SDR-Kits – PA0KLT Si570 VFO Synthesizer Kit for Third Edition PCB

IMPORTANT This information is for Kits supplied from **1 May 2021** for PCB marking **or higher**

1. Introduction:

The third edition Printed Circuit board maintains all the features of the Second Edition PCB, however in addition it offers the following benefits:

- The LCD Module is now fitted on the back side of the KLT Synthesizer PCB all connections made via 16 pin 2 row 2.54mm PCB inter board connectors. This speeds up assembly and also easier.
- Provisions have been made to fit additional configuration options to interface with more applications. Supported options now include:
    - Direct single CMOS output from Si570CAC Integrated Circuit
    - Differential RF outputs direct from Si570 LVDS or CML devices
    - Footprint to fit optional WBC4-1WLB SMD transformer to support 4:1 transformation from 200 Ohm CMOS to 50 Ohm output
    - Footprint to fit optional FIN1002 LVDS or DS90LV012A 1-Bit 400 Mbs High Speed Differential Receiver to convert Si570 LVDS output to 3.3V Square wave output
    - Footprint to fit 74ALVC74 Divider to provide I and Q quadrature square wave outputs at ¼ of the Si570 RF output frequency.
- Correct display of Receive frequencies with options for :1 :2 and :4 including programmable IF Offset. Si570 Local Oscillator frequency is always above Receiving Frequency.

Updated Bill of Materials for PA0KLT Synthesizer kit 3rd Edition

Pcs/kit	Part	Value	Remarks
1	C1	10uF Electrolytic	Radial
5	C2, C3, C4, C5	1uF Ceramic	0805 SMD Blue stripe
8	C6, C7, C8, C9, C10, C11	100nF Ceramic	0805 SMD - No marking
2	C12	1nF Ceramic	0805 SMD - Black Stripe
3	R1, R2, R3	4k7 0.25W	yellow violet red gold
1	RV1	4k7	adjustable
1	R4	47 ohm 0.6W - LCD Backlight	Yellow violet black gold brown
1	D1	1N4001	Diode
1	U6	LF33ABV	3.3V LDO Regulator TO220
1	U5	7805 or DE7805 or L07805	5V Regulator TO220
1	U1	ATMega328-20PU	PAOKLT Firmware version marked
1	IC Socket	28 pin DIL for U1	28 pin
2	P1 + P5	2 pin header plug (+8 - +12V)	0.1” male
1	P2 + P6	3 pin header plug (HF Out)	0.1” male
1	P3	LCD Header	16 pin 1 row inter-PCB Female connector
1	P4	Aux Conn Header	20 pin IDC Male
1	J1	LCD Connector	16 pin 1 row inter-PCB male connector
1	J2	Aux Connector	20 pin IDC female
1	PCB	PA0KLT	SDR-Kits - marked 201007 (see fig 1)
3		Mini push button switch	Red (Mem, ESC and RIT
3		Mini push button switch	Black (Cursors < > and RIT Clear
0.15m	IDC ribbon cable	20 cores	
1	Encoder	Encoder with switch	24 step contact
1		LCD Display with backlight	16 character by 2 lines
1	U2 option 1	Si570CAC000141DG	3.45-160 MHz - max 210 MHz - CMOS output
1	U2 Option 4	Si570DBC000141DG	3.45-280 MHz - CML output
1	U2 Option 2	Si570BBC000141DG	3.45-280 MHz - LVDS output
1	U2 Option 3	Si570DBA000141DG	3.45-1417 MHz - CML output
1	T1 Option	Coilcraft WBC4-1WL	1:4 transformer 0.5 – 1000 MHz -3dB
1	U3 Option	FIN1002mx5 **or** DS90LV012A	400 Mbs LVDS 1-bit Receiver
1	U4 Option	74ALVC74D SO14	I Q Quadrature Outputs

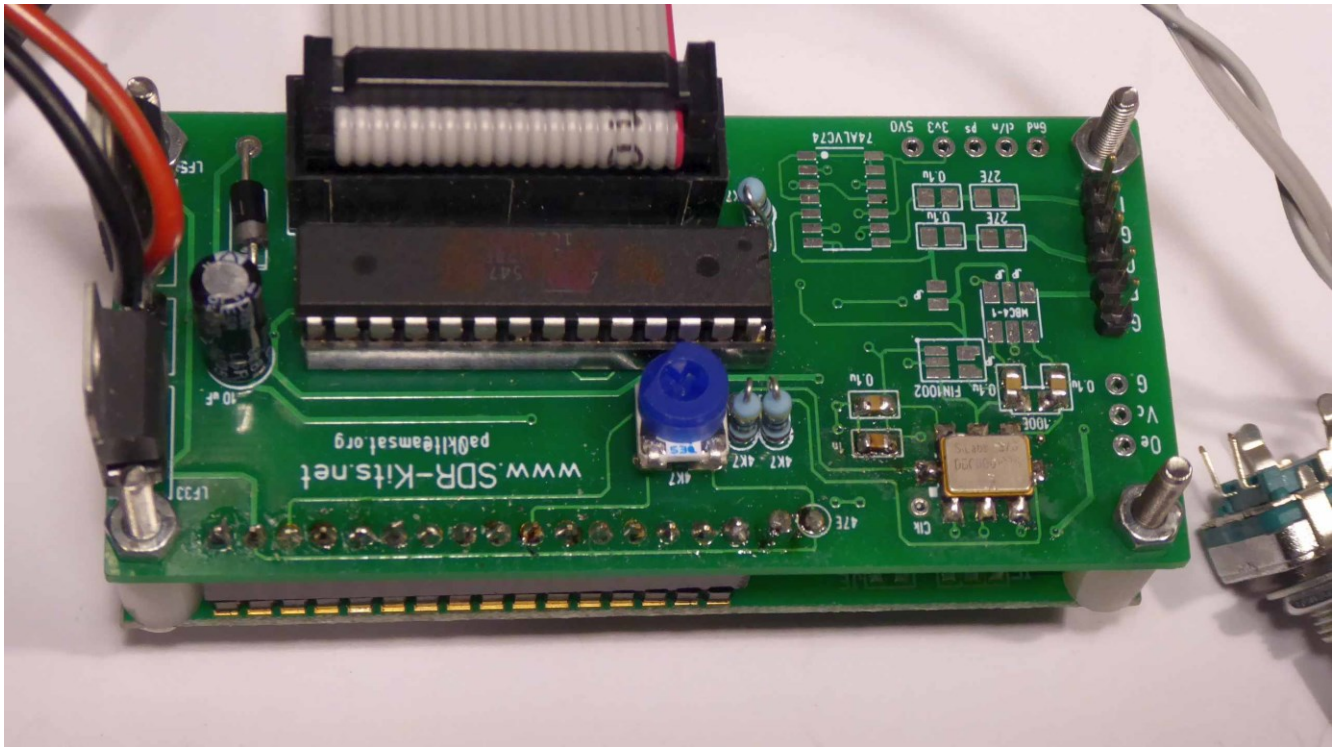
The "standalone" PAOKLT VFO Synthesizer kit uses the Silicon Labs Si570 XO Low noise Synthesizer chip controlled by a Atmel Mega 8 or Atmel Mega 88 Controller with connections to an external 16 or 20 character x 2 lines LCD Display and a 96 step rotary encoder for tuning.

