

A multi-function sequencer

Leigh Harrison VK6WA

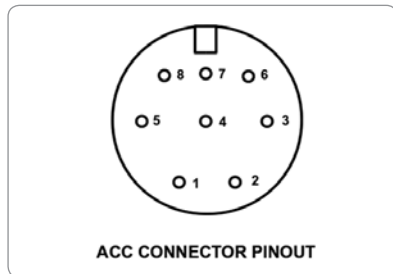


Figure 1: The ACC connector.

Introduction

This article describes a sequencer for controlling the timing of DC and coaxial relays used with various station configurations. It can be used to switch in or out power amplifiers for HF and VHF or UHF. In addition a preamplifier can be switched in or out if desired. It may also be used as a control system for transverters in the microwave bands. The idea for the Sequencer was based on an article in a German publication 'Funkamateu'(1). I wanted the Sequencer to be able to work with a Yaesu FT-817 which has an analogue band output as well other FT-8** series rigs which have a four-bit binary encoded band output. In addition it was intended to be also suitable for use with the Elecraft K3.

The three PCB mounted relays are controlled by the HF PA, VHF/UHF PA, preamp toggle switches and the rig's band setting.

If the rig is set to the 160 m - 6 m bands, the HF PA switch will close relay K3's contacts on transmit. If the rig is set to 2 m - 70 cm bands, the VHF/UHF PA switch will close relay K2's contacts on transmit. In addition, if the preamp switch is closed relay K3 contacts will close on receive and open on transmit.

Features

The sequencer has the following features.

Inputs:

- Push-to-talk from the rig, TX-GND signal.
- Band Data, either four-bit binary (FT-897 etc and K3) or analogue (0-5 V) (FT-817). Refer Table 2.
- Switches to select HF PA, VHF PA and preamplifier.

Outputs:

- Three 'floating' relay contacts available for switching linear amplifiers, a receiver preamplifier or transverters for the microwave bands.
- Four +12V pulsed outputs for driving two microwave relays used to switch VHF/UHF signals between preamplifiers, power amplifiers and microwave equipment as required. The pulse width is set at 10 ms. These outputs are only active on the two metre and 70 cm bands.
- TX-Inhibit signal to the rig. TX_INH is removed 100 ms after PTT is active. Voltage levels depend on the radio requirements. Yaesu uses +12 V and Elecraft K3 uses +5 V when TX_INH is active.

LED Indicators:

- PTT.
- TX-INHIBIT.
- HF PA relay contacts closed.
- VHF PA relay contacts closed.
- Preamplifier relay contacts closed.
- Band LEDs: HF, 6 m, 2 m, 70 cm.

Operating Voltage:

- 11-14 V DC (13.8 V nominal).

TX Inhibit function

When the TX Inhibit signal is active - Yaesu (+12 V) or Elecraft K3 (+5 V) no RF power is output from the rig. Pressing PTT or the key will result in no RF at the antenna connector(s). Conversely, when TX Inhibit is low (0 V) and PTT or the key is pressed, RF appears at the rig's antenna connector. The sequencer delays the removal of TX Inhibit for 100 ms after PTT or the key is pressed. This allows external equipment (power amplifiers or transverters) to be switched before the drive power is applied. The TX Inhibit signal appears on the rig's ACC connector - Refer Figure 1.

Band data

The band data is available from the ACC connector as four-bit binary code from the FT-897/FT-847/K3 or an analogue signal from the FT-817. Refer Table 1, below.

Typical Applications

See Figures 2a and 2b on page 2.

Circuit description

See Figure 3 on page 3.

Band	Analog level	* 4-bit binary	Band	Analog level	* 4-bit binary
1.8 MHz	0.12-0.48 V	0001	21 MHz	2.15-2.35 V	0111
3.5 MHz	0.5-0.84 V	0010	24.5 MHz	2.4-2.6 V	1000
7 MHz	0.87-1.1 V	0011	28 MHz	2.65-3.0 V	1001
10 MHz	1.15-1.4 V	0100	50 MHz	3.05-3.3 V	1010
14 MHz	1.45-1.67 V	0101	144 MHz	3.35-3.6 V	1011
18 MHz	1.75-2.1 V	0110	430 MHz	3.65-4.0 V	1100

Table 1: Band data.

*Note: Logic '1' is defined as +5V.

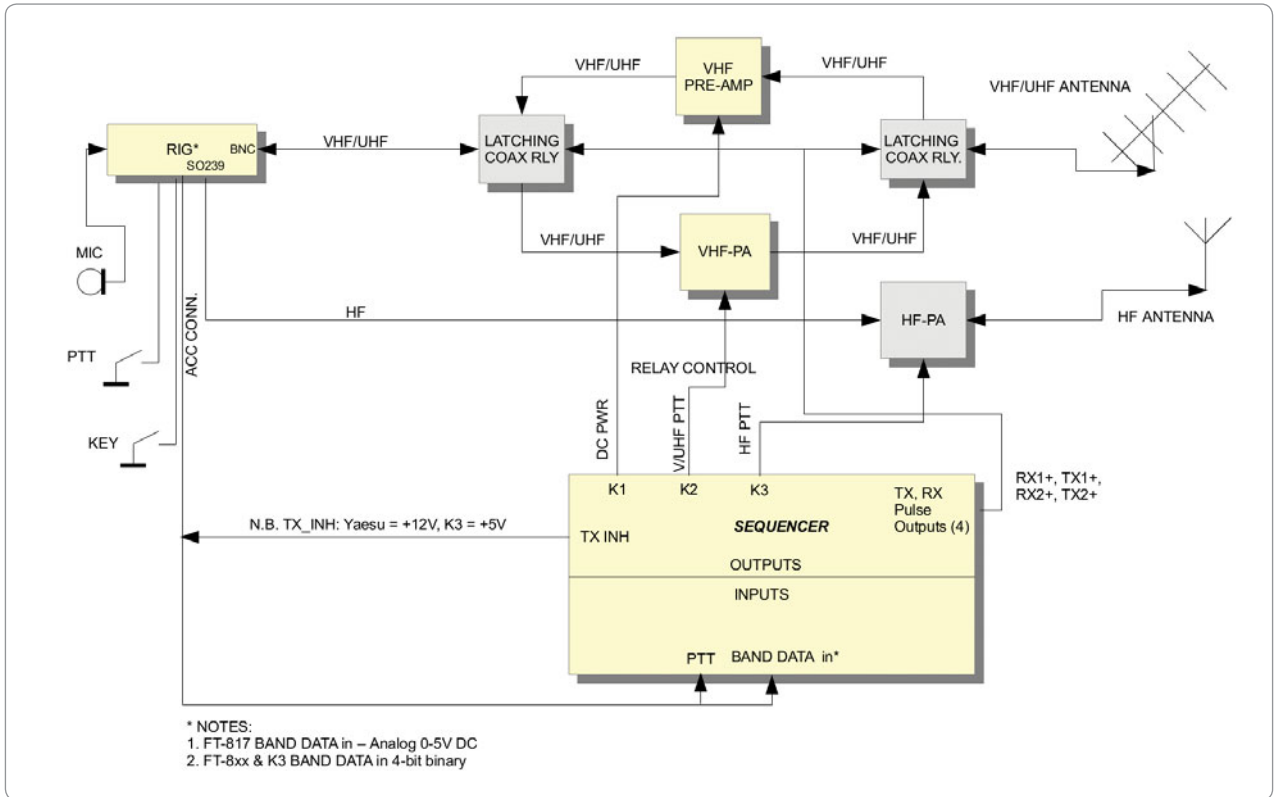


Figure 2a: Basic station configuration.

