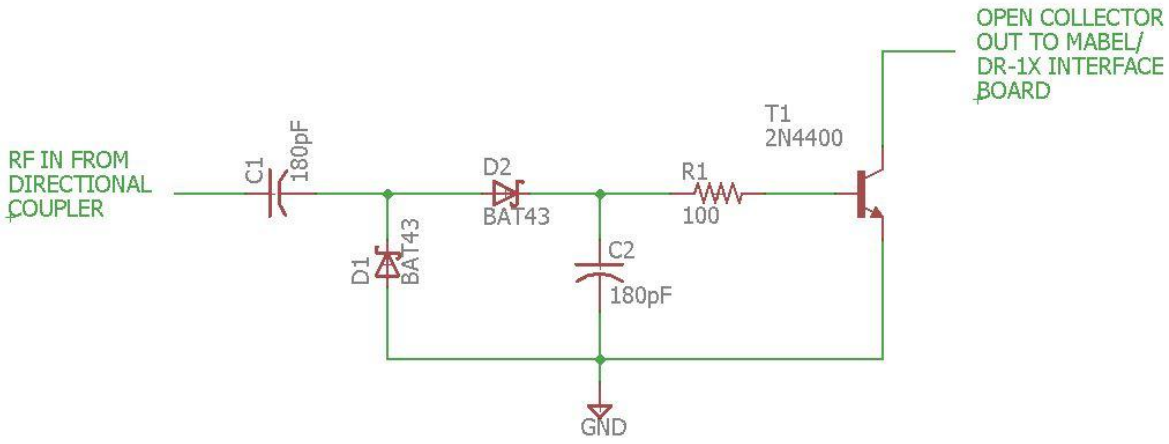


Figure 4 – RF Detector/Switch Schematic

Photo 3 – Typical directional coupler available on eBay

Photo 4 – RF Detector assembly

Photo 5 – RF Detector internal view

HARDWARE SETUP TO USE MABEL AND THE MABEL/DR-1X BOARD

SC-50 Squelch/CTCSS Decoder

The SC-50, REV 4 board has 3 jumpers that need to be set.

- SJ1/SJ2 - Install jumper in SJ1 position
- SJ3/SJ4 - Install jumper in SJ3 position
- SJ5 - Install jumper for SJ5

The SC-50 also has a six position DIP switch to set the CTCSS receive frequency. Set this DIP switch per the table provided with the board documentation on the Masters Communications site.

R20 is a potentiometer used to set the receive squelch level. After connecting the boards to the DR-1X repeater, adjust R20 as required by observing the green COS LED.

RA-35 USB Radio Adapter

The RA-35 USB Radio Adapter board has four jumpers that need to be set.

- JU1 A/B - Install jumper in B position
- JU2 A/B - Install jumper in A position
- H1 - Install jumper over the two middle pins on the 4 pin header
- H2 - Install jumper over the two middle pins on the 4 pin header

R5 is a potentiometer used to set the level of the receive audio sent to the CM119 USB Audio Controller. Set it to mid-position (i.e. 50% of rotation). You can fine-tune the level later in this procedure when setting up Allstar.

MABEL/DR-1X Interface Board

The MABEL/DR-1X Interface Board has no jumpers. Assuming you have installed the parts for the PiTone option to generate a transmit CTCSS tone, potentiometer TM1 is used to set the approximate CTCSS tone deviation (600 to 800 Hz). This level is deliberately set higher using the pot and reduced as required via a command line argument when invoking PiTone. Set this potentiometer to about one-third CCW rotation from the full CW position. (**NOTE:** The level increases as the potentiometer is rotated from CW to CCW)

DR-1X REPEATER SETUP

Begin the installation process by setting up the DR-1X repeater for normal use and verify it is working correctly.

Then, for use with the MABEL/Allstar external controller make the following changes to the DR-1X setup.