Frequency coverage is from 3.4 MHz up to 1417 MHz, depending on the type of Si570 device fitted. The minimum tuning step is selectable from 1 Hz, 10Hz, 100 Hz, 1kHz upwards.

The design offers a Smooth Tuning like in a high quality Analogue VFO – There is no interference when the frequency of the Si570 is tuned within +/- 3500 ppm from last Coarse Frequency command executed. Tuning speed is 96 steps for each turn of the tuning control knob.

Up to **32 frequencies** may be stored in **Memory** in two banks (Memory A and Memory B)

This kit is the latest version of the "Universal Si570 project" by Ton PA0KLT, which was first published in Dutch in "Nieuwsbrief" the club journal of BQC, the Belgium and Dutch QP in 2008 and 2009 (http://home.wanadoo.nl/bqc/)



PA0KLT Kit V3 The LCD module now plugs direct into the Main PCB

2. Brief Specification:

- Standalone Low Noise VFO Synthesizer suitable as Signal Generator, Local Oscillator or VFO etc with good frequency stability for many (Amateur) Radio Projects.
- Si570 “Smooth Tuning” Algorithm - No interuption of rf output when Si570 is tuned within +/- 3500 ppm of last Coarse Frequency command. 96 steps/rotation by firmware.
- 32 Frequencies may be stored in Memory in two Memory Banks
- Frequency coverage options depending on Si570/Si571 type fitted:
  - Si570CAC **CMOS: 3.5MHz - 160 MHz** at 3V pkpk Square wave CMOS Output **(280 MHz possible but not guaranteed)**
  - Si570BBC LVDS: **3.5 MHz - 280 MHz** at 0.7V pkpk LVDS level

- Si570BBB LVDS: **3.5 MHz - 810 MHz** at 0.7V pkpk LVDS level **(Max 945 MHz possible but not guaranteed)** ◦ Si570DBA CML: **3.5 MHz - 945 MHz, 970 MHz - 1134 MHz and 1213 MHz - 1417.5 MHz** at typically 1.5V pkpk CML level. (**In PA0KLT Kit typically 3.5 MHz - 1417 MHz continuous coverage is obtained in practice but not guaranteed**)
- Si571CFC CMOS: 3.5 MHz - 160 MHz with FM Modulation input. (**typically 3.5 MHz up to 210MHz is possible but not guaranteed**) See fig 5. note 5.

- Mode Offset applied: AM = 0 kHz, USB/LSB = +/- 1.5 kHz and CWU/CWL = +/- 750 Hz

3. PCB Assembly instructions

Assembly of the PCB should be quite straight forward. Observe antistatic precautions especially when handling Semiconductors - Si570 and the programmed AVR. The Kit assembly sequence is as follows:

- Check once again the actual KLT output configuration you require for your project: CMOS, CML or LVDS by reviewing the configurations in paragraph 4.
- Assemble the PCB and check voltages on regulators
- Wire up the 20 way cable/plug with Aux Connections to 4 or 6 push buttons and encoder
- Install AVR in socket
- Apply Power and check AVR and LCD functionality
- Solder in Si570 XO Synthesizer chip and test RF output

Use a 15-40W Solder station or a 15W - 25W soldering iron and 0.5mm solder. SMD soldering is not difficult - Apply a little tin to one of the pads, place the SMD capacitor over the pads and apply heat to make the bo.d. Once the SMD part has been soldered to one of the pads continue by soldering the second pad and finish off by reflowing the tin on the first pad, applying a little more tin if necessary. Use a magnifying glass to inspect any joints.

Caution: Do NOT solder U2 = Si570 until instructed to do so.

( ) Start by fitting the 1 uF Ceramic 0805 capacitors C2, C3, C4 and C5 (blue stripe) as shown in fig 1. (there is no polarity indication as capacitors are bipolar)

( ) Solder 100nF 0805 capacitors (no markings)
C11 in fig 1 and solder, also fit C6, C7, C8, C9, C10 in fig 2 and solder

( ) Solder C12 = 1nF - black stripe

( ) Solder R1, R2 and R3 = 4k7 resistors (yellow violet red gold)

( ) Solder R4 = 47 Ohm resistors (yellow violet red gold)

( ) Fit and solder RV1 4k7 Preset

( ) Fit diode D1 1N4001 - observe white band and solder

( ) Fit C1 10 uF - observe correct polarity. White stripe is negative - lead.

( ) Fit 28 pin DIL socket - Observe notch and align as shown on PCB.
Ensure that the socket is mounted flush to the board solder pin one and pin 28 then check for a snug fit to the board. If it is not apply a slight pressure to the DIL socket and re-solder the pins. Once it is flush solder the remaining pins

( ) Fit connectors P1 (location 8-12V) and P2 (location HF Out) making sure that the shorter pins are soldered to the PCB

( ) Refer to fig. and fit connectors P3 (14 pin LCD header) and P4 (20 pin AUX Connector).
Caution - ensure that the notch of the connector is located shown in Fig 1
Ensure that the connectors are fitted flush with the board. Use the same procedure as you did with the 28 pin DIL socket to ensure that the connectors are fitted flush with the board.

( ) Fit TO220 Regulators U3 (LF33) and U4 (7805) and check position against PCB before soldering

(..) Fit the 16 pin male head plug J1 with the shorter pins into the LCD module. Ensure the connector is at right angle to the LCD module and solder only pin 1/

(..) Fit LCD module J1 into P3 on the main PCB. Check whether the main PCB and the LCD module are aligned (if necessary by fitting the 11mm standoffs
and M2.5 screws and nuts. Once aligned solder all 16 pins to the LCD module.

Caution: It is recommended to fit a heat sink to U4 7805. A simple TO220 (not supplied) is recommended, alternatively make a small aluminium heatsink to keep this IC from over dissipating (generally when supply voltages are above 12V D