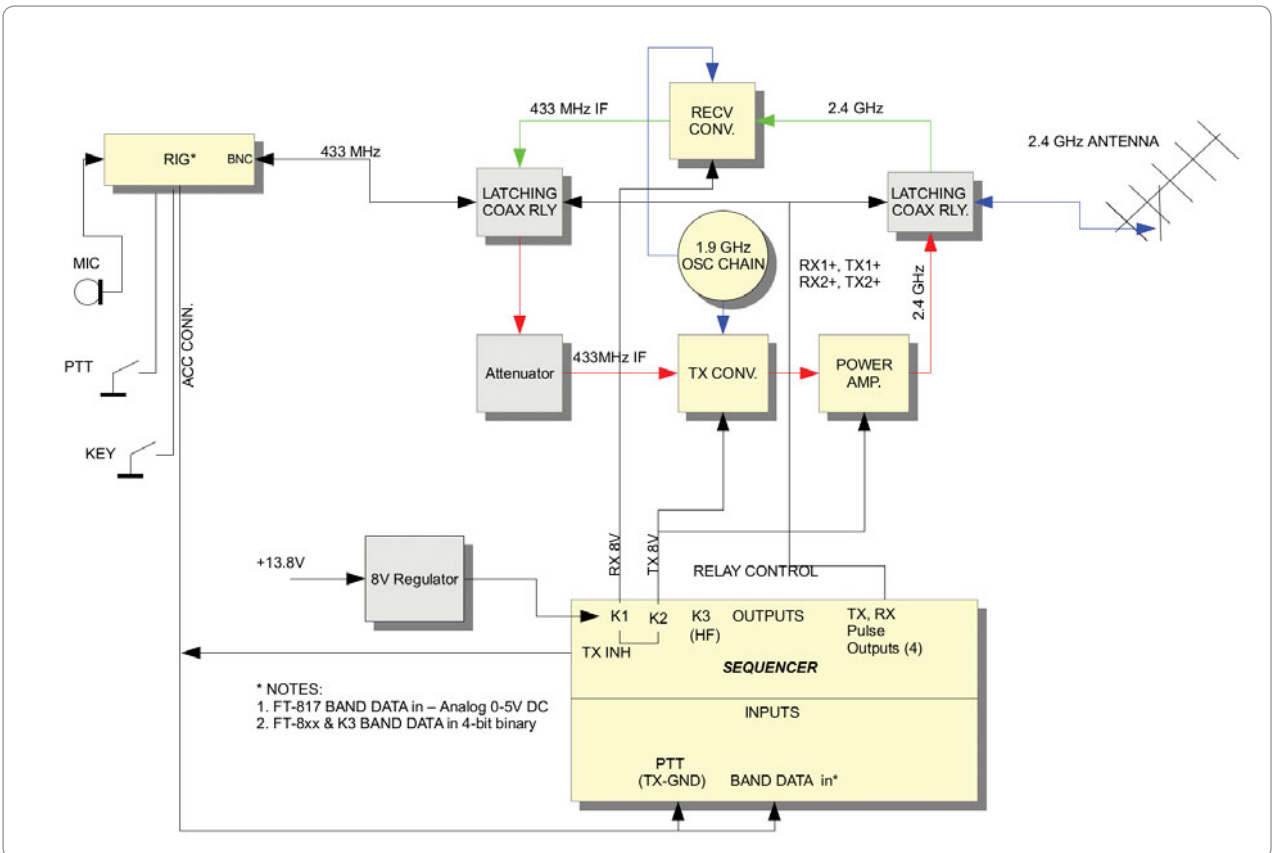


Figure 2b: 23 cm station configuration.

Overview

The sequencer consists of a printed circuit board housed in a 130 x 100 x 50 mm ABS case. The board contains the 7805, 5 V regulator (IC1), the ATMEGA 32 micro-controller (IC2), the relay driver chip ULN2300 (IC3), the three PCB mounted relays and the four coaxial relay pulse driver transistors (Q2 – Q5). Some of the components on the PCB are SMD types apart from the ICs, relays and connectors.

The front-panel has the three toggle switches (S1 – S3) and the indicator LEDs (1-9) hard-wired to a 16-way ribbon cable (PL3).

Jumpers

- **JP1** selects the rig type:
 - 1-2 selects the analog band data from the FT-817.
 - 3-4 selects the 4-bit binary data from the FT-897 etc and K3.
- **JP2** solder jumper selects the voltage level for TX_INH at Q1 collector:
 - 1-2 selects +12 V (Yaesu only!)
 - 3-4 selects +5 V Elecraft K3.

The main board has the following connections to the back-panel -

- PL4** 10-way header to 9-pin DB-9 (f) radio connector (ACC from rig).
- PL3** 10-way header to 9-pin DB9 (m) relay contact outputs
- SK1** 6-pin DIN board-mounted connector – pulse outputs to coaxial relays.
- J1** +13.8 V DC supply jack.

The board also has the following connections:

- PL1** 10-way flash programming connector for the ATMEGA32 micro-controller.
- PL2** 16-way front-panel ribbon connector to the front-panel assembly.

Schematic diagrams

The schematic diagram for the main board is shown in Figure 4 on page 4.

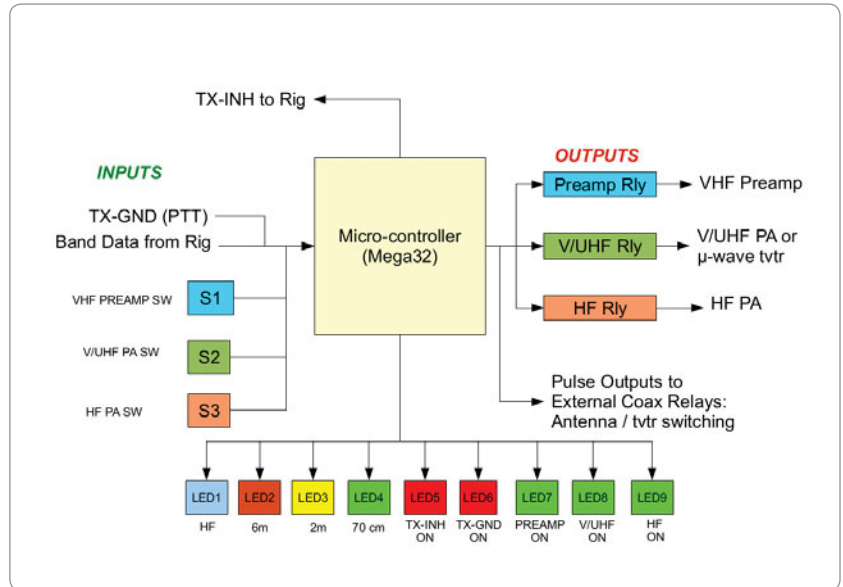


Figure 3: Sequencer block diagram.

