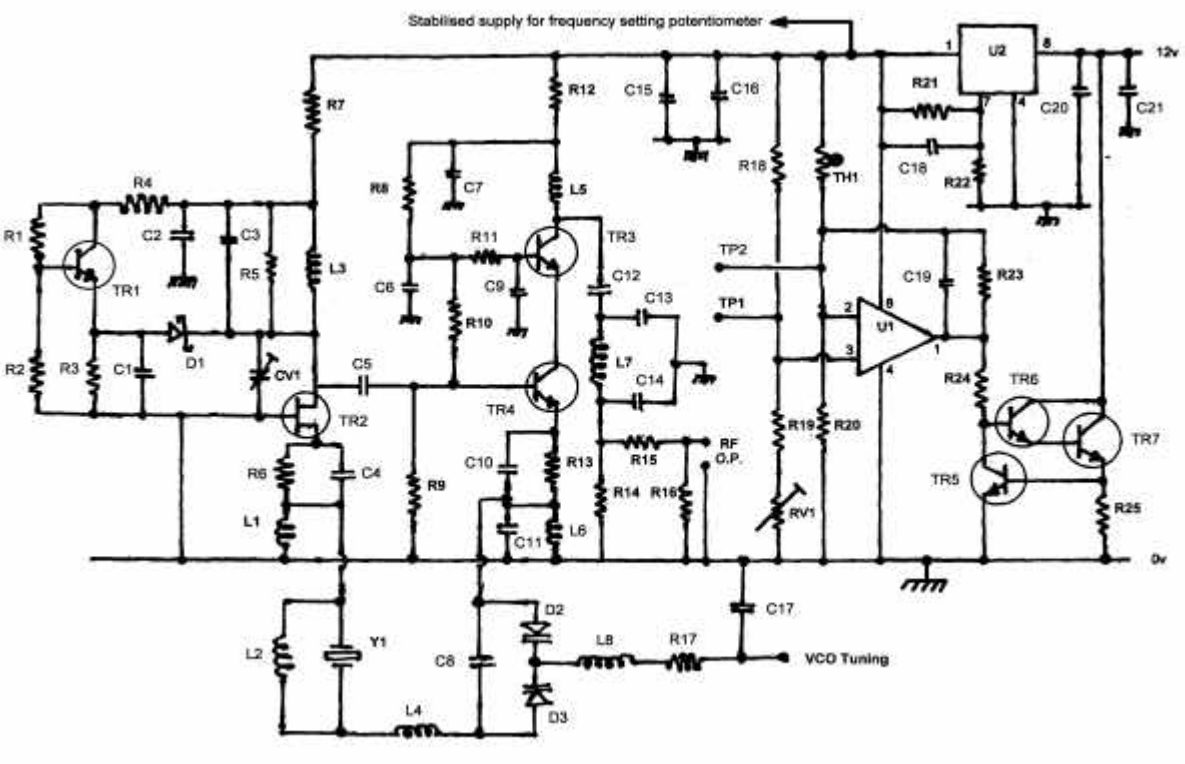
MK II Temperature Stabilised JFET Crystal Oscillator For Microwave Use
by G8ACE

Summary of Improvements from the MKI version

- Reduced circuit current consumption allowing the oven to operate in full control at lower temperatures.
- Improved trimmer adjustment access location.
- An emitter follower is used in conjunction with the oscillator limiter diode reducing the current used.
- A low pass filter option can be used at the output. This provides improved efficiency further lowering current requirements and lowers harmonic distortion.
- A Varicap tuning option in series with the crystal gives VCXO control of ± 1Hkz or more but this can be reduced according to the specific requirements. Varicap tuning allows for FM modulation, PLL operation or remote frequency setting by multi-turn potentiometer.

Circuit Diagram



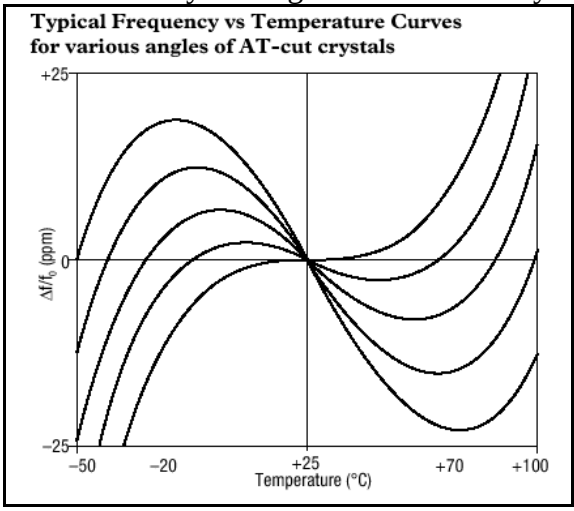
VCXO tuning can be achieved by connecting a potentiometer between the stabilised on board supply and ground. The slider connected to the diodes (C17 R17).
A resistor in series with the ground end of the pot will reduce the range.