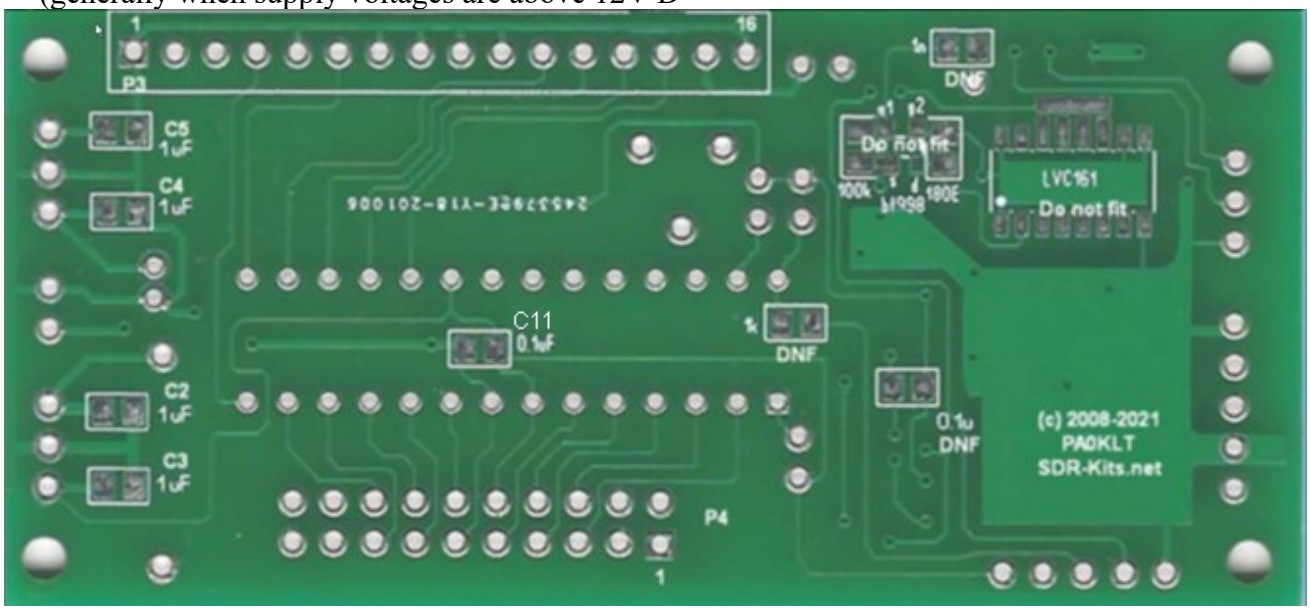


Fig 1 Bottom view of PCB

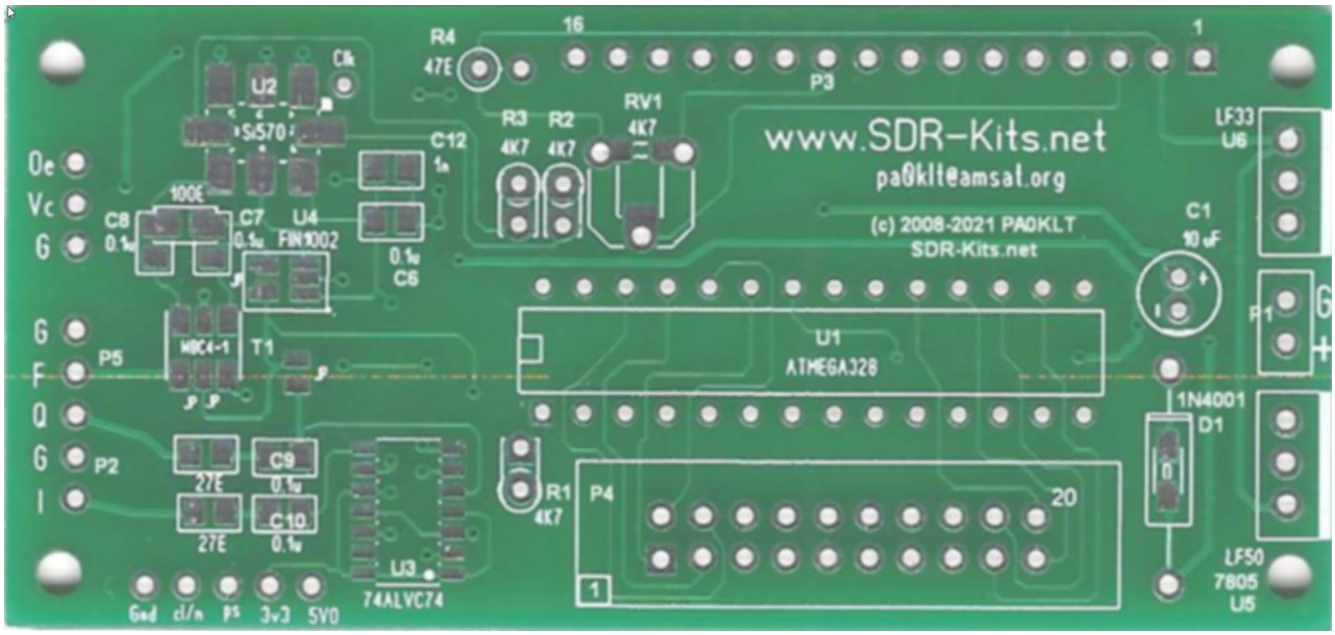


Fig 2 Top view of PCB

Inital PCB testing

At this stage all components except the AVR and SI570 are fitted on the PCB.

( ) Connect +8V - 12V DC Power to P1 on the PCB - observe polarity. Current consumption should be no more than 20mA at this stage. Switch of and investigate if current is too high or if any components are getting hot or any of the voltages are not within +/- 5% of the expected valued.

( ) Use a DC voltmeter to check whether +5V is present on the "IN" of U3 LF33. and +3.3V is present on the output pin of U3 - LF33 regulator before proceeding.

( ) Switch off Power and remove leads from P1.

(..) Adjust RV4 with a small screw driver until text on the LCD appears. Adjust RV4 for maximum contrast on the LCD display.

Final Assembly

( ) Switch off Power and remove leads from P1

( ) **AUX Connector J2:** Fit the required length of 20 way ribbon cable on the 20 Way connector J2
Before cutting to length you will wish to consider how long the cable needs to be to reach the Rotary encoder and the 6 push button switches

Fit the cable at right angle into the IDC connector **so the red coloured wire connects to P4 Pin 1** (See fig 2). Clamp the IDC connector with the cable into a

small vice. Turn the vice until the ribbon cable is solidly pressed into the connector. **Caution**: Over-tightening may damage the connector.

Caution - The red coloured wire should connect to pin 1 of P4, **Note:** the correct orientation of the pins for J2 is shown in Fig 2. Pin 17-Pin 20 are reserved for future use.

The table below shows the essential connections required to support the four **pushbuttons (< > ESC and MEM) and the Rotary Encoder for Tuning**.

Wiring Aux Connector – J2 (mates with P4)		
Pin	**Description**	**Remark**
1	Band Select Output A	Optional use
2	Band Select Output B	Optional use
3	Band Select Output C	Optional use
4	Band Select Output D	Optional use
5	**< cursor pushbutton**	essential connection
6	**> cursor pushbutton**	essential connection
7	Rotary Control “A”	essential connection
8	Rotary Control “B”	essential connection
9	AM Mode Select input	Optional use
10	+5V output	Optional use
11	GND	essential connection
12	**ESC** pushbutton	essential connection
13	**MEM** pushbutton	essential connection
14	SSB/CW Select input	Optional use
15	LSB/USB Select input	Optional use
16	LOCK input	Optional use
17	PB2 – D4	RIT On/Off
18	PB3 – D5	RIT Clear – reset off to 0
19	PB4 – D6	Rotary encoder switch
20	PB5 – D7	Future Use

Table 1: Aux Connector J2

( ) **Rotary Encoder:** The 24 step encoder (enhance to 96 steps due software) comes standard with a "click mechanism" which can be easily disabled. This is preferred by most users. Please see Appendix 1 for modification instructions.

( ) Viewed from the back of the encoder and with the pins facing down, solder wire from pin 11 (GND) to Left pin of the encoder.
The wire from Pin 7 (Rotary control A) is soldered to the Right lug and the wire from Pin 8 (Rotary Control "B") to the middle lug. See Appendix 1. fig 2.

Caution Carefully solder the wires to the Push button switches using minimum heat and shortest possible solder time to avoid the switches being damaged by the heat.