I chose not to make a board for the front-panel to reduce cost and maximise the available space. The front-panel wiring is shown in Figure 5a on page 6.

Connections to the radio and DC relay contacts are wired to DB-9 connectors as shown in Figure 5b on page 6.

The sequencer cable connections are shown in the Tables 2 and 3.

The pin-outs for SK1 (the pulse outputs to the coax relays) are shown in Figure 6.

Indicator LEDs

The LEDs display the status of the sequencer as shown in Table 9.

Jumper settings

The sequencer can be configured to operate with either analogue band-data (FT-817) or 4-bit binary band-data (FT-897, K3, etc). The jumper settings are shown in Table 10. JP1 is a pin header, whereas JP2 is a solder type. JP2 was chosen as a solder link to avoid damage to K3 rigs.

Operation

At power-up the sequencer initialises the micro-controller. The

rig type is then determined by JP1 setting, 1-2 (Yaesu FT-817, 2-3 FT-8** others and the Elecraft K3). The band LEDs are then lit once in turn (HF, 6 m, 2 m, 70 cm). The outputs to external coaxial relays are pulsed to initialise the latched contacts. The watchdog timer is set to time out in 0.25 seconds.

The program enters the main loop and the watchdog timer is reset.

Receive

The status of switches S1, S2 and S3 are read and stored. The rig type is read to determine the type of band data to be used, depending upon the JP1 setting above. If JP1 is 1-2, the band data is read as an analog signal which is converted to a 4-bit binary number. See Table 2. If JP1 is 2-3 the 4-bit band code is read directly from the radio.

Pin No	Signal	Pin No	Signal
1	MOSI	6	GND
2	+5 v	7	SCK
3	NC	8	GND
4	GND	9	MISO
5	/RESET	10	GND

Table 2: PL1 flash programmer connector.

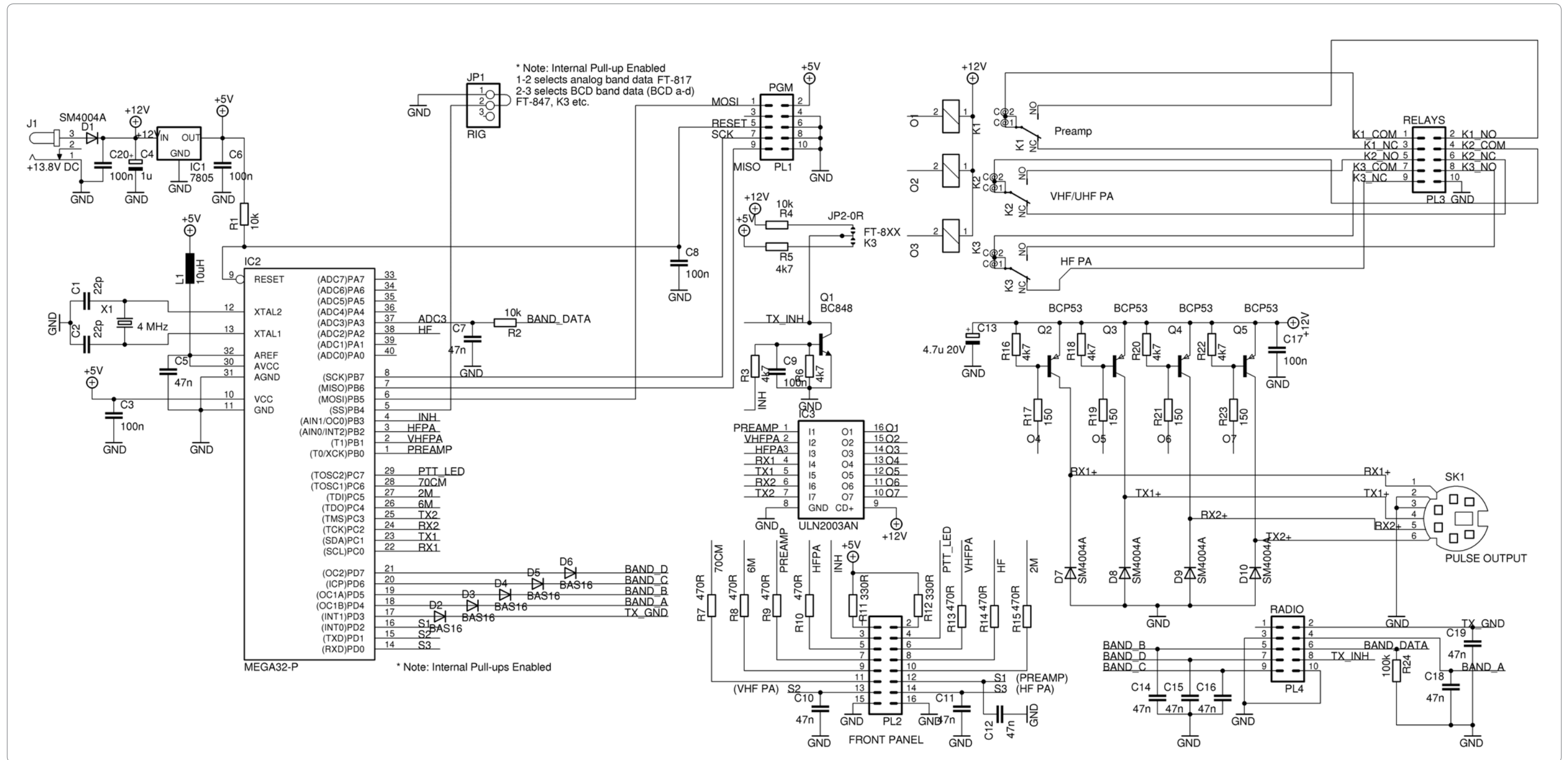


Figure 4: Main board.

144/430 MHz:

If the rig is tuned to 2 m or 70 cm, the TX pulse flag is set, ready for transmit. A pulse is sent to the coaxial relays to ensure they are latched in position 1 (receive).

The appropriate band LED is lit at this point. The rest of the processing is then done by the state-machine. This chunk of software (procedure)

determines the necessary actions to perform for each mode, including switching the appropriate on-board relays and timing. It simplifies the main-loop code and avoids a lot of typing. See Figure 7.

HF and 50 MHz:

If the rig is tuned to the HF bands (1.8 – 30 MHz) or the 50 MHz band

the TX pulse flag is reset. A pulse is sent to the coaxial relays to ensure they are latched in position 1 (receive) as above. The appropriate band LED is lit at this point. The rest of the processing is then done by the state-machine.

Transmit

If the rig is in transmit mode, the receive pulse flag is set.

144/430 MHz:

If the rig is tuned to 2 m or 70 cm, the PTT LED is lit, the coaxial relay output sends a pulse to place the contacts into position 2 (transmit). The state-machine removes the

TX inhibit signal after 100 ms to ensure that all switching has occurred before applying RF drive to the linear amplifier or transverter transmit chain.