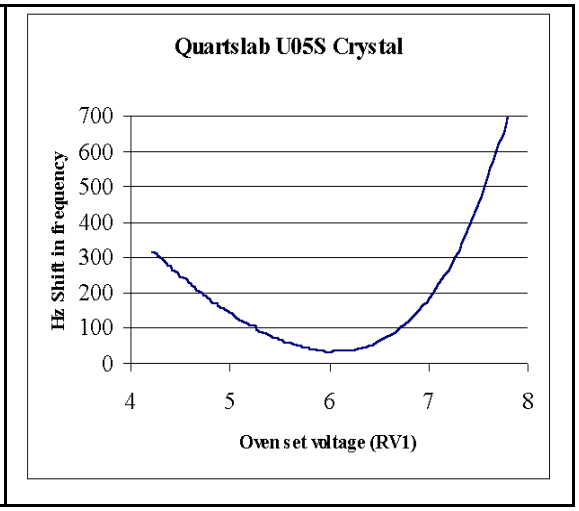
Circuit Description

TR2 and TR4 form the well known Butler oscillator circuit. TR2 in this circuit is a JFET in grounded gate. It is important with FETs to avoid bottoming the devices. TR1 and D1 provide clipping to limit the signal amplitude at TR2 drain. This also doubles to control the crystal drive level which is set to be typically 1mW. Varicaps D2 and D3 provide for pulling the crystal to an excess of ± 1 Khz if necessary in conjunction with L4 which assists in making the range symmetrical. For microwave use L4 is not required and C8 is used to swamp the varicaps reducing the range so it is satisfactory when followed by high orders of multiplication. TR3 is the upper half of the cascode stage used to provide some output isolation minimising frequency pulling by varying loads. The 3db attenuator also assists in this respect. Low distortion (harmonics) is obtained by using two inductors to form a filter. However the distortion is not significantly worse by using a single inductor. The 2nd harmonic being around 6db greater in amplitude at typically –30db.

The designed signal output level is +4dbm, sufficient to drive a multiplier. (2nd stage of the G4DDK004 board for example.) Typically 1-3db more output than +4dbm can be obtained if the output circuit is peaked carefully.

