X-Lock VFO Stabiliser

User Manual

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cumbria designs

www.cumbriadesigns.co.uk

The Steading
Stainton
PENRITH
Cumbria
CA11 0ES
UK

1 Introduction

Thank you for purchasing the Cumbria Designs X-Lock kit. We hope that you enjoy constructing this kit and find many uses for this feature rich design. This manual describes the assembly and operation of the X-Lock kit, even if you are a seasoned constructor, we respectfully ask that you read this manual and familiarise yourself with the instructions and kit contents before commencing construction. If assembled carefully, this unit will provide many years of reliable service.

The Cumbria Designs Team

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2 Preparation

2.1 Tools

We recommend that the following tools are used during assembly and testing;

25W fine tipped soldering

60/40 Rosin cored solder

5" or smaller diagonal side cutters

Small pointed nosed pliers

Solder sucker (just in case!)

Multimeter

2.2 Conventions

The following symbols are used within the assembly instructions to draw attention to critical steps such as component orientation and anti-static precautions. The associated narrative describes the action required.

Critical Step

Static Sensitive

2.3 Assembly

The production of a successful finished working kit is dependent upon careful component handling, placement and good soldering!

Don't be tempted to rush the construction, even though this is a relatively simple kit, a wrongly placed component can provide hours of frustrating fault finding. Also, as this kit uses a double sided Printed Circuit Board (PCB) with through plating, removal of a wrongly soldered part can be difficult. Follow the assembly instructions carefully to avoid mistakes.

2.4 Component Identification

All parts carry a coded identity to describe their values. It is important to be able to recognise these during assembly. Capacitors have their value printed numerically, e.g. 104 = 100nF, 103 = 10nF etc. Resistors have their values represented by coloured bands – this is a frequent source of confusion!

To simplify component identification, the parts list carries the identities of each component as it appears on the device. For resistors the colour coding is given. This should be referred to during assembly to ensure the right parts are placed in their respective positions on the PCB.

2.5 Component Leads

Many of the passive components will require their leads to be formed to align with the holes on the PCB. This mainly applies to the axial parts such as resistors and diodes. Forming

component leads is easily done with a pair of pointed nose pliers and using the hole spacing on the PCB as a measure. Alternatively, small formers made from scrap off cuts of Vero board etc make ideal templates that produce consistent results. Some parts, such as variable resistors, have preformed leads designed for machine assembly. These will require straightening to align with the board layout. Again, a pair of pointed nose pliers should be used to carefully flatten the factory performing to produce straight leads.

2.6 Soldering

Before applying solder check **carefully that the component you have placed is in the right position!** This is a through plated double sided board. Whilst some of the pads are very small, the area presented by the through plating is more than adequate to allow good solder flow to form mechanically strong good electrical joints. These can be difficult to undo, please double check!

The majority of problems are likely to be caused by soldering faults. These can sometimes be difficult to find. Here are some basic golden rules that will help you to avoid poor solder joints;

- **Clean Iron**

Make sure your soldering iron tip is in good condition and tinned. A small moistened pad for cleaning tips, regularly used to wipe off excess solder and flux, will ensure that your iron performs well. Remember to tin the iron immediately after each wipe.

- **Clean Leads and Pads**

All of the component leads and PCB pads in this kit are pre-tinned and should not need cleaning before soldering. Please ensure that parts are handled so as to avoid contamination with grease or fingerprints.

- **Soldering**

This is the bit that can trip up even experienced constructors. For the solder to fuse with the surfaces to be joined it is necessary for them to be hot – but not so hot as to damage the parts! It's a simple as ***1-2-3***;

1. *Place the tip of the iron against the joint, hold it there briefly to bring the metal surfaces up to temperature.*
2. *Apply the solder allowing it to flow smoothly onto the surfaces.*
3. *Remove the iron and inspect the new joint.*

The finished joint should have a smooth shiny coating of solder. If the joint is dull grey or has formed a spherical "blob", apply the iron to the joint, remove the old solder with a solder sucker and re-solder.