- In SIGNALING, set the TONE frequency to an unused CTCSS frequency. The desired frequency will have already been set during the SC-50 board DIP switch configuration. This arrangement shifts responsibility for CTCSS detection from the DR-1X internal controller to the MABEL/Allstar external controller.
- In MODE-REMOTE, turn Remote to "ON"

WIRING

Connect the MABEL/DR-1X interface board to the 15 pin HD VGA control connector on the rear of the repeater. All of the connections to the interface board are shown in silkscreen on the board. In order to minimize the chances of noise pickup, the audio connections (wires 7, 8 and 9) use shielded cables, and the power connection (wires 5 and 6) uses a twisted pair. Use a heavier gauge wire such as 20 AWG for the power connections. The connections are shown in Figure 1 and the following wiring table.

A breakout board for the Control I/O HD VGA connector on the rear panel of the DR-1X repeater is highly recommended, as shown photo 6. They are available from Adafruit (PN 3125), AtomsIndustries (PN ASD1564) and on eBay from Chinese vendors in various styles. The pin labeling varies on the different styles available. Thus, for wiring convenience you may use pins 5 or 10 interchangeably for ground and shield connections. Be sure to use jack screws to fasten the breakout board connector to the Control I/O connector jack posts.

Note that wire #10 is a jumper wire installed at the Control I/O connector.

WIRE #	DR-1X CONTROL I/O PIN NUMBER	SIGNAL NAME	MABEL/DR-1X CONN/PIN #	NOTES
1	1	BASE	X3-1	
2	2	PTT	X3-2	
3	12	EX2	X3-3	
4	10	GROUND	X3-4	
5	15	VCC (12VDC)	X10-1	TWIST WIRES 5 AND 6
6	10	GROUND	X10-2	TO CREATE A TWISTED PAIR
7	6	TONE IN (TONE)	X4-1	USE A SHIELDED CABLE FOR
7	5	TONE IN SHIELD	X4-2	WIRE 7
8	7	AF IN (AUDIO)	X6-1	USE A SHIELDED CABLE FOR
8	5	AF IN SHIELD	X6-2	WIRE 8
9	8	DISC OUT (DISC)	X5-1	USE A SHIELDED CABLE FOR
9	5	DISC OUT SHIELD	X5-2	WIRE 9
10	11	EX1		CONNECT A JUMPER WIRE
10	10	GROUND		AT DR-1X BTWN PINS 10 & 11
11	RF DETECTOR OUT	RF DET	X7-1	FROM RF DETECTOR
12	RF DETECTOR RTN	RF DETECTOR RETURN	X7-2	MODULE

