ELECRAFT XG1 RECEIVER TEST OSCILLATOR

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Introduction

The Elecraft XG1 is a 7040 kHz crystal oscillator with accurate 1 µV and 50 µV output levels. It's ideal for receiver test and alignment. The 1-µV output can be used to measure a receiver's sensitivity, while the 50-µV output is useful for S-meter calibration. The XG1's unique oscillator stage runs at an extremely low level, eliminating the need for interstage shielding. A power-on LED (green) is provided, as well as a low-battery warning LED (yellow), and a red LED to alert the operator to accidental transmit into the XG1's output.

Specifications

RF Output Level	1 µV (-107 dBm) and 50 µV (-73 dBm) into 50 ohms
Output Accuracy	Better than +/- 2 dB at 25 deg. C (+/- 1 dB typical)
Frequency	7040.0 kHz +/- 100 Hz at 25 deg. C after optional calibration
Reverse Protection	5 watts for 4 seconds, 10 watts for 2 seconds (typical; not guaranteed)
Current Drain	About 2.5 mA from on-board 3-V, 220 mA-hr battery (est. life 80 hours)
Size	PC board: 3"L x 1.5"W; 4.3"L including BNC connector

Parts Inventory

R2	(1)	Res, 18.7 k 1% (brn, gry, vio, red, brn), E500127
R3	(1)	Res, 16.5 Ω 1% (brn, blu, grn, gold, brn), E500122
R5	(1)	Res, 57.6 Ω 1% (grn, vio, blu, gold, brn), E500124
R4	(1)	Res, 348 Ω 1% (org, yel, gry, blk, brn), E500123
R6, R7	(2)	Res, 52.3 Ω 1% (grn, red, org, gold, brn), E500125
R8	(1)	Res, 1.27 k 1% (brn, red, vio, brn, brn), E500126
R10, R11	(2)	Res, 24.9 k 1% (red, yel, wht, red, brn), E500120
R1, R9	(2)	Res, 10 k 5% (brn, blk, org), E500015
R12	(1)	Res, 100 Ω 5% (brn, blk, brn), E500010
R13	(1)	Res, 560 Ω 5% (grn, blu, brn), E500046
C5	(1)	Mono Cap, 27 pF (27 or 270), E530141
C2	(1)	Mono Cap, 47 pF (47 or 470), E530014
C6	(1)	Mono Cap, 68 pF (68 or 680), E530150
C3, C4	(2)	Mono Cap, .047 µF (473), E530131
C6	(1)	Trimmer Cap, 1-40 pF (Blue body), E540002

D5 (1) Green LED, rectangular, E570008
D2 (1) Red LED, rectangular, E570007
D4 (1) Yellow LED, rectangular, E570009
D1 (1) Diode, 1N4148, E560002
U1 (1) IC, op-amp, LMC6482AIN, E600011
U2 (1) Ref. Diode, 1.22 V, ZXRE125DR, E600081
Q1 (1) Transistor, 2N3904, E580017
X1 (1) Crystal, 7040 kHz, E660023

BT1 (1) Lithium 3V battery, CR2032, E980039
S1 (1) Miniature slide switch, E640009
J1 (1) BNC Connector, E620020
S2 (1) Large slide switch, E640019
(3) Self-adhesive mounting feet, E700024
(1) Battery Holder, E980086
(1) XG1 Printed Circuit Board, E100189

Assembly

- ❑ Sort the resistors by value. Some of the color bands may be hard to read; use a magnifying glass if necessary. A Digital Multimeter (DMM) should be used to confirm the values.
- ❑ Orient the printed circuit board with the silk-screened side up and the title "XG1" at the top.
- ❑ Install the following resistors in their indicated positions, starting at the top of the PC board and working down. (Complete the left column, below, then the right column.) **Note: The XG1's output level accuracy depends on each resistor below being installed in the correct location.**

__ R7, 52.3 Ω, 1% (grn, red, org, gold, brn)
__ R8, 1.27 k, 1% (brn, red, vio, brn, brn)
__ R6, 52.3 Ω, 1% (grn, red, org, gold, brn)
__ R11, 24.9 k, 1% (red, yel, wht, red, brn)
__ R10, 24.9 k, 1% (red, yel, wht, red, brn)
__ R5, 57.6 Ω, 1% (grn, vio, blu, gold, brn)
__ R4, 348 Ω, 1% (org, yel, gry, blk, brn)