3 Circuit Description

3.1 General

The X-Lock is a micro-controller based frequency stabiliser designed as an easily applied "add-on" to enhance the frequency stability of existing free running variable frequency oscillators (VFOs). This compact module will operate with an input signal range of a few tens of kHz to 50MHz to produce a variable correction voltage to compensate for drift in the host oscillator. To minimise the risk of introducing digital noise to the host oscillator, the analogue section of the X-Lock operates from its own regulated supply and is optically coupled to the digital control circuitry. A dual-colour LED provides operational and diagnostic information of the X-Lock status. In common with all types of frequency stabilisers, the X-Lock will make a good VFO even better, however it will not make a badly designed or constructed VFO into a good one.

There are three two pin connectors on the X-Lock; RF Input, Control Voltage output and the nominal 12V DC supply.

3.2 Theory of Operation

The Cumbria Designs X-Lock is a derivative of the "Huff-Puff" stabiliser system devised by the late Klaus Spaargaren PA0KSB in the 1970's. This and similar frequency control systems operate by comparing the controlled oscillator with a crystal reference (hence X-Lock = Xtal-lock) to produce a correction signal. This is used adjust the frequency of the oscillator to compensate for the drift. The frequency control of the host oscillator is usually realised by a varactor (varicap) diode although some systems use an inductive device with variable permeability or even motor controlled capacitors. The X-Lock is design to operate with a varactor.

The X-Lock operates by measuring the frequency of the host oscillator by the gate/counter method. This is the same technique used by most digital frequency counters. At the heart of the X-Lock is a 16F716 processor (IC3) which performs all of the measurement and control operations. The input signal is taken from a buffer stage of the host oscillator and is amplified by Q1. The input the processor is on pin RA4, the gate circuit is formed by R11 and the TTL/tri-state operation of the 16F716's RA3 pin. This gating technique is effective but is dependent upon signal input level. VR1 is used to adjust the input signal for correct operation. A 100mSec gate period is used to count the input frequency to a resolution of 10Hz. The value of each measurement is compared with the previous and if the difference is within 40Hz, the 16F716 processor will generate a correction signal. This takes the form of a variable duration control pulse on either the Up or Down signal lines from the processor. These drive LED's within the Opto-coupler, IC4, to switch on or off their associated transistors either charging or discharging the voltage stored in the loop filter R9, C10 and C13. The time constant of the loop filter is very long resulting in a slow rate of change of the control voltage. To ensure that the control voltage starts at centre rail, a reset switch formed by FET Q2 is enabled by the processor on power on. This ensures that C10 and C13 are fully discharged. Following discharge, once Q2 is turned off the capacitors (because they are the same value) re-charge via R5 to restore a centre rail output voltage. In the unlikely event that the loop control voltage becomes "saturated", say after a prolonged period of operation, the control voltage can be set to centre again by briefly powering the X-Lock on and off to operate the Q2 reset switch. The host VFO will need to be retuned following a reset.

A rail to rail operational amplifier IC5, buffers the filter voltage to produce a low impedance voltage source for driving the external compensation varactor. Whilst the varactor circuit will exhibit a very high DC impedance, the low impedance of the operational amplifier output reduces the effects of stray voltages on the control voltage line. A simple RC filter (R10 and C15), decouples the control signal at the point where it leaves the X-Lock PCB.

There are two voltage regulators on the X-Lock PCB. IC2 provides the +5V supply for the 16F716 and the input amplifier, IC1 provides +8V supply for the loop filter and output amplifier. The use of separate regulated supplies provides good isolation between the digital and analogue stages and offers a wide operating range for the control voltage reducing the possibility of loop saturation.

A red LED, 100K resistor and 68pF capacitor are included with the X-Lock kit. These are intended to be

configured as a varactor correction circuit shown in **fig.1**. This circuit should be suitable for most applications up to about 15MHz. Above this frequency the value of the 68pF capacitor may need to be reduced to prevent over correction.

4 Assembly

The following assembly sequence is recommended. This allows most of the smaller parts to be held in place with the board turned over whilst soldering the underside. All components are mounted on the top (silk screen) side of the board.