Table 1 - MABEL/DR-1X interface board to DR-1X Control Connector wiring

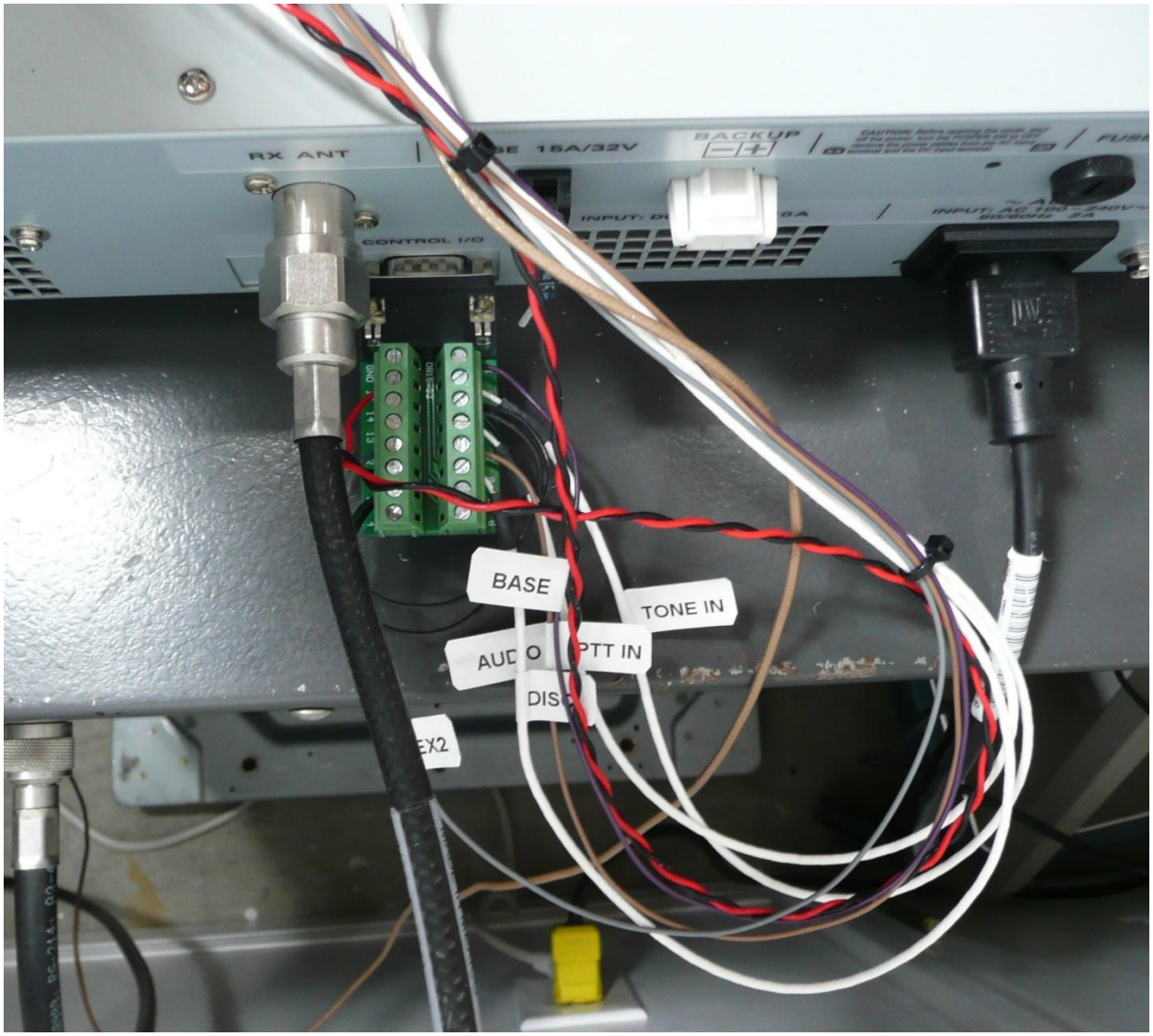


Photo 6 – Breakout board on DR-1X rear panel

ADDITIONAL FEATURES AND INFORMATION

EXTERNAL RELAY OUTPUTS

As shown in Figure 2 and Photo 3, the design of the MABEL/DR-1X Interface Board also provides for optional control of eight external devices using a SainSmart 8 Channel Relay Module available on the internet from multiple sources. The SainSMart relay module 10 pin header connects to the 10 pin header labeled J2 on the MABEL/DR-1X Interface Board in a one-to-one mapping with GND connecting to GND, K1 to IN1 and so on. Dupont female-to-female jumper cables work great for this connection. (see Figure 6)

These relays can easily be controlled using simple bash scripts as described by WA3DSP in this document:

http://www.crompton.com/hamradio/BeagleBoneBlackAllstar/GPIO_how-to.pdf

Sample scripts to turn on all the relays, turn off all the relays and test the relays are included in the setup files for the HamVOIP Allstar distro.