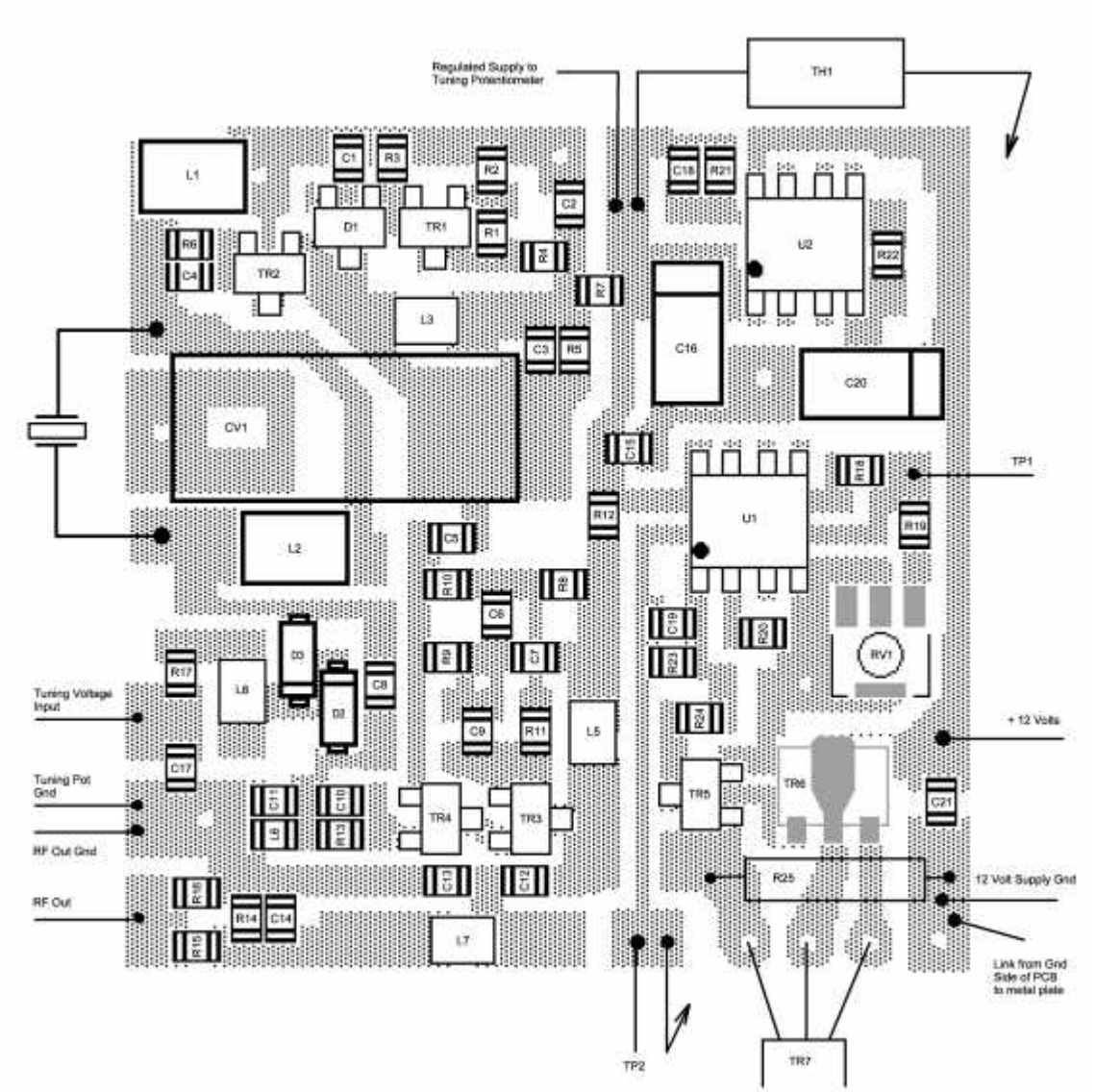
The oven control circuit is identical to that used in all oscillator modules produced. A crystal (overtone AT cut) will exhibit a frequency/temperature characteristics determined by the angle of cut for the crystal. Shown on the left below.





On the right is a plot of a Quartslab (U05S (60°C oven)) crystal. The x axis is plotted against oven set voltage (RV1) in this instance 6.1volts, 53°C, this is the turnover point. By operating the oven at this point minimal frequency shift will observed for slight oven temperature variation. In practice ambient temperature changes will affect stability since there will be a thermal resistance/gradient between the heater, the thermistor detector and the crystal. In the construction these should be connected together with the smallest thermal resistance possible. Insulation also plays an important part and sufficient should be used. Frequency movement will then be minimised. Note the specified temperature on the crystal (where the crystal will meet its specification) may not agree exactly with the turnover point. Turnover must be determined experimentally during alignment for optimum results. However a crystal where the turn over is well away from the oven temperature will still give acceptable results in this module due to the stability provided by the oven.

PCB Layout and Typical Connections



Use thin lead out wires from the module to avoid sinking the heat away. These should be preferably ptfe insulated. Use at least 1cm of thermal insulation all around the module when boxing. Stability is determined by the accuracy of setting the oven to the turnover temperature of the crystal and also adequate insulation. Current consumption is approximately 600mA from cold which then reduces to an amount necessary to maintain the set oven temperature. The oven temperature is set by connecting a voltmeter between TP2 and ground. Increase RV1 to maximum temperature allow heating to complete. Turn RV1 to minimum. With the module insulated so it cools slowly, monitor output frequency against TP2 voltage. When the frequency changes direction, note this voltage and set RV1 to provide this voltage at TP1. Usually with AT cut crystals the frequency will be lowest at the turnover point. The startup current can be reduced by increasing the value of R25.
RF Output is nominally +4dbm.
Total Harmonic Distortion using the filter option is typically better than 2%.
The single inductor output version is typically better than 5% distortion.