4.1 Fixed Resistors (Broad tolerance band shown in capitals)

15R	R18	Brown, Green, Black, (GOLD)
100R	R5, R17	Brown, Black, Black, (BROWN)
390R	R6, R13, R14, R15	Orange, White, Black, Black, (BROWN)
470R	R2, R8, R11	Yellow, Mauve, Black, Black, (BROWN)
1K	R3, R4, R16	Brown, Black, Brown, (BROWN)
10K	R1, R10, R12	Brown , Black ,Black, Red, (BROWN)
100K	R7	Brown, Black, Black, Orange, (BROWN)

4.2 IC Sockets

! Ensure correct orientation! Match index cut out on socket to board printing. Tip; solder one pin only then check positioning before continuing. Heat solder and reposition if necessary.

a) Fit the 18 pin microcontroller socket for IC3
b) Fit 8 pin sockets for IC4, IC5

4.3 SIL Socket (For R9)

Cut off the thin sections of two centre pins in the 4 way SIL strip to allow it to be fitted flush into the R9 position. Solder the SIL strip in place. Trim and fold the leads of R9 such that it plugs neatly into the SIL socket.

390K	R9	Orange, White, Black, Orange, (BROWN)

4.4 Crystal

Fit X1, the 20MHz crystal. This is heat sensitive and is easily damaged if overheated. It is recommended that a gap of about 2mm is left between the crystal and the PCB. This will provide a little extra thermal isolation during soldering.

4.5 Ceramic Capacitors

Suggested Installation order;

22pF	C5, C6	22J
10nF	C8, C9, C14, C15, C16	103
100nF	C2, C7, C12	104

4.6 Transistors

Polarity conscious components. Make sure that orientation is correct.

The 2N7000 is a Static sensitive part. Discharge yourself to ground before handling. Avoid wearing static generating clothing (e.g. wool, man made fibres etc) during assembly.

a)	Fit Bipolar transistor Q1	2N3904
b)	Fit FET Q2	2N7000

4.7 Regulators

Polarity conscious components. Make sure that orientation is correct.

When installing the two T092 Voltage regulators, ensure that their orientation matches that shown on the silk screen.

a)	Fit 5V regulator IC2 78L05
b)	Fit 8V regulator IC1 78L08

4.8 Variable Resistor

The pre-formed leads will require to be straightened to fit. Note that due to PCB through plating tolerances, VR1 may be a tight fit. If this is the case, work it gently into position or alternatively carefully trim the width of the pins.

Fit the 10K input level Cermet VR1 (103)

4.9 Electrolytic Capacitors

C9 and C11 are polarised Capacitors, observe the polarity shown by the silk screen.

10uF	C1, C4, C11
100uF	C3, C10, C13

4.10 Connectors

Recommended Pin Header Connector orientation is with rear locking tab facing into the centre of the board.

Fit the 3 two pin headers PWR, RF, VAR

4.11 LED

The Tri-colour LED has three leads. The centre lead is the cathode and the two outer leads are anodes for the red and green LEDs. The shorter of the outer leads is the red LED anode. The Tri-colour LED is inserted with the short lead nearest the crystal X1.

4.12 Semiconductors

Static sensitive parts. Discharge yourself to ground before handling. Avoid wearing static generating clothing (e.g. wool, man made fibres etc) during assembly.

Orientation is critical. Observe correct alignment of IC pins which will need to be gently formed for correct alignment before insertion into sockets. IC pins can be pushed inwards by placing the device on its' side on a firm surface, and gently pressing the body down against the pins. When inserting parts, take care to check pin alignment.

Fit	IC3	PIC16F716	Processor (18 pin DIL)
Fit	IC4	TIL192	Dual opto-coupler (8 pin DIL, white body)
Fit	IC5	TS951	Operational Amplifer (8 pin DIL)