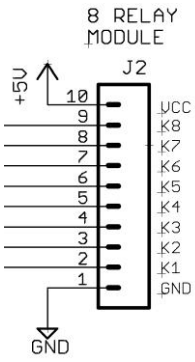


Figure 6 - Sainsmart Relay Module Connection to MABEL/DR-1X Interface Board

WARNING: The relay module has a second 3 pin header labeled GND | VCC | JD-VCC If a jumper is installed between VCC and JD-VCC, the relay coils are powered by the 5 VDC from the interface board which comes from the rPi. Each powered relay requires about 71 mA. Thus a module with all relays activated would require 568 mA for the relays and 40 mA for the optocouplers on the relay module – over 600 mA total which is being supplied by the rPi. If the jumper is removed, the relay board coils can be powered separately by providing 5 VDC to the pin labeled JD-VCC, greatly decreasing the 5 VDC load on the rPi. The relays are mapped to the rPi GPIO as follows:

GPIO#	TYPE	RELAY
GPIO4	OUTPUT	K1
GPIO16	OUTPUT	K2
GPIO17	OUTPUT	K3
GPIO18	OUTPUT	K4
GPIO19	OUTPUT	K5
GPIO20	OUTPUT	K6
GPIO21	OUTPUT	K7
GPIO26	OUTPUT	K8

Table 2 – Raspberry Pi GPIO to Sainsmart Relay Module Mapping

SPARE OPTO-COUPLED INPUTS

The signal from the RF detector module is received by the optocoupler labeled OK1 on the MABEL/DR-1X Interface Board. Two optioal optocoupler input circuits are provided for additional user inputs to the rPi using terminal blocks X8 and X9. These circuits and there GPIO assignments are shown in Figure 7.

To use the spare inputs connect the lead with the more positive voltage of your input signal to terminal 2 of the terminal block and the other, more negative lead to terminal 1. A 1.8K ohm resistor is provided on the board to set the current to the optocoupler. Voltages from 5 to 16 volts will work. Do not exceed a reverse voltage greater then 6 volts.

Also, optional terminal block X12 provides connections to +5 VDC and GND on the board. It can be used to provide a positive voltage to the optocoupler input (i.e. X8 or X9 terminal 2). A ground applied to the corresponding X8 or X9 terminal 1 will then activate that input. (**NOTE:** This +5 VDC comes directly from the rPi. It is not current limited so your rPi could be damaged if excessive current is drawn from it.)