HF and 50 MHz:

If the rig is tuned to the HF bands (1.8 – 30 MHz) or the 50 MHz band the PTT LED is lit. The state-

machine removes the TX inhibit signal after 100 ms to ensure that all switching has occurred before applying RF drive to the linear amplifier.

Software

The software was written for the AVR Atmega 32 micro-controller in C, using the AVR-GCC compiler.

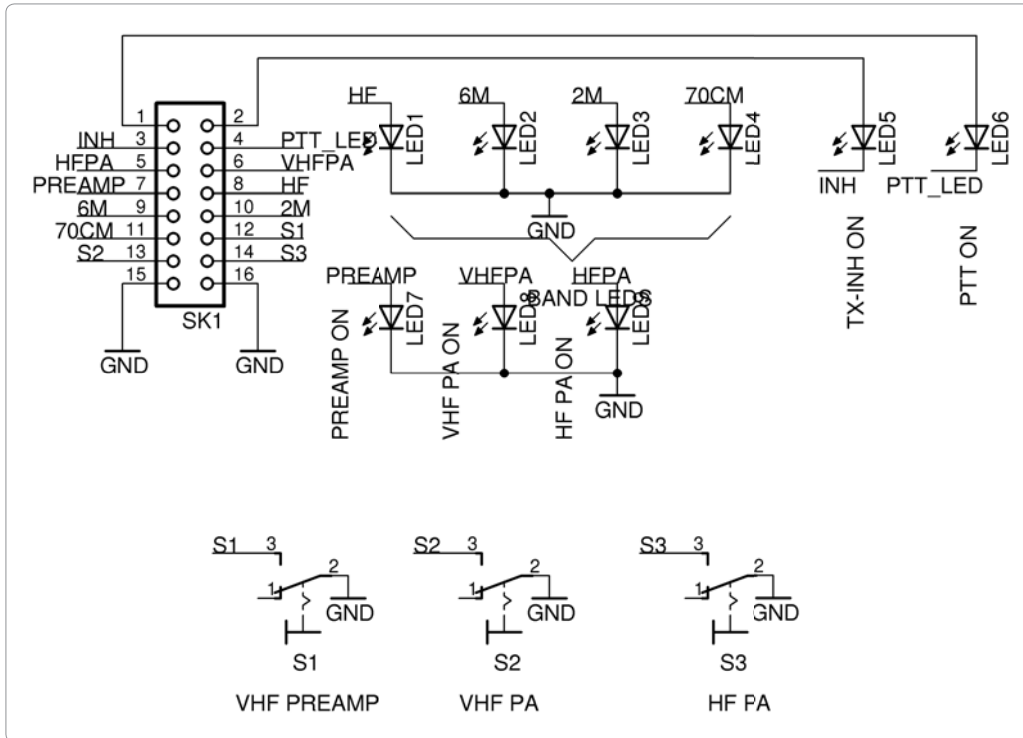


Photo 5a: Front panel wiring.

SUB-D9 connector		10-pin ribbon connector		
Pin No.	Signal	Pin No.	Signal	Wire colour
		1	NC (not connected)	BRN
2	*TX_GND	2	*TX_GND	RED
3	GND	3	GND	ORG
4	BAND_A	4	BAND_A	YEL
5	BAND_B	5	BAND_B	GRN
6	BAND_DATA	6	BAND_DATA	BLU
7	BAND_D	7	BAND_D	VIO
8	TX_INH	8	TX_INH	GRY
9	BAND_C	9	BAND_C	WHT
1	GND	10	GND	BLK

Table 3: Radio connector (PL4) pin connections.

* Note TX-GND is the PTT signal from the rig.

SUB-D plug Pin No.	Signal	Wire colour	ACC connector Pin No.
1	Shield (drain wire)	-	NC
2	TX_GND (PTT)	RED	2
3	GND	ORG	3
6	BAND_DATA	BLU	6
8	TX_INH	BRN	8

Table 4: Radio cable sub D9 – FT-817 ACC connector.

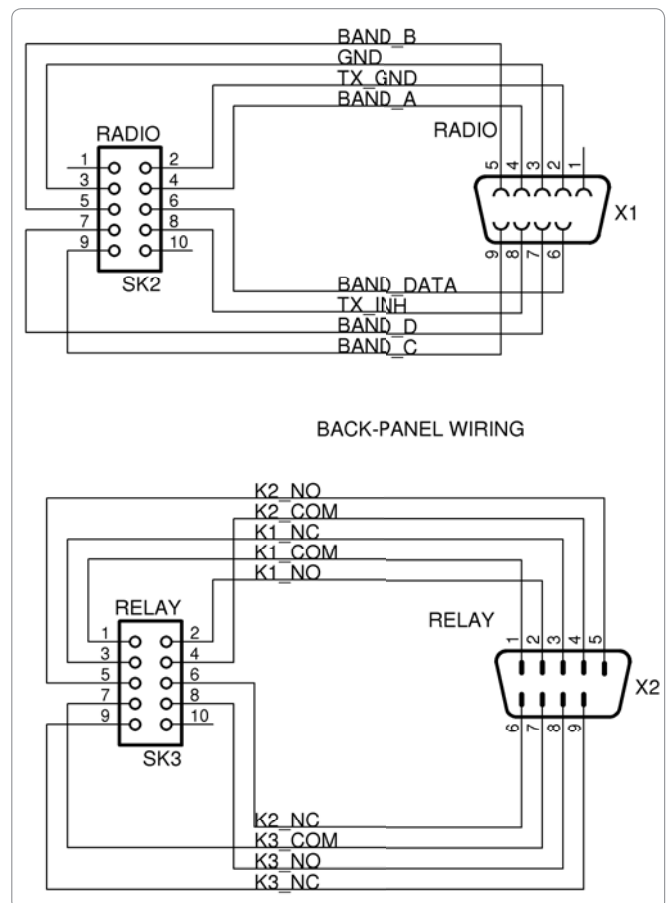


Photo 5b: Cable connections.

SUB-D plug Pin No.	Signal	Wire colour	ACC connector Pin No.
1	Shield (drain wire)	-	NC
2	TX_GND (PTT)	RED	2
3	GND	ORG	3
4	BAND_A	YEL	4
5	BAND_B	GRN	5
6	-	-	NC
7	BAND_D	VIO	7
8	TX_INH	BRN	8
9	BAND_C	WHT	6

Table 5: Radio cable PL4 – FT-8**, K3 ACC connector.

Pin No	Signal	Wire colour	Pin No	Signal	Wire colour
1	R11	BRN	9	R8	WHT
2	R12	RED	10	R15	BLK
3	INH	ORG	11	R7	RED
4	PTT_LED	YEL	12	S1	ORG
5	R10	GRN	13	S2	YEL
6	R13	BLU	14	S3	GRN
7	R9	VIO	15	GND	BLU
8	R14	GRY	16	GND	VIO

Table 6: PL2 front panel connector.

PL3 Pin No.	Signal	Sub-D9(M) Pin No.	Wire colour
1	K1_COM	1	BRN
2	K1_NO	2	RED
3	K1_NC	3	ORG
4	K2_COM	4	YEL
5	K2_NO	5	GRN
6	K2_NC	6	BLU
7	K3_COM	7	VIO
8	K3_NO	8	BLK
9	K3_NC	9	WHT
10	GND	NC	

Table 7: PL3 - Sub-D9(M) relay connector.