4.13 Connector Assemblies

Connector shells and pins are supplied to allow connection of power and signal lines to the X-Lock. The use of good quality, colour coded, heat resistant, multi stranded wire is recommended. To avoid accidents, a colour code convention should be chosen to represent function, e.g. Red +ve supply, Black ground, striped colours controls etc. The connector assemblies comprise of two components; the shell and the pins. To terminate a conductor first strip back about 2mm of insulation and tin the exposed wire. Place the tinned end of the wire into a pin such that the tinned wire sits inside the inner pair of tabs and the insulation sits within the outer tabs. With small pointed nose pliers carefully compress the outer tabs onto the insulation to hold the wire. Repeat this with the inner tabs to grip the exposed conductor. Very carefully solder the exposed conductor in place taking care not to allow solder to flow onto the locking tab. Finally, insert the pin into the shell with the small locking tab orientated to the face of the shell with the small cut outs. Push home until the locking tab snaps into the cut out. Should you need to remove a pin, gently press the locking tab in with a small screwdriver or the end of a pair of pointed nose pliers. The pin will be released and can be pulled out of the shell.

Assembly complete, well done! Now carefully check your work for dry joints and bridges before moving on to testing.

5 TESTING

Before connecting the X-Lock to your power supply for the first time, carry out these simple checks – just to be safe!

5.1 Basic Electrical Tests

5.1.1 +12 Volt Input

With a multimeter set to resistance, place the Red meter lead onto +12v and the Black to Ground and check for a high resistance. Note that due to C11 charging the reading will show change, providing there is not a short circuit then all is well.

5.1.2 +5 and +8 Volt Rails

Carry out the resistance test on the output side of the regulators (IC1 and IC2) to check the integrity of the regulated rails. Due to the circuitry of the X-Lock a much lower resistance will be measured, the reading will depend upon the characteristics of the multimeter but typically should be around 250 Ohms.

5.2 Powering Up

5.2.1 Power

With no controls set, connect a +12 volt supply to the X-Lock. Double check the polarity, take a deep breath and switch on. The LED will sequence through Red, Amber and Green and then flash Red on and off indicating that there is no signal input.

5.2.2 RF Checks

Connect a signal source of around 500mV peak to peak or greater between the RF input pin and ground, the LED should stop flashing Red. If it doesn't, adjust VR1 to change the input level, a pint will be found that will give a reliable off state for the flashing Red indication. If the signal source is stable enough, the LED may illuminate Green indicating that the drift rate between measurements is low.

This concludes the unit testing.

6 USER SET UP

6.1 Installation

Install the X-Lock as close as possible to the VFO that it will work with. Keep all signal leads as short as possible to minimise any unwanted radiation or pick up. The X-Lock requires a smoothed DC supply in the range +10V to +16V, supply voltages greater than +16V should be avoided to prevent over heating of the regulators.

6.2 Connection to a VFO

The RF input should be taken from the output of the buffer stage to avoid loading the VFO. This will typically be a low to medium impedance source which should be capable to developing 500mV peak to peak or greater across the X-Lock RF input without a significant reduction in level.

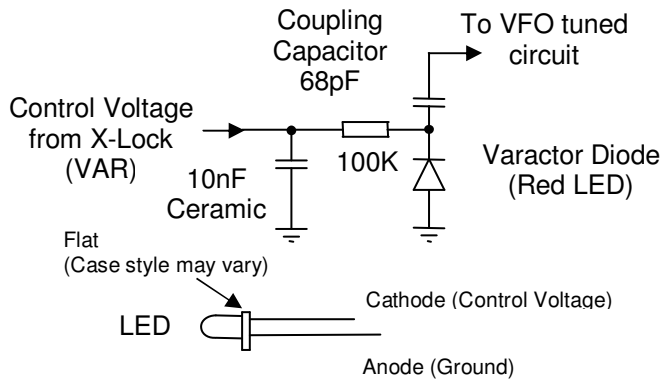


Fig.1 VFO Connection

The control voltage output (VAR) of the X-Lock is used to drive a varactor in the VFO tuned circuit. A Red LED, 100K resistor, 10nF and 68pF capacitors are included in the kit to form a varactor circuit. This should be

satisfactory for most applications. **Note**, *the LED will not light up!* Depending upon the characteristics of the VFO it may be necessary to adjust the value of the coupling capacitor or change the LED for a variable capacitance diode with a smaller capacitance range. The circuit configuration is shown in **Fig.1**, all component leads on the VFO side of the 100K resistor should be kept as short as possible to offer best mechanical stability. Be careful to confirm that the voltages at the point of connection in the VFO do not exceed 50v DC. The AC component should be no greater than 5v p-p.