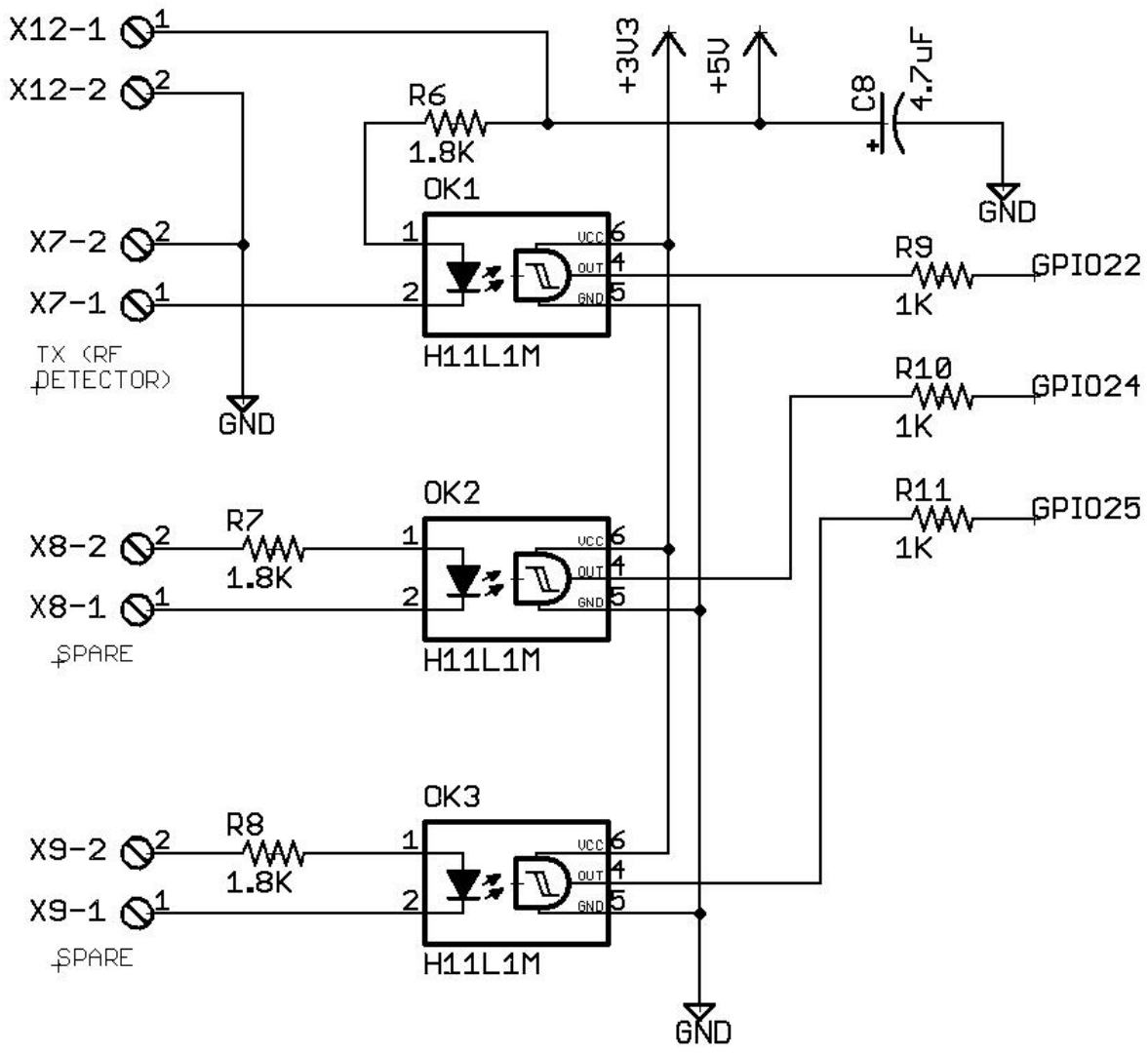
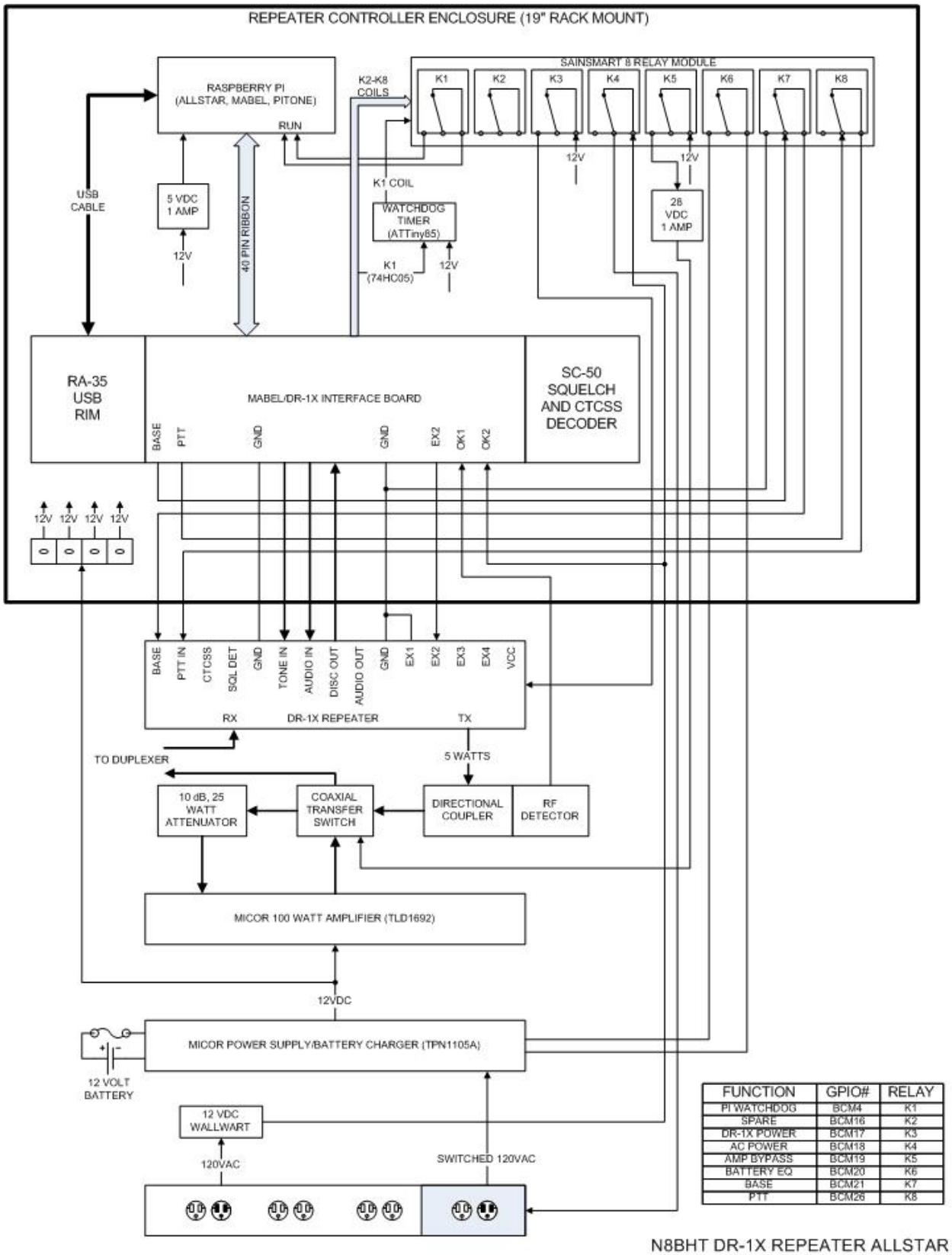