__ R12, 100 Ω, 5% (brn, blk, brn)
__ R3, 16.5 Ω, 1% (brn, blu, grn, gold, brn)
__ R2, 18.7 k, 1% (brn, gray, vio, red, brn)
__ R1, 10 k, 5% (brn, blk, org)
__ R9, 10 k, 5% (brn, blk, org)
__ R13, 560 Ω, 5% (grn, blu, brn)

- ❑ Sort the small ceramic capacitors by value. Install the capacitors listed below:

__ C3, .047µF (473) __ C4, .047µF (473) __ C5, 27pF (270) __ C1, 68pF (680) __ C2, 47pF (470)

- ❑ Using your DMM, measure the resistance to ground at each of the points listed below. Any incorrect reading could indicate that you have one or more resistors installed incorrectly.

__ **junc. of R7, R8:** 48-52 ohms
__ **junc. of C1, C2, R2:** 18-19 k
__ **junc. of U2, R1:** 57-63 k
__ **junc. of R6, R8:** 48-52 ohms
__ **junc. of C4, R3:** 57-63 k
__ **junc. of R10, R11:** 24-26 k
__ **junc. of C4, R4:** 385-425 ohms
__ **junc. of R1, C1:** 67-73 k

- ❑ Install diode D1 (1N4148). The cathode (banded end) must be aligned with the banded end of the outline.
- ❑ Install the Red LED at D2 (LED component outlines may be round). Insert the **long** lead into the **square** pad.
- ❑ Install the Yellow LED at D4. Insert the long lead into the square pad.
- ❑ Install the Green LED at D5. Insert the long lead into the square pad.
- ❑ Install J1, the BNC connector, on the edge of the board as shown by its outline (see right photo on page 6).
- ❑ Install trimmer capacitor C6. Orient the shorter flat side of the trimmer toward the *C6* label.
- ❑ Install the battery holder for BT1.
- ❑ Install switches S1 and S2 in their indicated positions.
- ❑ Install the 8-pin integrated circuit, U1. Orient the notched or dimpled end of U6 toward the notch in the component outline.
- ❑ Install U2 and Q1. Align the flat side of the packages with the flat side shown on the component outline. **Note:** When U2 is correctly installed, its labeled side will face U1.
- ❑ **Mount the crystal, X1, on the bottom side of the PC board**. (See left photo on page 6.)
- ❑ Solder a scrap of wire to the top of the crystal case, and solder the other end of this wire to the square pad near BT1. Limit soldering time to 3 seconds, since excessive heat may damage the crystal.
- ❑ Install 3 mounting feet on the back side of the board as shown in the center photo on the page 6.

Initial Test

- ❑ Set S1 (small slide switch) to the OFF position. Set S2 to the 1 µV position.
- ❑ Set S2 (large slide switch) to the 50 µV position.
- ❑ Install the Lithium battery into its holder. **Make sure that the (+) side of the battery is UP.**
- ❑ If the unit to be tested is a transceiver, set its power output for minimum and disconnect the key, keyer, and microphone to prevent accidental transmit into the XG1's output jack.
- ❑ Connect the output of the XG1 to the antenna jack of the receiver or transceiver.
- ❑ Tune the receiver to 7040 kHz. **DO NOT TRANSMIT.**
- ❑ Turn on the XG1. The green LED will light.
- ❑ The XG1 output should be heard on the receiver. If the VFO calibration of the receiver is accurate, the frequency of the XG1 can set to exactly 7040.00 by adjusting C6 with an insulated tuning tool. Otherwise leave C6 set at its midpoint.
- ❑ Turn the XG1 off to conserve battery life.

Using the XG1

Indicator LEDs

- ***Power-on LED (green)***: Turns on when the XG1 is in use.
- ***Low-battery warning LED (yellow)***: Turns on if the battery voltage falls below about 2.4 volts. If this happens, change the battery to ensure accurate output levels.
- ***Transmit warning LED (red):*** Turns on as a warning if you accidentally transmit into the XG1's output jack at 100 milliwatts or more. **Note:** Some protection is provided by the back-to-back diode limiter formed by D2 (red LED) and D1. This circuit has been tested at up to 10 watts for 2 seconds.