6.3 Time Constant

The rate of change of the control voltage is set by the value of the R9, C10 and C13 time constant. To allow this to be changed, R9 is mounted as a push fit into a strip of SIL socket. The 390K resistor provided should work well in most applications but can be easily changed by plugging a new value into the SIL socket. The optimum value will provide good stabilisation with no "warble" caused by changes in the correction signal. If the 10Hz correction signals can be heard as a warbling effect on a received signal then try increasing R9 or alternatively reduce the value of the coupling capacitor in the varactor circuit to reduce the tuning range of the varactor.

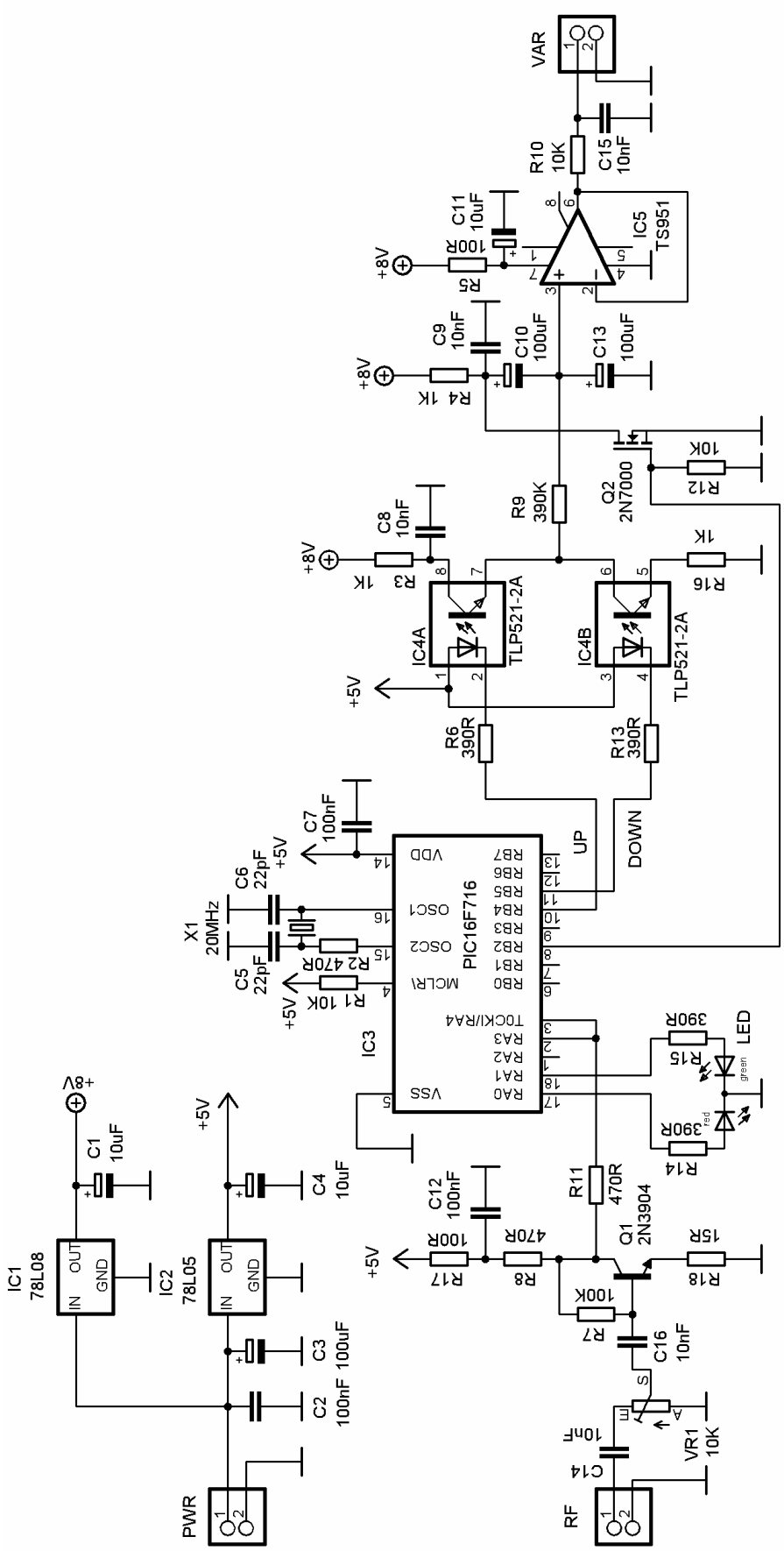
Appendix A

Troubleshooting

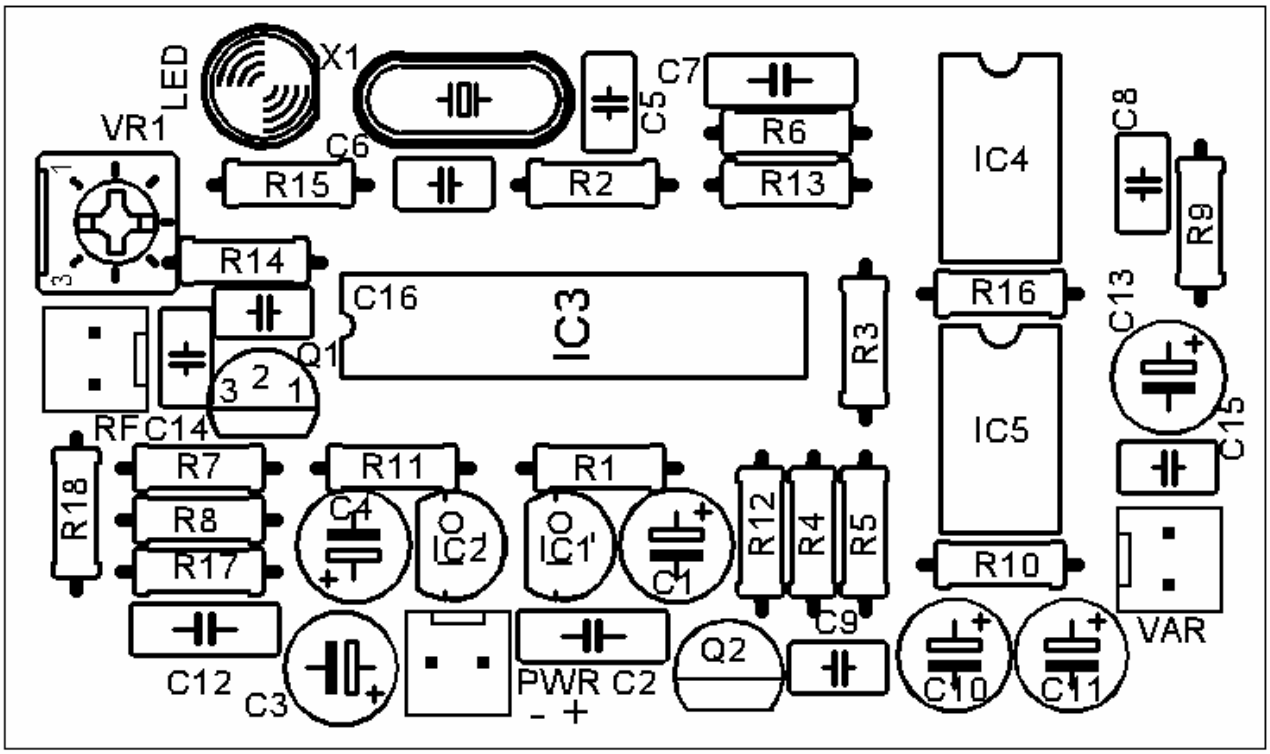
The following checks may help in identifying the cause of operational problems.