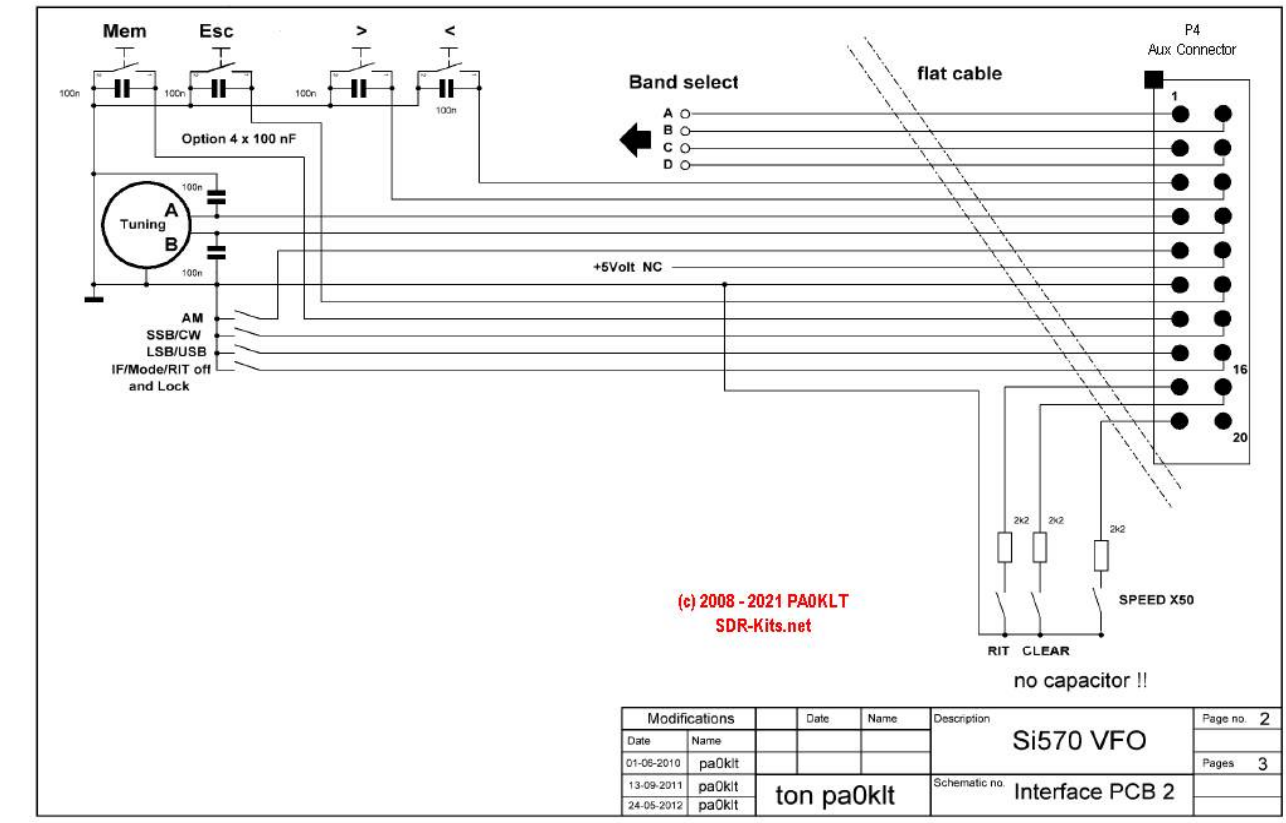


Fig 3 Wiring of the Aux Connector cable

Notes:

LCD Display supplied by SDR-Kits - backlight connections:

C1 10uF electrolytic is required to stop oscillation on 3.3V supply. C2 is 1uF capacitor in parallel

Rotary encoder: Viewed from rear with pins facing down: GND = Left, B = Middle and A = Right
Capacitor colour coding: 1uF 0805 = blue, 1nF 0805 = black, 100nF 0805 = no colour/no stripe