Applications

A 50-µV signal is a commonly-accepted level for "S9," and a 1-µV signal is often used to measure signal-to-noise ratio to evaluate the sensitivity of a receiver (see procedures starting on next page). The XG1 can be used to evaluate a new receiver, check the condition of an old receiver, or check a receiver after exposure to lightning or other traumatic events. A homebrew receiver's sensitivity is easily measured, and design choices can be evaluated to improve the design. Since the XG1 is self-powered, lightweight and small in size, it's an ideal tool to take to a flea market to evaluate used gear.

Using Harmonic Outputs (14080, 21120, and 28160 kHz) and Other Crystal Frequencies

The XG1 is optimized for accuracy at its fundamental frequency of 7040 kHz, yet there is also substantial harmonic content. The output level at the 2nd harmonic is approximately 7 dB down, the 3rd harmonic is about 14 dB down, and the 4th harmonic is about 24 dB down. These levels will vary somewhat, but will normally remain within about +/- 3 dB of the values given. While this accuracy is not suitable for precision measurements, the harmonics are useful for alignment and performance monitoring on 20, 15, and 10 m.

Fundamental-mode crystals at other frequencies can be substituted in many cases, with a nearly identical output level. But crystals vary widely in their characteristics, so accuracy is only guaranteed with the crystal supplied with the kit. *The use of a socket or crystal switching circuitry may change the output level.*

Receiver Sensitivity Testing (Using 1 µV Signal)

The XG1 can be used to test absolute receiver sensitivity, providing a means of comparing various receivers or transceivers. The instructions below apply to any type of receiver or transceiver, but we've included settings for the Elecraft K1 and K2.

1. If you're testing a transceiver, turn its power output level to minimum as a precaution, and disconnect the key or keyer and mic. If you're using an ATU, put it into bypass mode (CAL or CALS on Elecraft tuners).

2. Connect the XG1 to the antenna jack on the receiver (or transceiver). You can connect the XG1 directly to receiver or transceiver using a suitable adapter, such as our model BNC-MM .

NOTE: Keep your hands and other objects away from the XG1 during measurements, as this may affect the output signal level, especially at the 1-microvolt setting.

3. Turn AGC OFF if possible. (K2, hold PRE+AGC switches. K1, use AGC menu entry.)

4. Set RF GAIN to maximum.

5. Turn off the attenuator.

6. Turn on the preamp. NOTE: Preamp OFF tests may also be useful.

7. Select CW mode, narrow passband if available ("CW-N" on some rigs).

8. If possible, set the filter bandwidth for about 500 Hz, the standard for lab receiver tests. (K2, use FLx = 0.70, which corresponds to about 500 Hz. For the K1, use FLx = 500.)

9. Turn off, bypass, or widen the audio filter if applicable. (K2: see KAF2 or KDSP2 manual.)

10. Connect the probes of a digital multimeter (DMM) across the speaker terminals. Set the DMM for 2 or 3 volts AC (or RMS) full-scale. (K2: Connect the DMM across the internal speaker or the external speaker jack. If you use the headphone jack, don't plug in headphones at the same time, since this will form voltage dividers with R35 and R36, lowering the AC voltage reading.)

11. Set the receiver or transceiver for about 7040 kHz.

12. Turn on the XG1 and set it for 1 microvolt output. Replace the battery if the low-battery LED turns on.

13. Locate the XG1 signal with the receiver. Peak the signal in the crystal filter passband.

NOTE: BFO settings can affect sensitivity. If the passband peak occurs at a pitch well outside the expected range (typically 500-800 Hz), you may need to realign your BFO settings using an appropriate method (K2: see application notes on our web site).

14. Set the AF GAIN control fully clockwise (if this results in a signal that is loud enough to damage the speaker or cause distortion, use a reduced setting, but make sure you use the same setting each time).

15. Note the DMM's reading: _____ Vrms (this is the S+N, or signal+noise reading). NOTE: This value is useful for comparing overall receiver gain with that of a reference receiver.

16. Turn off the XG1 and note the new reading: _____ Vrms (this is the N or noise reading).

Signal-to-Noise And MDS Calculations

Using the results from the previous page, you can calculate the signal-to-noise to noise ratio (S+N/N) at 1 microvolt, and estimate the MDS (minimum discernable signal) as follows:

A. Divide S+N by N; call the resulting ratio R.
B. Take the base-10 logarithm of R ("log" key on most calculators).
C. Multiply the result by 20 to obtain the S+N/N ratio at 1 microvolt, in dB.
D. If the S+N/N is greater than 10 dB, then the MDS is approximately equal to the result from (C) subtracted from -107 dBm.