SK1 Pin No.	Signal All Signals +12 V, 10 ms wide	Wire colour Pin No.
1	RX1+	BRN
2	GND	RED
3	GND	ORG
4	TX1+	YEL
5	RX2+	GRN
6	RX3+	BLU

Table 8: SK1 – 6-pin mini DIN coaxial relays pulse output connector.

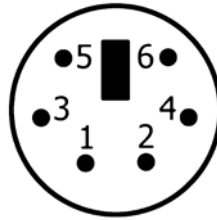


Figure 6: Pulse output connector.

LED	Indicates	LED	Indicates
LED1 (BLU)	HF BANDS (1.8-30 MHz)	LED5 (RED)	TX_GND (PTT)
LED2 (ORG)	6 m BAND	LED6 (RED)	TX_INH
LED3 (YEL)	2 m BAND	LED7 (GRN)	PREAMP ON
LED4 (GRN)	70 cm BAND	LED8 (GRN)	V/UHF TX
		LED9 (GRN)	HF TX

Table 9: Indicator LEDs.

JP1	Rig type	JP2	TX_INH signal
1-2	FT-817	1-2	+12 V: FT817, FT-8**
2-3	FT-8**, K3	2-3	+5 V: K3

Table 10: Jumper settings.

I used the Eclipse 3.8 IDE on a Linux platform (3,4).

The sequencer source code is freely available under the GNU Public License (GPL v3.). A copy of the software licence is included with the source code. A hex file is also available to program the micro (6).

Hardware

Voltage Regulator

The +13.8 V DC is connected to IC1 via D1 to prevent accidental reverse connection of the supply. IC1 (7805, TO220 package) runs without the need for a heat-sink.

Micro-controller

The MEGA32 micro-controller is housed in a 40-pin DIL package. I tried a QFP44 package in an earlier version but found that it was quite difficult to solder by hand and did not offer any great advantage. The micro-controller main clock is derived from an internal 4 MHz crystal oscillator. The +5 V supply (VCC) to the micro is decoupled by C3. The +5 V analogue supply (AVCC) and analogue reference (AVREF) are decoupled by L1 and C3.

Noise on the analogue BAND_DATA signal is filtered by R2 and C7. R24 provides a 100 k termination at PL4.

TX_GND, BAND_A, BAND_B, BAND_C and BAND_D are connected to PL4 via D2–D6. These signals are decoupled at PL4 by C14–C19.

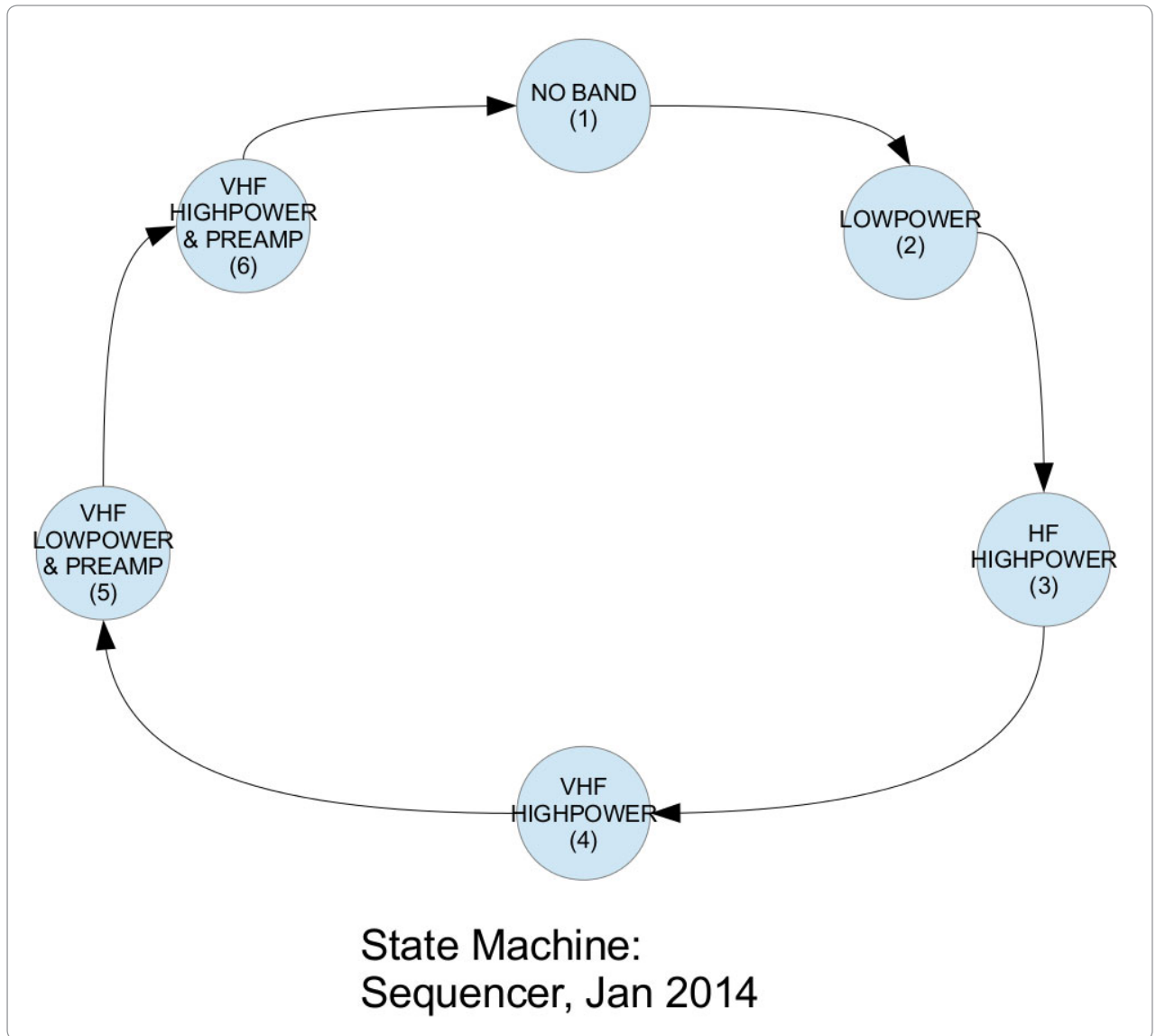


Figure 7: State diagram.

JP1 pin header is connected to PB3. Linking 1-2 is detected as analogue band data input. Removing the link (or 2-3) is detected as a 4-bit binary input.

The INH signal is connected to Q1. The collector is connected via R4 or R5 to +12 V or +5 V depending upon the setting of JP2. The TX_INH signal appears at the collector of Q1.

Relay Driver

The relay driver IC (IC3, ULN2003) drives K1-K3 directly (O1-O3). The signals O4-O7 are connected to the pulse relay driver transistors (Q2-Q5). D7-D10 are used to protect the transistors from the back EMF from the external coaxial relays.

The parts list, including the suppliers (7, 8 and 9) are below in Table 11.

PCB Data

The PCB layout was created using Eagle PCB CAD software. The Eagle PCB CAD files are freely available (6). The sequencer PCB measures 100 mm x 85 mm.