4. Available Output Configurations:

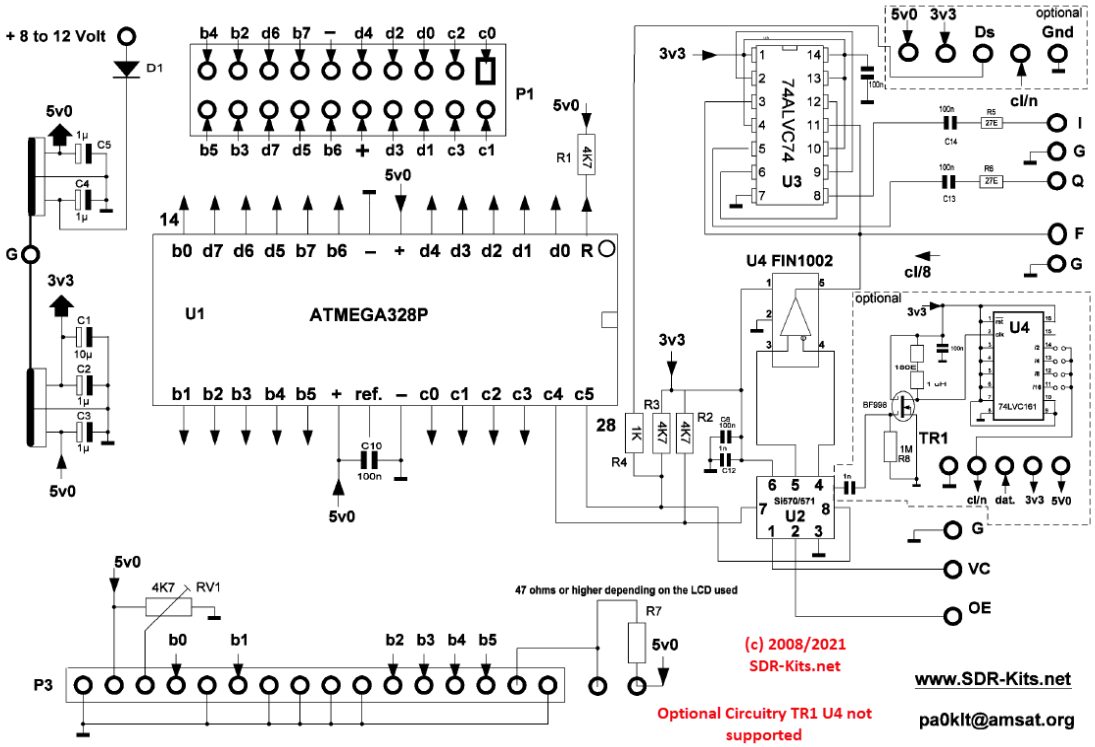


Fig 4 Full Circuit Diagram for all Options, Circuitry TR1 and U4 not supported

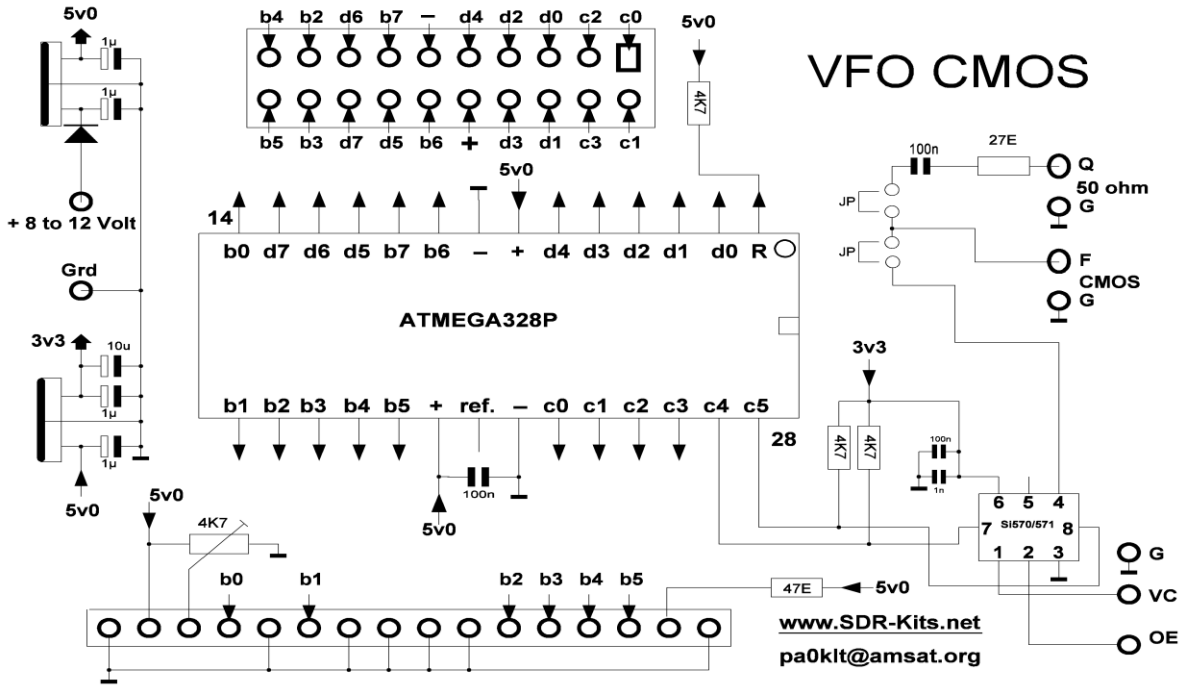


Fig 5 Simple Si570CAC CMOS Output or 50 ohm Interface options

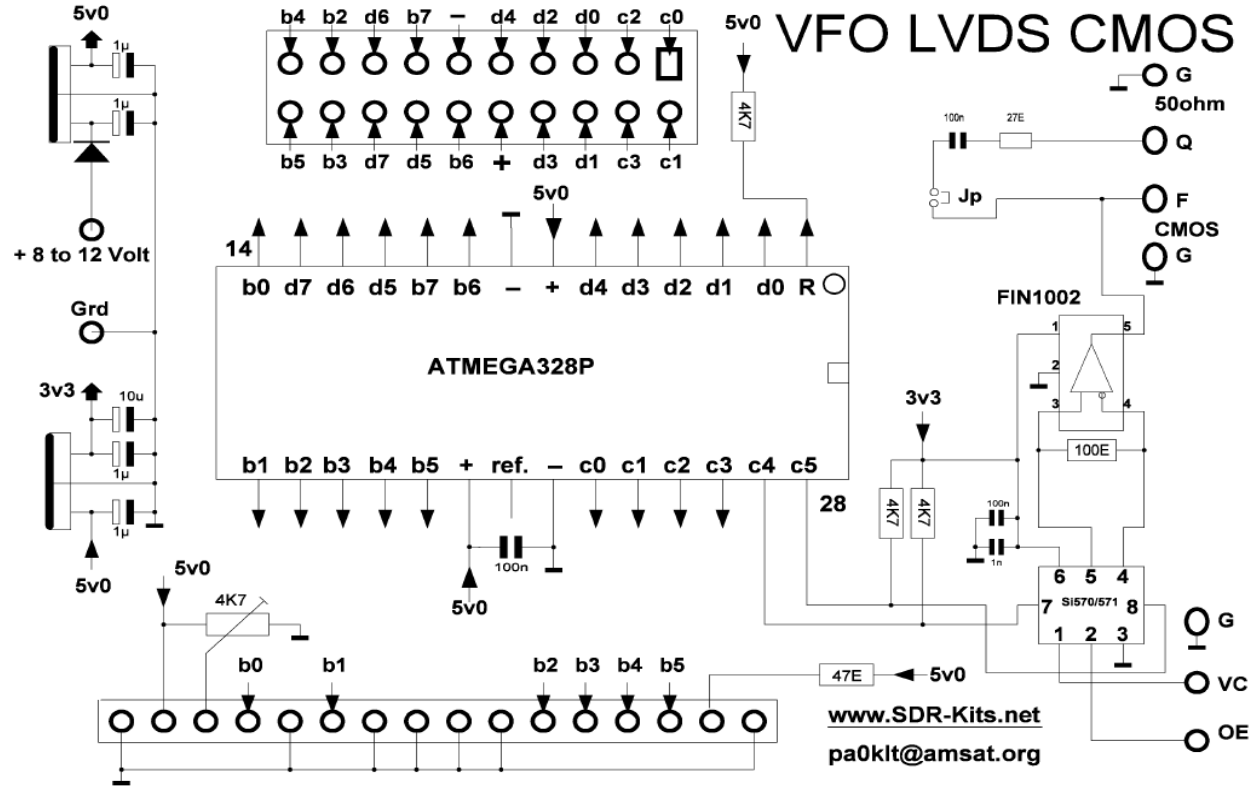


Fig 6 Si570 CML or LVDS with optional F1002 IC CMOS Output options

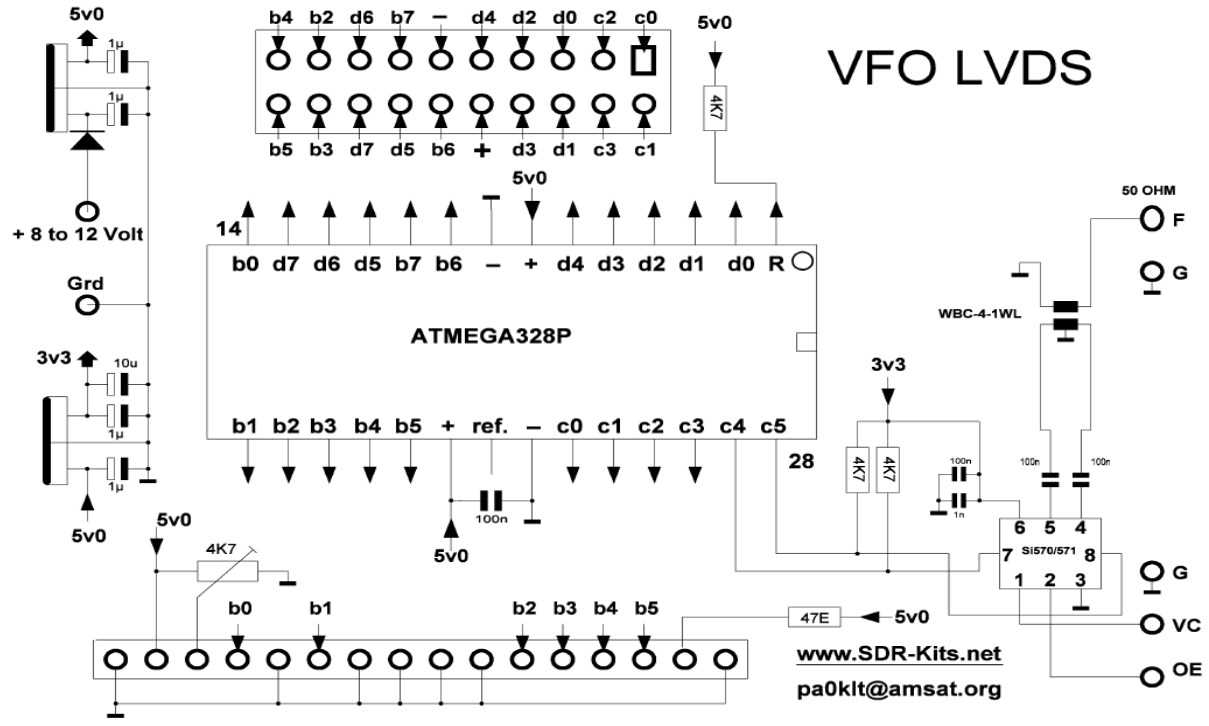


Fig 7 Si570 CML or LVDS with optional WBC4-1WL transformer option