Figure 7 – Opto-coupled Inputs Schematic

THE N8BHT REPEATER CONFIGURATION

A block diagram showing the configuration used for the N8BHT repeater in South Lyon, Michigan is shown on the next page. (NOTE: The supplied scripts are used on this repeater). The DR-1X is powered using 13.5 VDC from a Motorola Micor power supply with battery backup. The DR-1X is run at 5 watts output. A 10 dB power attenuator reduces the 5 watts to 0.5 watts to drive a Motorola Micor 100 watt amplifier. The amplifier can be switched in and out using an RF transfer relay so the repeater can run at 5 watts to conserve battery power. A separate watchdog timer implemented with an ATTiny 85 is used to ensure the rPi is always running. The Sainsmart relay provides for a number of control features implemented with BASH scripts running on the rPi.



FUNCTION	GPIO#	RELAY
PI WATCHDOG	BCM4	K1
SPARE	BCM16	K2
DR-1X POWER	BCM17	K3
AC POWER	BCM18	K4
AMP BYPASS	BCM19	K5
BATTERY EQ	BCM20	K6
BASE	BCM21	K7
PTT	BCM26	K8

N8BHT DR-1X REPEATER ALLSTAR
CONTROLLER BLOCK DIAGRAM 1Pi
7/26/2017

ALTERNATE CONFIGURATION

The MABEL/DR-1X interface board has been designed to also work with the Masters Communications CT-30 CTCSS Tone Decoder board. The CTCSS circuitry on the two boards is identical. The SC-50 also includes the highly desired Motorola noise squelch circuitry. Additional information on this squelch circuit can be found at http://www.repeater-builder.com/micor/micor-bi-level-squelch-theory.html .

In the CT-30 configuration, the CT-30 is installed in place of the SC-50 and the COS signal is taken from the DR-1X (Pin 4 labeled SQL DET). A screw terminal labeled SQL(4) on the 4 pin screw terminal header on the MABEL/DR-1X Interface Board is provided for this connection (**NOTE:** do not use this terminal in the SC-50 configuration.**)**