The motional inductance crystal are of importance when designing cr

$$C_M = \frac{2(C_S + C_0)\Delta f}{f}$$

$$L_M = \frac{1}{(2\pi f)^2 C_M}$$

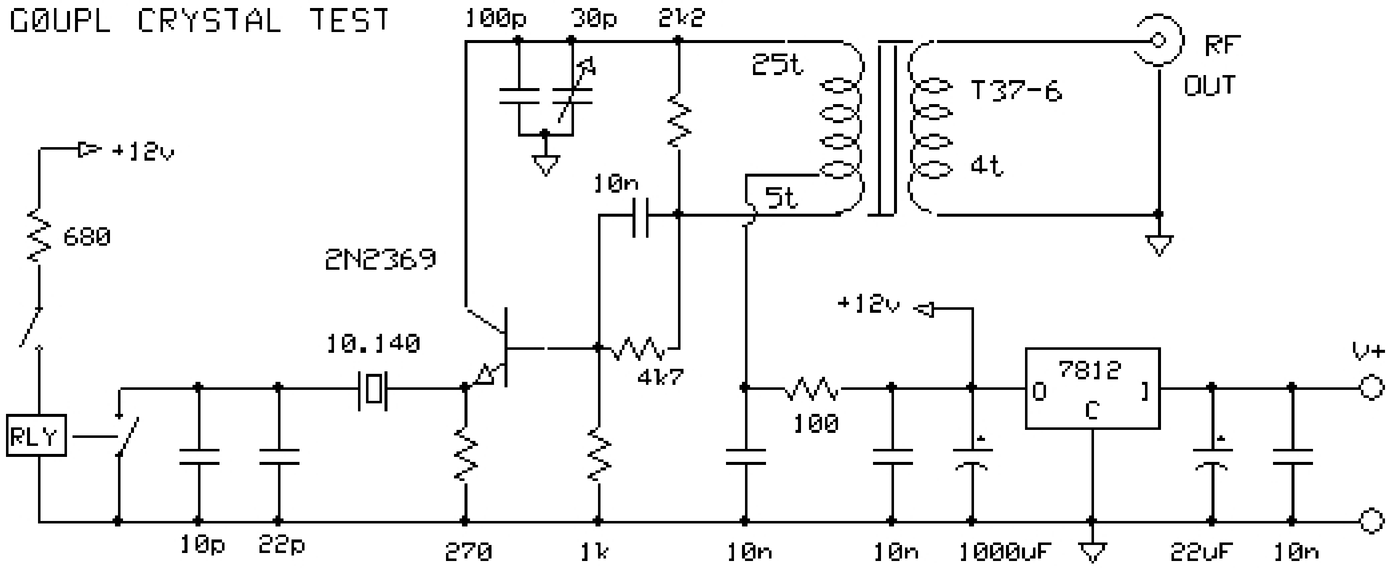
A good reference material on this topic is Crystal Motional Parameters, A Comparison of Measurement Approaches , by Jack Smith K8ZOA. G3URR's method is also described in the book Experimental Methods for RF Design (see also the ARRL Bookstore). The equations for motional inductance Lm and motional capacitance Cm are shown to the right. In these equations:

Co is the crystal holder capacitance. I assumed that this means the measured capacitance of the crystal when not in circuit.
Cs is the series capacitance, which includes stray capacitance of the circuit wiring and switch.
f is the oscillation frequency when the switch is closed (series capacitance shorted out).
Df (Delta f) is the change in oscillation frequency when the switch is opened.

Andy Smith G4OEP did some an excellent derivation of these equations, Click here to see!

Circuit diagram

G3UUR used a Colpitts oscillator but I wanted to build a Butler because it's been an oscillator topology I have wanted to try for a long time. I made the assumption (perhaps incorrectly) that the same equations apply. My Butler oscillator circuit diagram is shown below.



[illegible]

Construction

I built the circuit on a 52 x 37mm rectangle of tinplate, which used to be the wall of a 200g tin of Heinz baked beans. This is a great substrate for the "ugly" construction method and soldering to the tinplate is even easier than soldering to single sided PCB. Note that the 200g half-sized tins are better than the larger size, since the larger sized cans have corrugated sides for additional strength, which can be used but is not ideal. I included an onboard 7812 voltage regulator. I used an 8-pin DIP IC chip as a crystal socket. Pins 1 & 3 were connected as the crystal socket. I like to include a small LED (in this case a 3mm green junk box LED) so that there is an instant visual indication that the circuit is switched on; I connected it to +12V via a 560 ohm resistor (the LED and resistor are not shown in the above circuit diagram). The photos below can be clicked to show full size versions.