Area	Symptoms	Actions
LED	LED regularly flashes RED	Input level too low or absent, check connection to VFO and drive level. Adjust VR1 if necessary.
	LED permanently RED or LED flickers RED/GREEN. Received signals sound clean.	Input OK but VFO drifting greater than 40Hz/second. (Normal during VFO initial warm up). Check varactor circuit installed correctly, check control voltage present at varactor circuit input.
Power	Power applied but unit doesn't work. Little or no current drawn.	Check Power Supply polarity. Check +12V on inputs to Regulators. Check Regulator Ground continuity
	LED goes through initialisation sequence but there is no control voltage output.	Check +8V regulator for input and output, confirm correct orientation. Is IC5 inserted correctly? Check soldering of IC5 pins
No Lock	VFO "jitters" causing warbling modulation on received signals. LED Flickers GREEN/RED.	Varactor is over compensating pulling VFO out of lock range. Reduce coupling capacitor value and/or replace Red LED with a varactor diode with a lower capacitance range.
	VFO sounds clean but still drifts. LED Flickers.	VFO not stable enough. Check design. Time constant too high, reduce plug in resistor R9.
Time Constant	X-Lock LED shows lock and VFO is stable but warbling evident on received signals.	Increase time constant by changing value of plug in resistor R9.

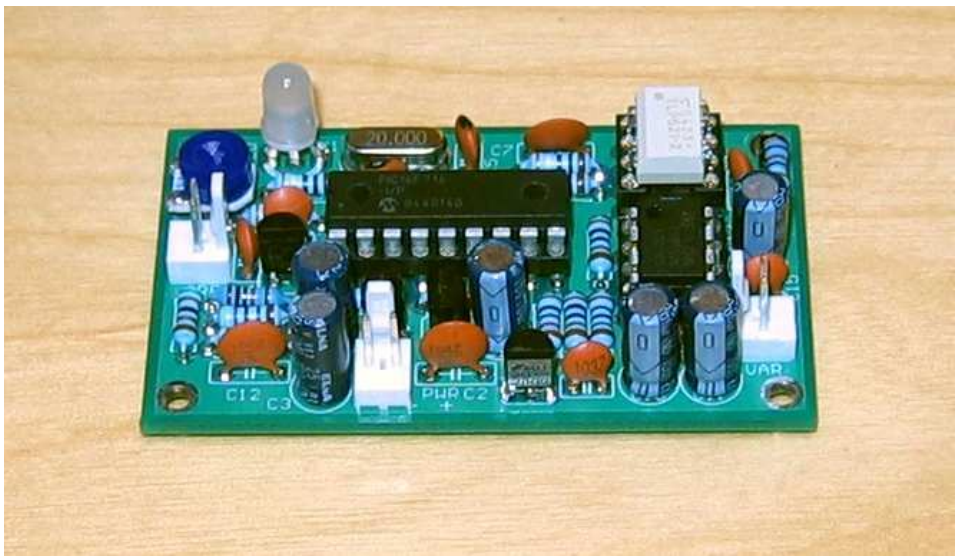
X-Lock Schematic



X-Lock Component Overlay



The Assembled Kit



X-LOCK PCB VERSION 1.1 PARTS LIST

Resistors

1	15R	R18
2	100R	R5, R17
4	390R	R6, R13, R14, R15
3	470R	R2, R8, R11
3	1K	R3, R4, R16
3	10K	R1, R10, R12
1	100K	R7
1	390K	R9
1	10K	VR1 Potentiometer

Capacitors

2	22pF	Ceramic Capacitor	C5, C6
5	10nF	Ceramic Capacitor	C8, C9, C14, C15, C16
3	100nF	Ceramic Capacitor	C2, C7, C12
3	10uF	Electrolytic Capacitor	C1, C4, C11
3	100uF	Electrolytic Capacitor	C3, C10, C13

Semiconductors

Q1	2N3904	NPN transistor
Q2	2N7000	FET
IC1	78L08	8v T092 Regulator
IC2	78L05	8v T092 Regulator
IC3	PIC16F716P	Microcontroller
IC4	TLP521	Dual optocoupler
IC5	TS951	Operational Amplifier
LED	Tri-colour LED	

Connectors and IC Sockets

3	2 Way Pin Header	PWR, RF, VAR
3	2 Way Shells	
6	Crimp Pins	
1	18 Pin DIL Socket	
2	8 Pin DIL Sockets	

PCB

X-Lock v1.1

External VFO Parts

1	5mm Red LED
1	100K Resistor
1	68pF Ceramic Capacitor
1	10nF Ceramic Capacitor