Construction

The components are housed in a 130 x 100 x 50 mm ABS case. The front-panel drilling diagram is shown in Figure 13. The separate ABS front-panel measures 120 x 45 mm.

A front-panel label template is also included as shown in Figure 14. I used the template to mark out the front-panel for drilling. The drilling diagram is included for those who prefer this method. The label template is cut to suit the front-panel and the holes cut out using a craft knife or scalpel.

Part	Value	Package	Qty	Pk	Min	Altronics	Jaycar	Futurlec
PCB Assembly								
C1, C2	22p	C1206	2	10	1	R9836	-	-
C10, C11, C12, C14, C15, C18, C19, C5, C7	47n	C1206	9	10	1	R9929	-	-
C13	4.7u 20V	SMD TANT	1	10	1	R9138	-	-
C17, C20, C3, C6, C8, C9	100n	C1206	6	10	1	R9935	-	-
C4	1u 35v	SMD TANT	1	10	1	R9044A	-	-
D1, D10, D7, D8, D9	SM4007A	SOD80	5	10	10	-	ZR-1009	SM4007A
D2, D3, D4, D5, D6	BAS16	SOT23	5	10	10	Y0089		BAS16
IC1	7805	T0220	1	1	1	Z0505	ZV-1505	7805T
IC2	MEGA32-P	DIL40	1	1	1	-	ZZ-8760	ATMEGA32-16PU
IC3	ULN2003AN	DIL16	1	1	1	Z3000	ZK-8855	ULN2003A
J1	+13.8V DC	DC JACK, 2.5 MM	1	1	1	P0621A	PS-0520	-
JP1	RIG	"1X03 PIN HDR (40 PIN HDR STRIP)"	1	1	1	P5430	HM-3212	N/A
JP2	TX-INH	SOLDER LINK / OR	1			ON PCB	ON PCB	ON PCB
K1, K2, K3	HY1-12V	SPDT 12V 1A PCB Relay	3	1	3	S4113	N/A	JRC-23F-12
L1	10uH	0207/12	1	1	1	L7022	LF-1552	IND010
PL2	FRONT PANEL	ML16	1	1	1	P5016	PP-1106	IDCMH16
PL1, PL3, PL4	PGM, RELAYS, RADIO	ML10	3	1	3	P5010	PP-1100	IDCMH10
Q1	BC848	SOT23	1	10	10	Y1312	-	BC848
Q2, Q3, Q4, Q5	BCP53	SOT223	4	4	4	-	-	BCP53
R1, R2, R4	10k	R1206	3	10	1	R8188	-	-
R10, R13, R14, R15, R7, R8, R9	470R	R1206	7	10	1	R8092	-	-
R11, R12	330R	R1206	2	10	1	R8080	-	-
R16, R18, R20, R22, R3, R5, R6	4k7	R1206	7	10	1	R8164	-	-
R17, R19, R21, R23	150R	R1206	4	10	1	R8056	-	-
R24	100k	R1206	1	10	1	R8260	-	-
SK1	PULSE OUTPUT	MD06S	1	1	1	P1106	-	MINIDIN6PC
X1	4 MHz	CRYSTAL HC49S LOW PROFILE	1	1	1	V1219A	-	-
Case Assembly								
LED1	BLU	LED5MM	1	1	1	Z0806A	ZD-0180	LED5BULB
LED2	ORG	LED5MM	1	1	1	Z0870	-	LED5OULB
LED3	YEL	LED5MM	1	1	1	Z0867	ZD-0160	LED5YULB
LED4, LED7, LED8, LED9	GRN	LED5MM	4	1	4	Z0864	ZD-0170	LED5GULB
LED5, LED6	RED	LED5MM	2	1	2	Z0863	ZD-0154	LED5RULB
S1, S2, S3	SPST TOGGLE	SOLDER TYPE	3	1	3	S1310	ST-0300	SPST10
SK1	16-PIN IDC RIBBON CONN.	CON16	1	1	1	P5316	PS-0985	IDCC16
SK2, SK3	10-PIN IDC RIBBON CONN.	CON10	2	1	2	P5310	PS-0984	IDCC10
X1	SUB-D9 (F) RADIO CONN.	DB-9 (F) PANEL MTG	1	1	1	P3010	PS-0804	DSUBSCF9
X2	SUB-D9 (M) RELAY CONN.	DB-9 (M) PANEL MTG	1	1	1	P3000	PS-0800	DSUBSCM9
	CASE ABS 130X100X50MM		1	1	1	H0371	-	-
	16-WAY RIBBON CABLE		1	1	1	W2516	WM-4516	-
	9-CORE SHIELDED CABLE		1	1	1	W2712	WB-1578	-

Table 11: Parts.

The assembly of the PCB is fairly straightforward but care is needed when soldering some of the smaller SMD components. A magnifier is a 'must' for the older generation such as myself!

If you don't feel that SMD is for you it is possible to build the sequencer using conventional leaded

components on prototype boards. During the prototype test stage, I managed to fit most of the bits on the board and the pulse driver on a separate board within the ABS enclosure.

The switches and LEDs are hard-wired on the front-panel.