Example: DMM readings of 1.0 Vrms (XG1 on), and 0.030 Vrms (XG1 off).

A. R = 1.0/.03 = 33
B. log(30) = 1.52
C. 20 x 1.48 = about 30 dB (this meets the requirement for step D)
D. MDS = -107 dBm - 30 dB = -137 dBm

A K2 should produce a S+N (XG1 on) reading of roughly 0.4-0.8 Vrms, and more importantly, an MDS of about -135 dB or better. With an audio filter installed, the S+N and N readings may be higher, especially if you've modified the gain settings, but the MDS should be about the same. Many factors can affect the S+N and N readings, including whether a KSB2 or KNB2 is installed, how the 40-m band-pass filter and BFOs are aligned, how L34 is adjusted, and whether the 2nd XFIL modification has been made (already present in K2s with S/N 3000 and higher). If the estimated MDS value is lower than expected, make sure that you have the preamp on, AGC off, ATU in bypass mode, and RF GAIN set fully clockwise.

A K1 should produce a S+N (XG1 on) reading of roughly 0.1-0.2 Vrms, and an MDS of about -130 dB.

S-Meter Calibration (Using 50 µV Signal)

50 microvolts is widely used as the standard for an S-meter reading of "S-9". The manufacturer of your receiver or transceiver may prefer a different level; consult its manual. Also note that S-meter readings are relative. On some transceivers, including the Elecraft K2, turning the preamp off or the attenuator on will drop the indicated value. (The K1 adds one bar to the reading if the attenuator is turned on.)

To align your S-meter at 50 microvolts:

1. Set up the receiver or transceiver as indicated in steps 1-13 on the previous page. In this case, there's no need to turn AF GAIN to maximum.

2. Turn the AGC **on** (K2, hold PRE+AGC switches. K1, use AGC menu entry).

3. Switch the XG1 to its 50-microvolt setting.

4. Adjust the S-meter "scale" value such that the S-meter indicates S-9. (K2, use CAL S HI function. K1, use SIG menu entry, "H" parameter. The K1 does not have a labeled S-meter scale; use 4 bars for S-9.)

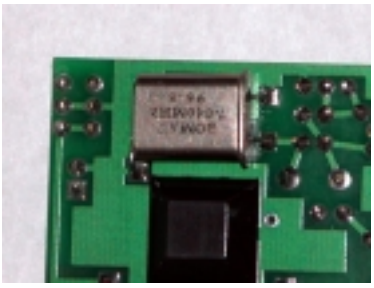
5. Turn the XG1 off. The S-meter reading should now drop to approximately zero (1 bar may be flickering on/off). If not, adjust the S-meter's "zero" value. (K2, use CAL S LO. K1, use SIG, "L" parameter.) Repeat steps 4 and 5 if necessary.

Circuit Description

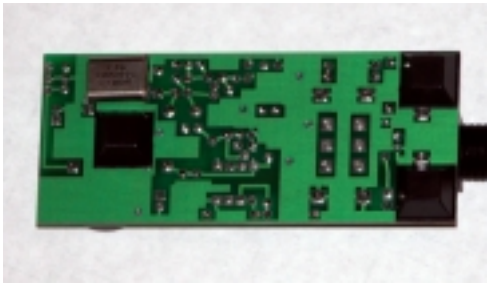
The XG1 produces a signal at 7040 kHz with very accurate amplitude. Unlike most signal generators capable of accurate 1-µV output, the XG1 requires no shielding. This is due to the extremely low power level of the crystal oscillator, as well as careful PC board layout and component selection. The output of the oscillator (-50 dBm or 10 nanowatts into 50 ohms) is attenuated by 23 dB to obtain the 50-µV test signal. An additional 34 dB attenuator stage is placed in series with the signal path by switch S2 when an output level of 1 µV is needed. Output accuracy is determined by the precision voltage regulator and 1% resistors.

Photos

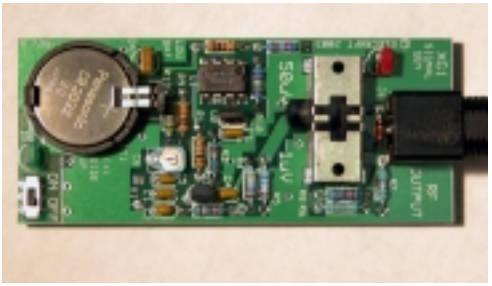
Crystal Installation



Rubber Foot Installation



Finished Assembly, Top Side



Schematic