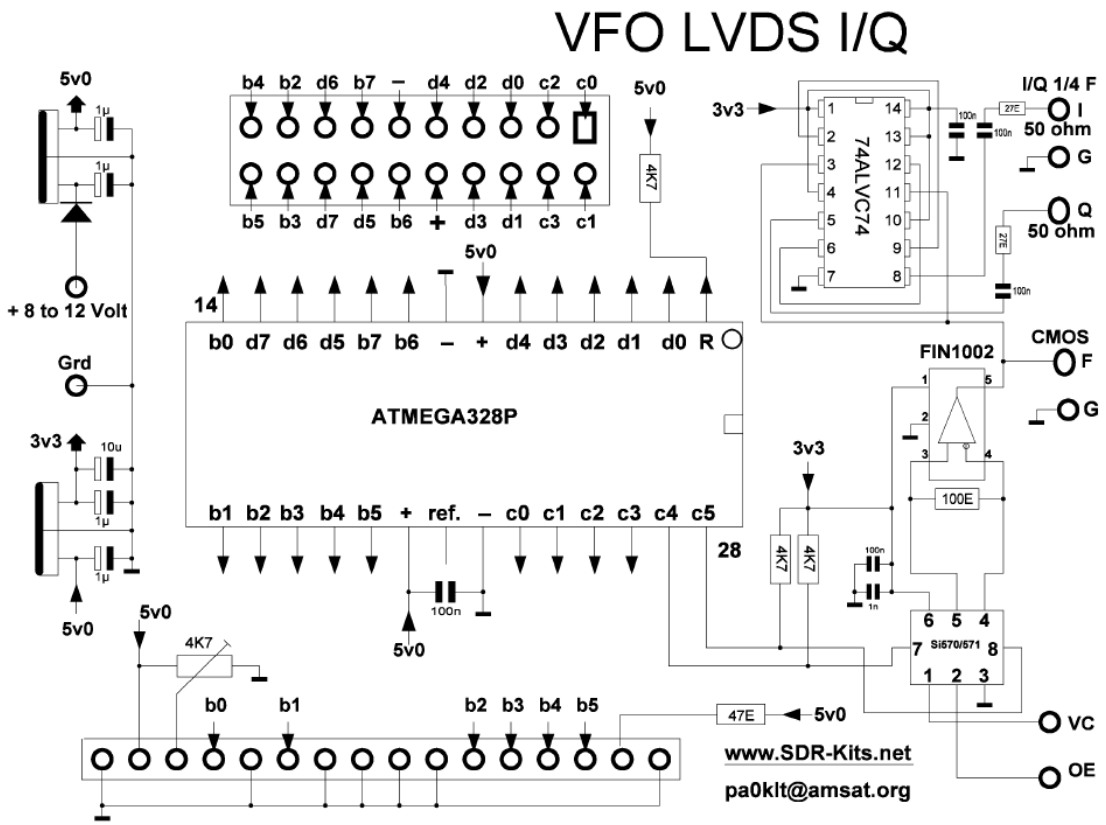


Fig 8 Si570 CML or LVDS with optional FIN1002 or (Divide by 4) I-Q Output

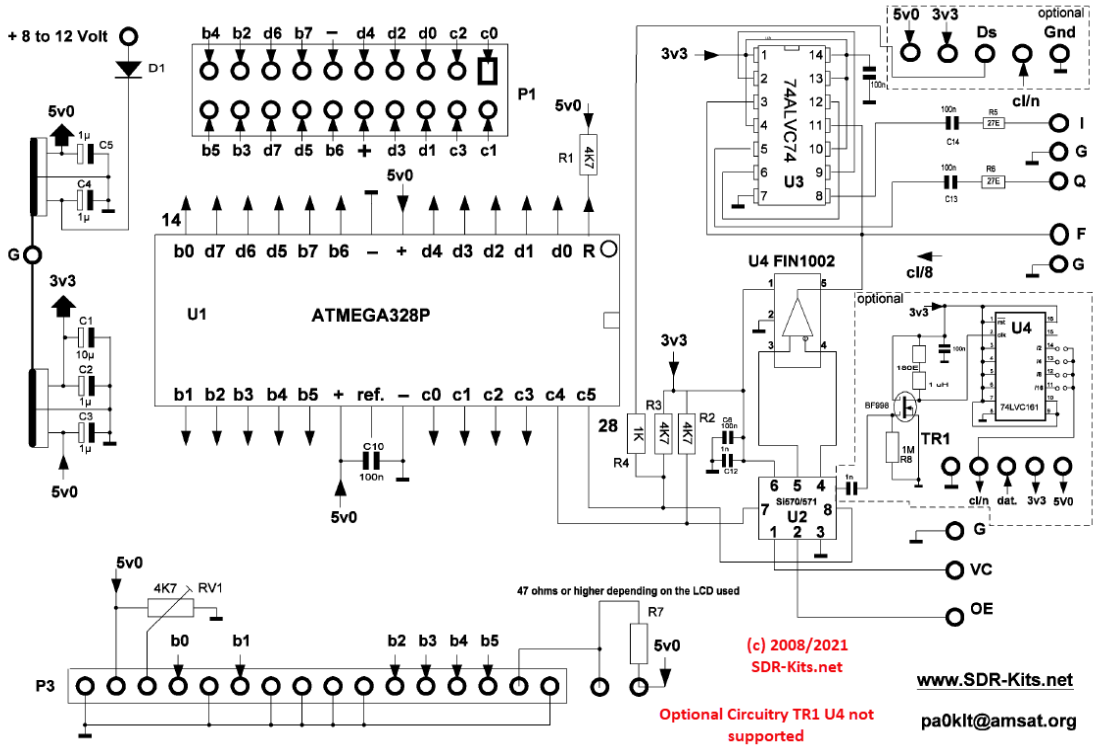


Fig 9 Full Circuit Diagram for all Options, Circuitry TR1 and U4 not supported

Table 2: Band Select Output on AUX Connector J2 pin 1, 2, 3 and 4 (A, B, C, D)

5. Kit Configuration Options:

A number of options are available depending on the type of Si570 chip ordered and typical applications are shown in fig 7. Reasons for using a transformer are:

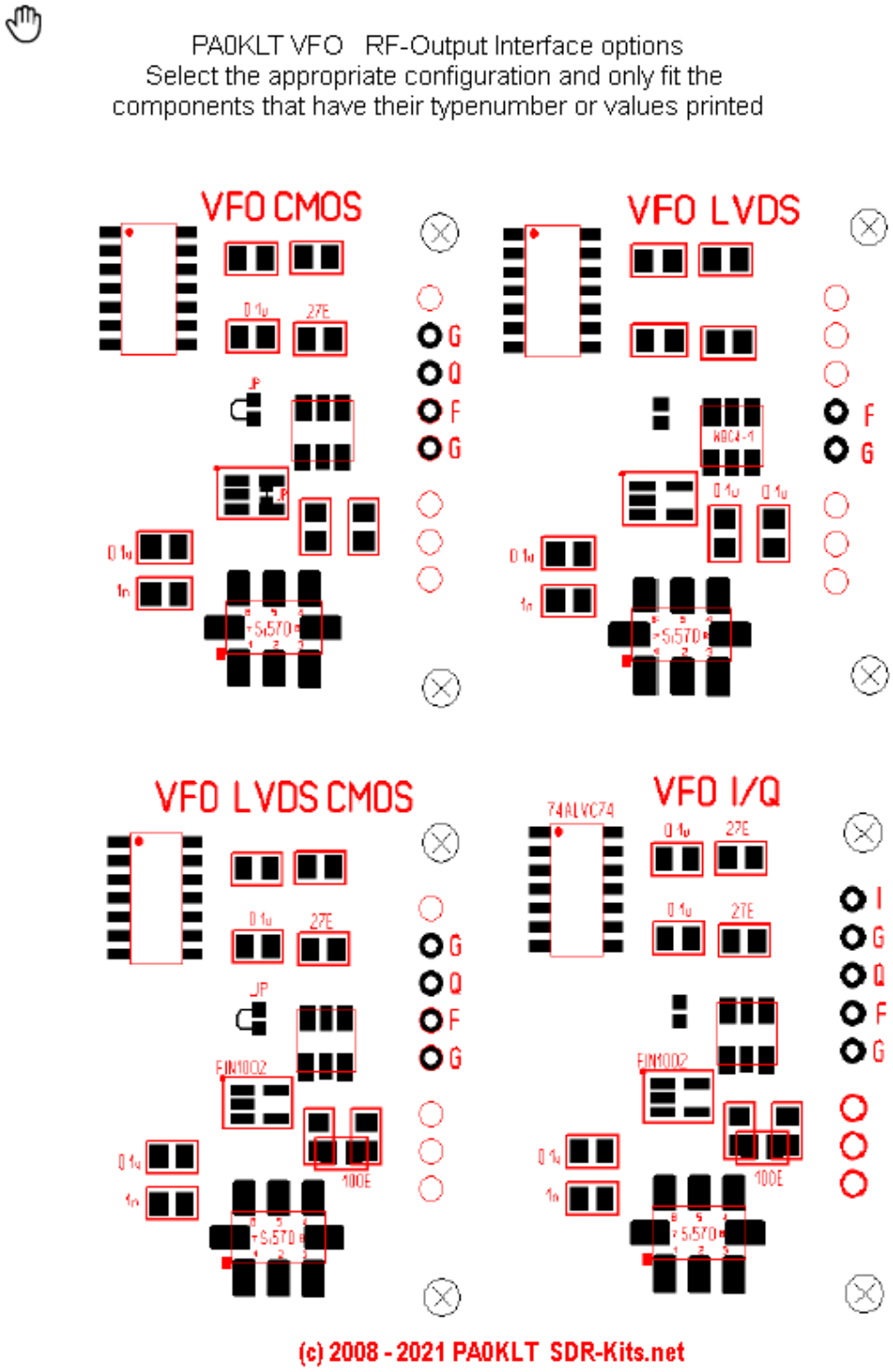
- Matching the Si570 CMOS device which has approx 200 Ohm output impedance to a 50 Ohm load by using a 4:1 transformer. Up to +12dBm output over 50 Ohms may be obtained this way. Please note the Si570 CMOS only has one RF output.

- Si570 LVDS and CML devices have two (push-pull) complimentary outputs. Using a 4:1 transformer with a centre tap on the primary allows combining the two outputs and matching into 100 Ohms. An MMIC amplifier (MAV11 or equivalent) will provide 12dB gain...

- The secondary of the transformer should be grounded at one end to obtain single ended output required when using coax cable to connect to other circuitry.

- Si570 CML device has two (push-pull) complimentary outputs. Each RF output may be interfaced directly into a 50 Ohm Load or feed a MMIC Amplifier stage (ie MAV11)

The following transformers have been used:



Band Select Output 4.21		
	Band Output	**Frequency MHz**
0	0000	0.1357 – 0.1378
1	0001	0.472 – 0.479
2	0010	1.8 – 2.0
3	0011	3.5 – 4.0
4	0100	7.0 – 7.3
5	0101	10.1 – 10.15
6	0110	14.0 – 14.35
7	0111	18.068 – 18.168
8	1000	21.0 – 21.45
9	1001	24.89 – 24.99
10	1010	28.0 – 29.7
11	1011	50.0 – 54.0
12	1100	70.0 – 72.0
13	1101	144.0 – 148.0
14	1110	430.0 – 440.0
15	1111	Outside above bands
*** = Frequency selected outside Amateurband**		

Table 2: Band Select Output on AUX Connector J2 pin 1, 2, 3 and 4 (A, B, C, D)

6. Kit Configuration Options:

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- The secondary of the transformer should be grounded at one end to obtain single ended output required when using coax cable to connect to other circuitry.

- Si570 CML device has two (push-pull) complimentary outputs. Each RF output may be interfaced directly into a 50 Ohm Load or feed a MMIC Amplifier stage (ie MAV11)

The following transformers have been used:

- homebrew transformer. This consists 5 turns 0.2mm wound trifiliar on a BN43-2402 core up to 200 MHz. alternatively use a BN61-2402 core with 6 turns 0.2mm trifiliar for up to 300 Mhz.

- You can also use a Minicircuits T-622 4:1 up to 200 MHz - This drops into the PCB.

- A Coilcraft WBC4-1WTB 4:1 is supplied with PA0KLT Kit C and is specified up to 800 MHz and usable up to 945 MHz. This is a SMD transformer which may be soldered direct on pads on the 2nd ISSUE PCB as shown in fig 1. This transfomer may also be configured as a 4:1 transformer for Si570 CMOS chip.

7. Operating instructions PA0KLT - Si570 VFO v4.32 firmware

Four push Buttons and the Rotary Tuning control are used to operate the VFO:
These are: Cursor "<", Cursor ">", Escape ESC , Memory MEM and TUNING (Rotary tuning Control)

7.1) There are four modes of Operation: These are:

- VFO A(VFO A frequency - Manual tuning - Frequency Recal and Store)
- VFO B (VFO B frequency - Manual tuning - Frequency Recal and Store)
- Memory A (16 Memory Locations 1 - 16 to Recall or Store Frequencies)
- Memory B (16 Memory Locations 1 - 16 to Recall or Store Frequencies) **A**

Short push on "MEM" button switches between these four modes

7.2 VFO Mode A or VFO Mode B

- The Tuning speed - Frequency step is adjusted with < and > CURSOR keys. The mininimum frequency step can be set from 1 Hz, 10 Hz, 100 Hz, 1 kHz etc up to 100 Mhz

- Press ESC sets all the digits right of the curser to zero

- To store the displayed frequency in VFO mode to EEPROM, the MEM key is pressed for 2 seconds until the LCD displays STORED

- Tuning to a frequency and pressing the MEM button for two seconds stores that frequency ready for the next time the unit is switched on. When in VFO use, pressing MEM is only to store the last frequency used in EEPROM. Setting that frequency does not store it in any of the 16 Memory locations.