{gallery}xtalchar/pics{/gallery}

Measurements

The Butler oscillator produced in excess of 3V p-p sinewave into a 100 ohm load resistor (11mW power). See above HP1741A oscilloscope image where the horizontal scale is

0.05us/div and the vertical scale is 0.5V/div. My AADE LC-meter was used to measure the capacitances, Co was 3.5pF and Cs was 43.4pF. Frequency measurement was on a Racal 9911 frequency counter. This instrument was tested and calibrated on 12-Mar-04, and the timebase oscillator set at ambient temperature 19C. It was allowed to warm up for some time (7 hours) before the measurements were made. I cannot be certain of the absolute frequency measurements since I could not measure the ambient temperature nor vouch for the accuracy of the calibration. The frequency measurements could therefore be inaccurate.

In the table below, "Freq" is measured with the relay closed (series capacitance shorted out); "Freq s" is the frequency with the series capacitance in circuit; Motional Capacitance Cm is stated in femto Farads where 1000fF = 1pF; Motional Inductance Lm is stated in mH (milli Henries). The crystals were marked with numbers 1 to 50 using a black permanent ink pen. The arithmetic mean and standard deviation of each column of results is shown at the bottom of the table. I was quite pleasantly surprised by how closely matched the crystals were.

Xtal	Freq	Freq s	Cm (fF)	Lm (mH)
1	10,137,545	10,139,713	20.06	
2	10,137,622	10,139,724	19.45	
3	10,137,579	10,139,711	19.73	
4	10,137,437	10,139,684	20.79	
5	10,137,486	10,139,700	20.49	
6	10,137,401	10,139,697	21.24	
7	10,137,504	10,139,682	20.15	
8	10,137,475	10,139,700	20.59	
9	10,137,505	10,139,701	20.32	
10	10,137,529	10,139,711	20.19	

11	10,137,401	10,139,691	21.19
12	10,137,366	10,139,671	21.33
13	10,137,532	10,139,697	20.03
14	10,137,438	10,139,715	21.07
15	10,137,527	10,139,700	20.11
16	10,137,492	10,139,697	20.40
17	10,137,570	10,139,696	19.67
18	10,137,550	10,139,726	20.13
19	10,137,585	10,139,727	19.82
20	10,137,543	10,139,708	20.03
21	10,137,500	10,139,715	20.49
22	10,137,558	10,139,730	20.10
23	10,137,522	10,139,733	20.46
24	10,137,573	10,139,744	20.09
25	10,137,402	10,139,695	21.22
26	10,137,552	10,139,673	19.63

27	10,137,418	10,139,582	20.02
28	10,137,373	10,139,710	21.62
29	10,137,487	10,139,702	20.49
30	10,137,445	10,139,735	21.19
31	10,137,350	10,139,682	21.58
32	10,137,432	10,139,713	21.11
33	10,137,548	10,139,708	19.99
34	10,137,478	10,139,702	20.58
35	10,137,466	10,139,721	20.87
36	10,137,583	10,139,703	19.62
37	10,137,480	10,139,750	21.00
38	10,137,531	10,139,721	20.26
39	10,137,397	10,139,684	21.16
40	10,137,383	10,139,690	21.35
41	10,137,393	10,139,685	21.21

42	10,137,440	10,139,690	20.82
43	10,137,545	10,139,699	19.93
44	10,137,453	10,139,721	20.99
45	10,137,586	10,139,716	19.71
46	10,137,488	10,139,660	20.10
47	10,137,493	10,139,700	20.42
48	10,137,490	10,139,763	21.03
49	10,137,479	10,139,628	19.88
50	10,137,460	10,139,738	21.08
Mean	**10,137,488**	**10,139,703**	**21.49**
Std.dev.	**67.2**	**29.1**	**0.58**

Many thanks to Christian DL6JAN for supplying the 10-140MHz crystals, and to David VK6DI [illegible] materials such