Construction

The smallest parts should be soldered to the PCB first. The trimmer should be mounted last. Trimmers supplied and made for vertical mounting need the extra long connection straightening and carefully cutting off. Whilst not an elegant method, a twist of t/c wire around the threaded part of the trimmer (for ceramic bodied types) passed through the grounding hole and soldered to both sides of the PCB allows the trimmer to be fixed securely and horizontally. A PCB track passes beneath the trimmer and care needs to be taken to avoid shorting this to the trimmer. Inductors L3, 5 & 7 are wound according to the table and crystal frequency used. Clean the enamel from the leads and tin, then bend the ends to lie horizontally to mount on the pad areas on the PCB. The coils should be mounted no more than 2mm above the PCB. L3 is left tight wound. The heating transistor and the thermistor cannot be connected until the PCB is glued to the heater plate with epoxy adhesive. The module can however be safely pre-tested with these components omitted. Make connections according to the component placement diagram and temporarily connect the crystal. The vcxo dc input can be open for initial testing. Monitor the output and adjust CV1 for correct frequency of operation. Check the output level can be achieved by moving the turns of L5 & 7. If all is well, the test leads and crystal can be removed and the PCB mounted onto the aluminium heater plate. The plate needs a tapped hole for the heater transistor. Two notch cut outs are required, one to clear the transistor lead outs the other (optional) allows the crystal can flange to be set in from the plate edge and the can to lie flat on the plate. Best results are obtained if the thermistor and crystal are embedded in the plate but good results can be achieved with 'on the plate mounting'. Good thermal conductivity between components is essential whichever method is used. Epoxy is satisfactory for attaching the thermistor. The crystal is best 'super-glued' A knife under the edge of the can will enable its removal if desired.

An earth wire for the heater plate can be attached using a tag under the TO220 transistor (TR7) fixing screw to the PCB back plane and linked through the hole to the PCB 12v input ground point. Check TR7 collector is insulated from the plate.

Testing after assembly to the heater plate

If the varicap diodes are fitted but the potentiometer or control voltage is not available then wire the vcxo dc input point directly to the +10.5v rail. Power the module and initially the current will be 600ma with RV1 set mid track. Allow the module to heat to check that the control circuit will shut off. The current will reduce as the temperature set point is reached but will hunt according to the heat loss. Turn RV1 anti clockwise and the current should reduce to 20+ma. (non heating mode). Check oscillation of the crystal by adjusting CV1 then adjust L5 & 7 for maximum output. Fix the turns of L3, 5 & 7 by brushing with instant glue. Whilst it is an impact adhesive, given a few minutes it will set and provide some rigidity to these coils. Obviously do not touch with the fingers etc. until you are sure it has dried. Once the module is housed in an insulated box the oven set voltage can be found for optimum operation at the crystal turnover point. Place a temporary voltage monitor connection TP2 on the end of TH1 adjacent to the heater transistor. Turn RV1 to maximum and allow heating to complete. Turn to minimum and cover with insulation. Monitor the crystal frequency and measure the thermistor voltage, TP2, as the frequency passes through a minimum. Set RV1 to this voltage at TP1. After ageing for a while the turnover can be set more accurately using the same method but perhaps plotting a