7.3 Memory Mode

- Use a single quick press of the MEM button selects Memory A or Memory B.

- When in Memory A or Memory B mode, press < > cursor buttons to select the required memory location (1 - 16). The previously stored frequency in the selected memory location is now displayed.

- When in the selected Memory location press the ESC button to turn on Manual memory tuning and tune to the frequency you want to memorise (store)

- When at the desired frequency press the MEM Button for 2 seconds to store that frequency

- Press ESC sets all the digits right of the curser to zero

7. 4 Synthesizer Configuration Mode for Firmware Version V4.21

The desired frequency and mode is configured as follows
Press CURSOR < and > keys together for about 2 seconds until the configuration menu appears.
Release and use CURSOR buttons **< or >** to select Configuration Option as described below. Store your selection by pressing the MEM key
You can leave the Configuration mode by pressing ESC. This will reset the AVR which will use the options which were stored during Configuration Setup.

Intermediate Frequency (IF) Offset Mode:
Press MEM and select the desired (MF Offset =IF Offset). The offset can only be a positive frequeny (Local Osc is higher than IF Signal Frequency). Press MEM to store the offset frequency. Pressing ESC will exit the Configuration mode.

Note If the Lock (PTT) is activated by grounding this line to earth then the IF Offset specified will be removed.

Calibration mode:
Press MEM momentarily. The Si57x Crystal frequency is now displayed and may be changed so the SI57x output frequency measured on a counter is exactly as displayed on the LCD display. The < > Cursor buttons may be used to select the digit to be changed. Once the new Crystal frequency has been selected using the Tuning Knob, press the MEM for 2 seconds to store the new value. Pressing ESC will abort and exit to the IF Offset Mode.
Note: If displayed Frequency is lower than measured frequency then the Crystal frequency needs to be lowered and visa versa.

Multiplier (Si570 output frequency = (Displayed Frequency * Multiplier) Presss MEM momentarily and select the required multiplier factor with the <> cursor buttons: 2^0 for Multiplier 1, 2^1 for Multiplier 2, 2^2 for Multiplier = 4 and 2^3 for Multiplier = 8. Press MEM for 2 seconds to store. Pressing ESC will abort and exit to the IF Offset Mode.

Set Maximum Frequency (280 Mhz for C-grade, 945 for B-grade and 1417 A-grade)
The maximum frequency which is supported by the Kit depends on the grade of the installed Si570 chip as well as the IF Offset and the Multiplier value selected. For example: Si570BBB max frequency is 945 MHz. If a IF Offset of 40MHz and Multiplier of 4 is selected then the maximum frequency will be around (940-40)/4 =225 MHz. Press MEM briefly and set maximum frequency using rotary control and <> buttons. Press MEM

for 2 seconds to store or press ESC to cancel. (Max Freq = 1417 MHz is only supported from V4.19 firmware with Si57x A-grade chips.

Minimum frequency
The minimum frequency which is supported by the Si57x and the firmware is 3.45 MHz but IF Offset and Multiplier need to be taken into account. For Example if IF Offset = 40 MHz and multiplier of 4 is selected then the mimimum frequency should be set to: (3.5+40)/4

Configuring I2C adres Si57x
This option allows you to select the correct I2C address for AVR to communicate with the Si57x chip. Si57x chips supplied by SDR-Kits from England or by Tom Hoflich KM5H have address HEX 55. Si57x supplied by others may use other addresses (for example on German Supplier uses HEX 50). **Y**ou may specify any I2C address between Hex 50 and Hex 5F. The default is Hex 55.

Si570/Si570 Selection (default settings Kv = 0 for Si570)
Selection of of this option allows entering of a value for Kv. If Si570 is used then Kv should be set to 0 (default setting). If a Si571 chip is fitted then Kv should be set to a starting value of 180 to ensure that the generated Frequency is as close as possible to the frequency displayed on the LCD screen AFTER calibration. If errors are seen then try a different value (170 or 190) for Kv and after performing calibration. then check whether the fequency error the Si571 has been reduced. After Kv value has been set press MEM to store the new value or press ESC to quit this option.

7.5 Complete Power-up Reset.

On **rare** occassions the EEPROM data may become corrupted which could prevent the VFO from initializing properly. Erasing EEPROM and applying the default Configuration is not possible and a Power-up Reset may be necessary as follows:

Press ESC and MEM buttons at same time and apply DC Power until the LCD Screen shows the normal start-up screen. Release ESC and Mem buttons.
Any configuration information previously applied have been lost and need to be re-applied.

PAOKLT	***Firmware 4.21***	***Frequency Range 3.45 MHz - 1417 MHz***	
Support for A Grade chip 3.45 MHz to 1417 MHz without gaps (not warranted)			
Support for Si570 and Si571 Chips			
AM mode selected as default – Easier Calibration			
Required Mode	**Connection J2**	**Output Frequency (Offset)**	**Remarks**
AM	No connection	0 Hz (No offset)	Default – calibration
LSB	9 to GND	Displayed Freq – 1.5 kHz	

USB	9 and 15 to GND	Displayed Freq + 1.5 kHz	
CWL	9 and 14 to GND	Displayed Freq – 0.75 kHz	
CWU	9, 14 and 15 to GND	Displayed Freq + 0.75 kHz	
LOCK	16 to GND	Any IF offset and all Mode Offsets are removed regardless what mode is selected	

Table 4: Connections and Offsets for firmware up to V4.21 and higher

Success & 73s Jan Verduyn G0BBL Jan.Verduyn@gmail.com

www.SDR-Kits.net - kit production - English Manual - Kit support -

Ton Blokker PA0KLT Pa0klt@amsat.org
PCB Design and Firmware development

APPENDIX 1 - Removing clickstop from Rotary encoder

Note: The rotary encoder supplied has 24 clickstops, **which is enhanced to 96 steps per resolution through firmware by detecting additional steps between each clickstop**. Removing of the clickstop is essential for the enhancement to resolution of 96 steps per resolution.

( ) Gently bend open the four lugs from (two at each side) of the encoder and remove the rear plate as shown in the picture below.

Appendix 1 - Fig 1 - Adjusting Click Stop Spring

( ) Remove the contact assembly as shown in the photo below and locate the contact spring.

Gently bend the sliding contract spring away to the back so the pressure on the rotary disc is reduced.

Ideally you want to maintain a little pressure - You can test by placing the contract assembly back and trying out until you feel it is right for you.

CAUTION: Do not touch or try to adjust the three sliding contacts below as it may damage the encoder and cause erratic operation.

( ) After adjustment fit the rear plate and secure by bending the lugs back in original position

Appendix 1 - Fig 2 - Adjusting Click Stop Spring

End of Appendix 1.