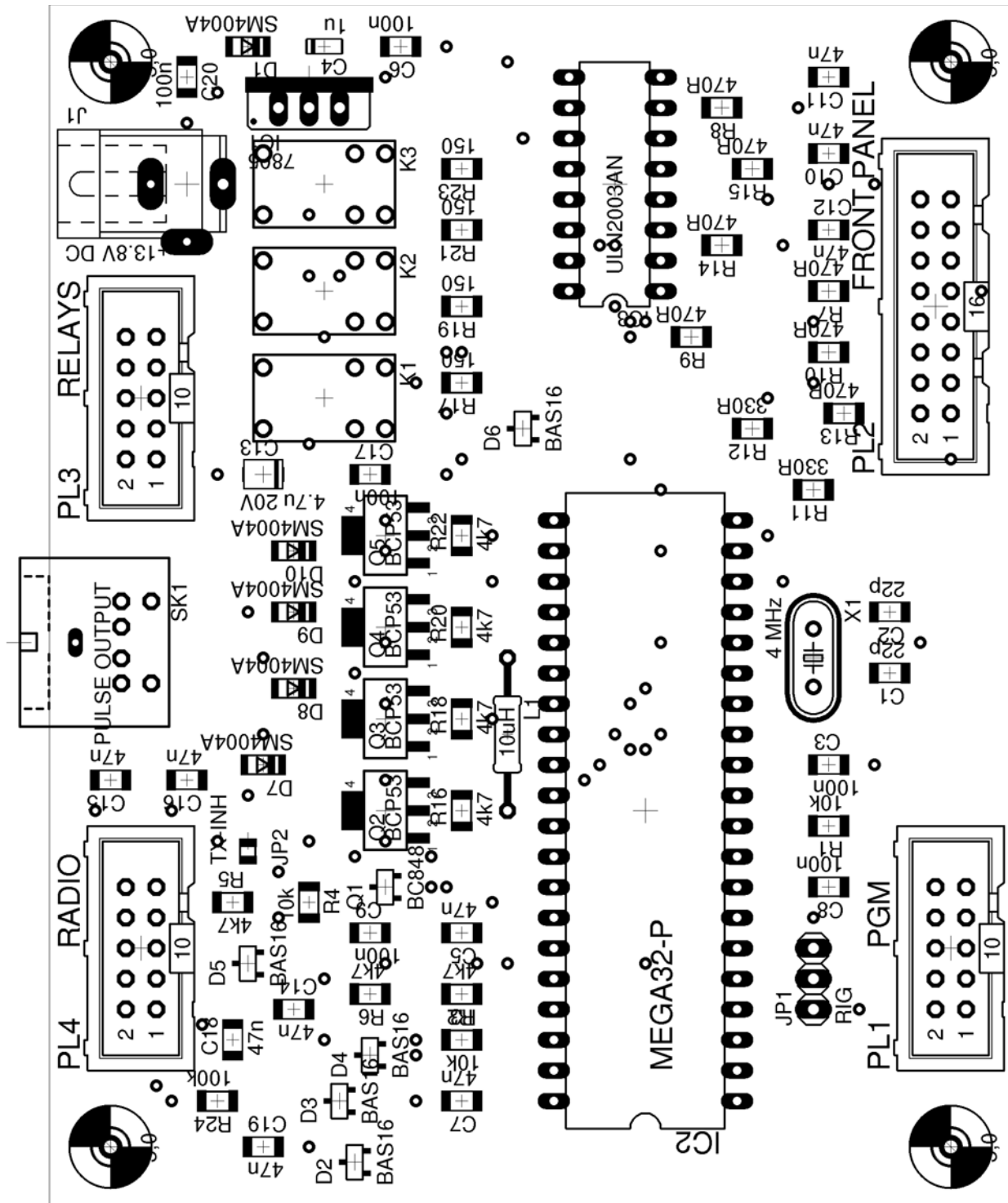


Figure 8: PCB component layout.

DC specification

Operating voltage: 12 V DC (11-14 V DC).

Coil current: 230 mA maximum.

Switching time: 15 ms maximum.

Conclusion

I hope that you have as much fun as I did building this project and it proves to be a useful addition to the shack. Please direct any queries

to the following email address:
vk6wa@wia.org.au

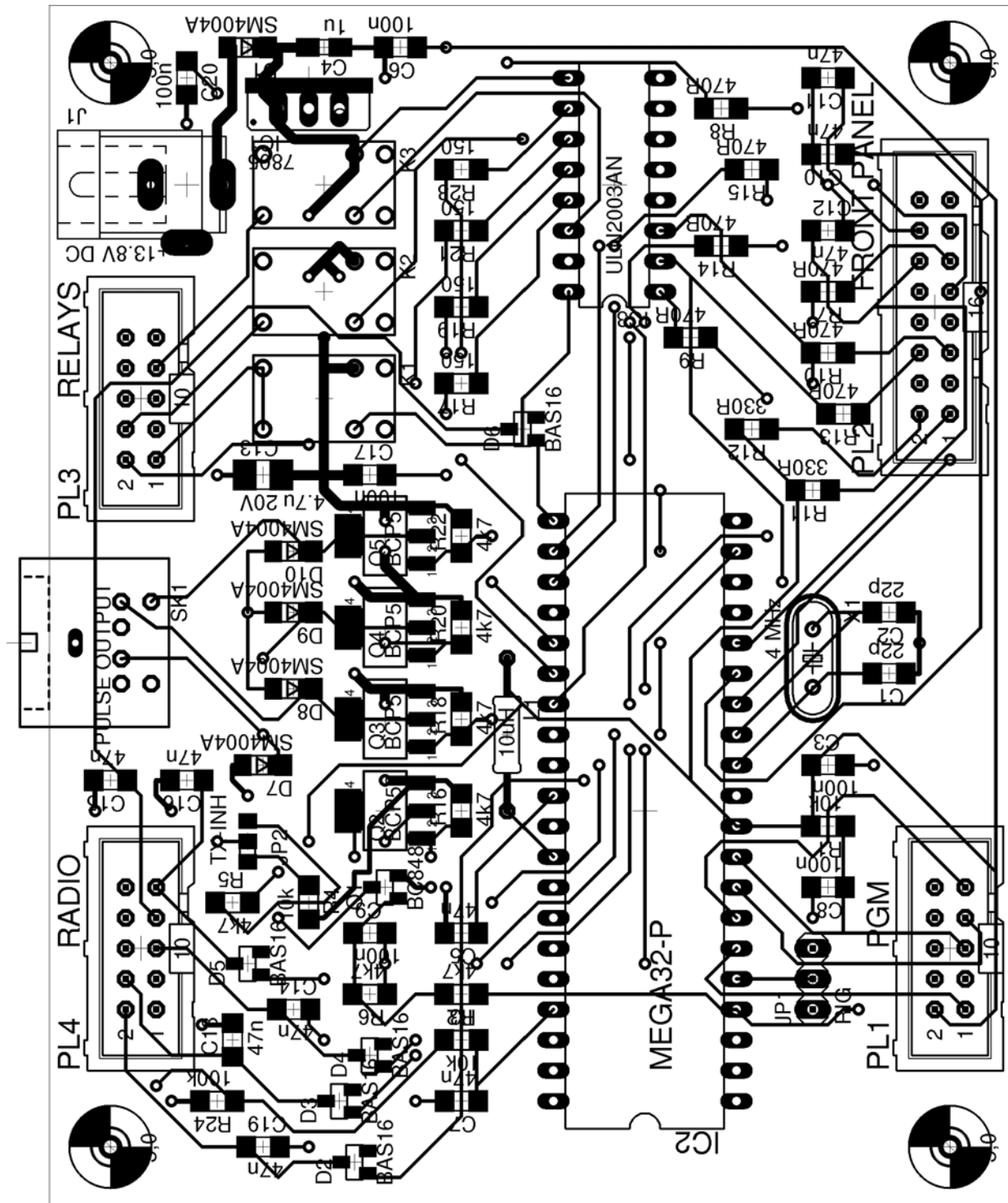


Figure 10: Main PCB bottom layer.

Project update

At the time of writing, I have been unable to complete the final version of the PCB for testing, due to supplier problems. The original prototype built on 'Veroboard'

has been running successfully for several months.

References

1. 'Komfort-Sequenzler für Elecraft und Yaesu-Transceiver', Oliver

Dröse DH8BQA, Funkamateurl 10, 2011.