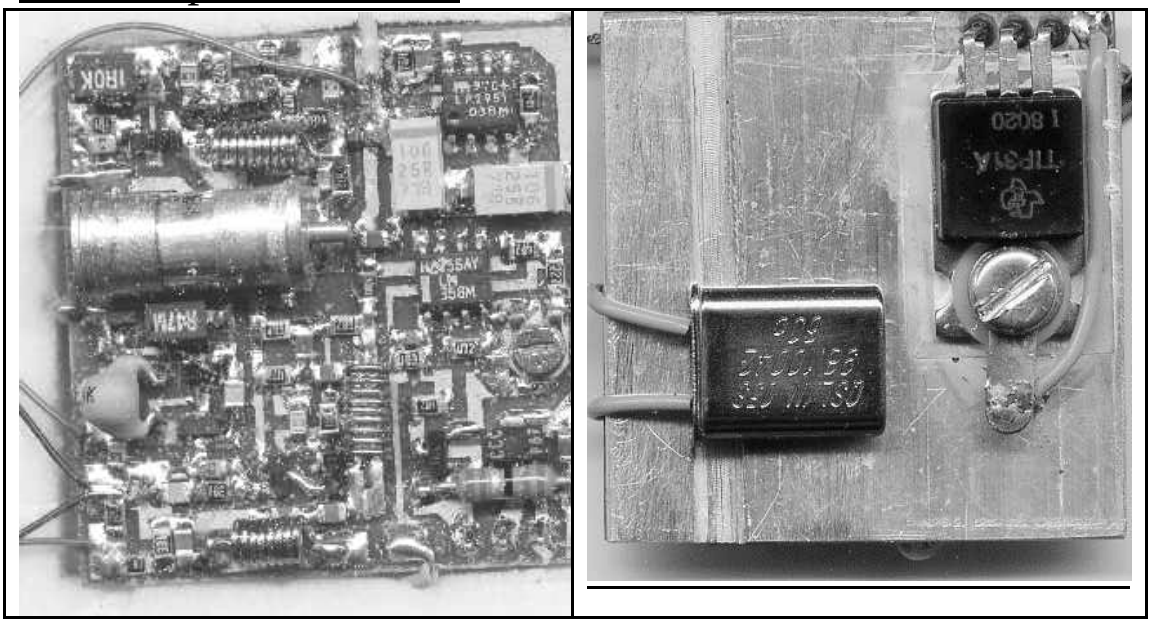
graph of freq/voltage to aid optimising stable operation. The frequency counter must itself have good stability and 1Hz resolution for this step. The crystal frequency should be set accurately after optimising the oven temperature and adequate stabilisation. During warm up the frequency will move quite considerably.
The quality of the insulation can be determined by monitoring the final current consumed. Less than 50ma indicates adequate insulation. More than 100ma is indicative of insufficient or poor quality insulation. Remember thick connecting wires will sink heat away which must be replaced. The module will withstand some variation of input supply voltage. However as the heater transistor is connected to the raw input supply, variations greater than 0.5volts should be removed with a three terminal external 1amp regulator. Minimum supply voltage for stabilised operation is 11 volts enabling it to perform well in 12v portable systems.

Inductor Data

Inductors L3 ,5 & 7 are close wound with 0.5mm Copper enamelled wire on a 2mm diameter former. A cocktail stick will serve for this purpose. L3 is used close wound. L5 & L7 are stretch tuned for best output. A coating of Instant Glue will hold the turns in place but beware !! give it time too dry before touching the inductors again.

Crystal Frequency	94 Mhz	96 Mhz	98 Mhz	100 Mhz	102 Mhz	104 Mhz	106 Mhz	120 Mhz	
L3	12 turns	11 turns	11 turns	11 turns	11 turns	10 turns	9 turns	7 turns	
L5	10 turns	10 turns	10 turns	9 turns	9 turns	9 turns	8 turns	7 turns	
L7	14 turns	13 turns	12 turns	12 turns	11 turns	11 turns	9 turns	8 turns	

The completed module



The heater plate, right, has the thermister threaded through a hole in the plate. The crystal is attached to the surface with instant glue with the flange located in a slot running across the plate so the can is in good thermal contact. The earth link is visible on the right hand edge to the tag under the screw.

MKII Oscillator Component List

Resistors		Capacitors		Misc.		Marking
R1	1K	C1	1500p	TH1	Neg temp Coeff	
R2	22K	C2	1500p			
R3	4K7	C3	12p	TR1	BC848c	1L
R4	10	C4	1500p	TR2	PMBT310	M10 or Z0
R5	1K	C5	27p	TR3	MMBT2369A	1S
R6	180	C6	8n2	TR4	MMBT2369A	1S
R7	10	C7	8n2	TR5	BC848c	1L
R8	6K8	C8	22p	TR6	BC860	CCC
R9	4K7	C9	1500p	TR7	TIP31A	
R10	6K8	C10	1500p	D1	HSMS2800	A0
R11	1K	C11	22p	D2	BB811	White
R12	10	C12	100p	D3	BB811	White
R13	390	C13	100p	U1	LM358	
R14	330	C14	100p	U2	LP2951	
R15	18	C15	27n			
R16	300	C16	10uF			
R17	10K	C17	1500p	Y1	Crystal	
R18	4K7	C18	10n			
R19	2K2	C19	100n	PCB		
R20	4K7	C20	10uF			
R21	750K	C21	27n	Wire	0.5mm diam.	
R22	100K	CV1	1-10p			
R23	10K			Sleeving		
R24	1K	Inductors				
R25	1R2	L1	1mH	Insulator	TO220	
		L2	390uH	Kit		
RV1	10K	L3	Table			
		L4	Link	Coil	2mm diam.	
		L5	Table	Former	(cocktail stick)	
		L6	100nH			
		L7	Table			
		L8	10uH			

G8ACE October 2001.