

Crystal parameters

Written by Hans Summers

Saturday, 11 July 2009 22:43 - Last Updated Thursday, 14 April 2011 11:35

The motional inductance

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

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

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 L_M and motional capacitance C_M are shown to the right. In these equations:

C_0 is the crystal holder capacitance. I assumed that this means the measured capacitance of the crystal when not in circuit.

C_S 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).

Δf (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!](#)

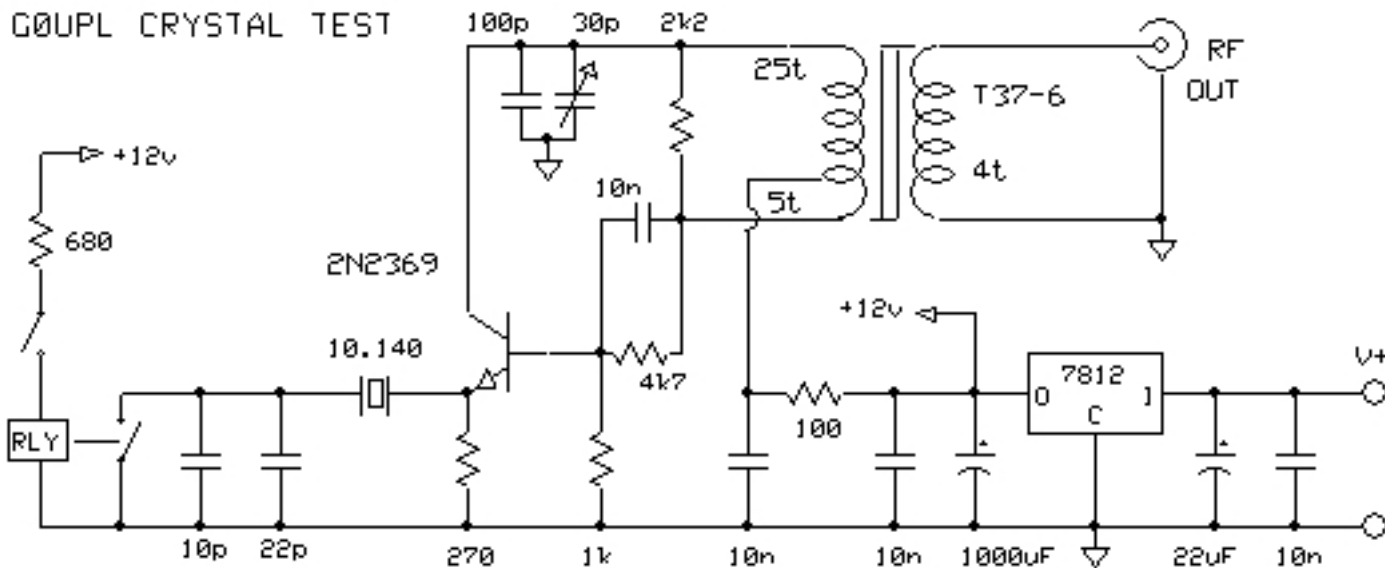
Circuit diagram

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.

Crystal parameters

Written by Hans Summers

Saturday, 11 July 2009 22:43 - Last Updated Thursday, 14 April 2011 11:35



Construction

I built the circuit on a 52 x 37mm rectangle of tinfoil, 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 tinfoil 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

Crystal parameters

Written by Hans Summers

Saturday, 11 July 2009 22:43 - Last Updated Thursday, 14 April 2011 11:35

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 | |

Crystal parameters

Written by Hans Summers

Saturday, 11 July 2009 22:43 - Last Updated Thursday, 14 April 2011 11:35

| | | | |
|----|------------|------------|-------|
| 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 |

Crystal parameters

Written by Hans Summers

Saturday, 11 July 2009 22:43 - Last Updated Thursday, 14 April 2011 11:35

| | | | |
|----|------------|------------|-------|
| 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 |

Crystal parameters

Written by Hans Summers

Saturday, 11 July 2009 22:43 - Last Updated Thursday, 14 April 2011 11:35

| | | | |
|-----------------|-------------------|-------------------|--------------|
| 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 |

Crystal parameters

Written by Hans Summers

Saturday, 11 July 2009 22:43 - Last Updated Thursday, 14 April 2011 11:35



Manufactured by [Christina B. Smith](#) for the Dutch firm [Gildan](#) in crystals and to [David VKSD!](#)
for his part, he specifies the exact structure of the molecules in a paper by the same name such