2. Eclipse IDE: <http://www.eclipse.org/>

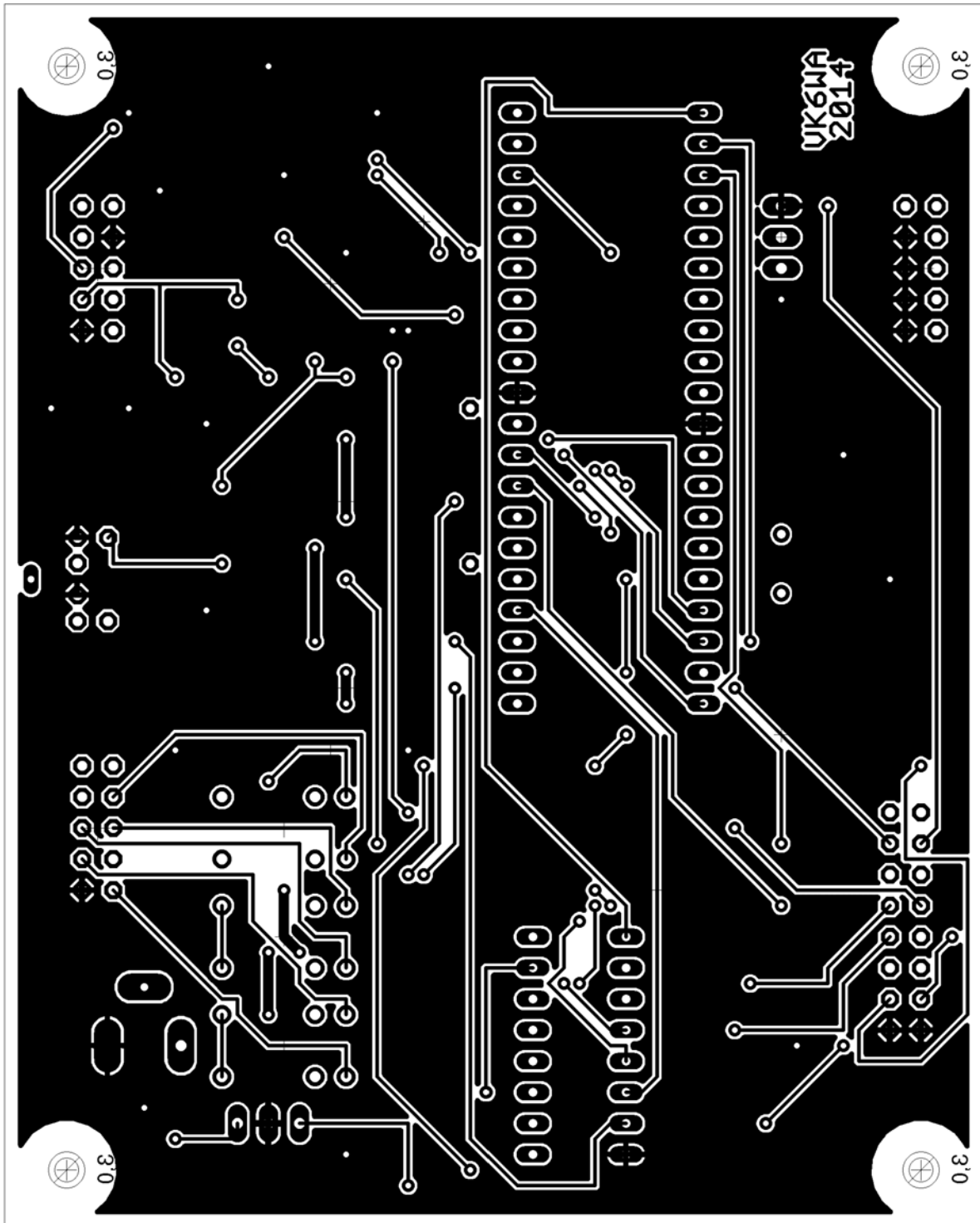


Figure 11: Front panel drilling diagram.

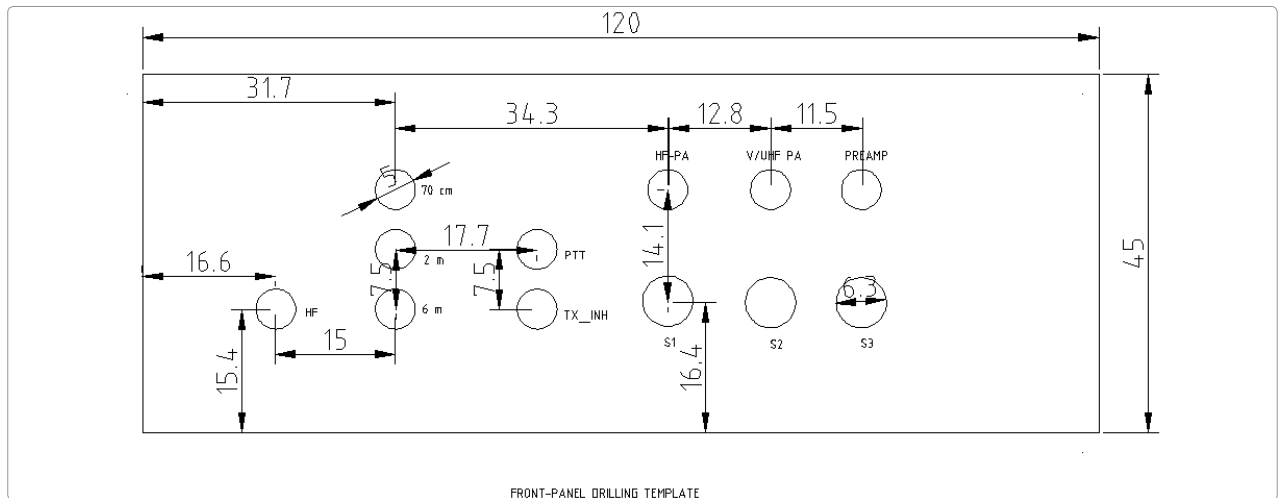


Figure 12: Front panel label template.

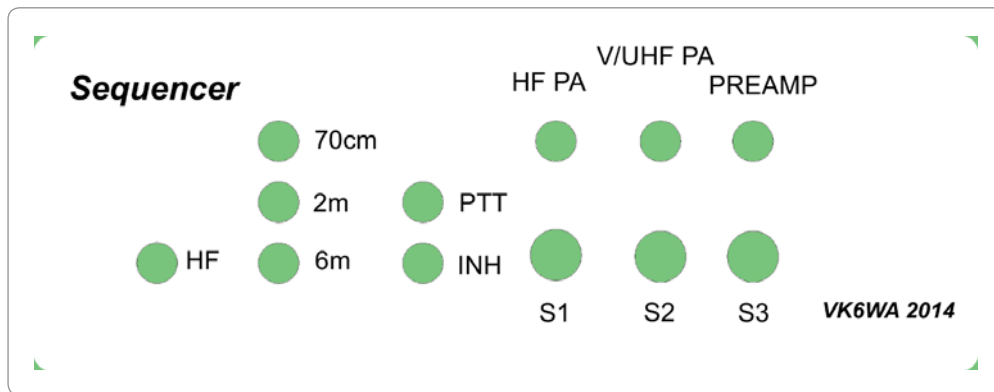


Figure 13: The completed front label.

3. Eclipse AVR-GCC plug-in: http://avr-eclipse.sourceforge.net/wiki/index.php/The_AVR_Eclipse_Plugin
4. Eagle PCB CAD Software: <http://www.cadsoftusa.com/download-eagle/freeware/>
5. RF relays: <http://www.dowkey.com>
6. Leigh Harrison VK6WA: vk6wa@wia.org.au
7. Futurlec: <http://www.futurlec.com>
8. Altronics: <http://www.altronics.com.au>
9. Jaycar: <http://jaycar.com.au>

