ELECRAFT 2T-gen 2-Tone TEST OSCILLATOR

Rev B, March 10, 2010

Introduction

The Elecraft 2T-gen is a 2-Tone test oscillator that can be used to make distortion measurements on SSB transmitters and amplifiers. The 2T-gen is battery operated and provides sufficient output level to be connected directly to the microphone connector of almost any transceiver.

Specifications

AF Output Level	200 mV max, adjustable, female RCA connector
Frequency	700 Hz and 1900 Hz
Harmonic Distortion	-55 dB typical
Current Drain	About 3mA from on-board 9-V battery
Size	PC board: 3.5"L x 2.4"W; 1.0"H

Parts Inventory

R2,R6	(2)	Res, 8.25 k 1% (gry, red, grn, brn, brn), E500176
R3,R9	(2)	Res, 3.3k 5% (org,org,red), E500017
R5,R11	(2)	Res, 1M 5% (brn,blk,grn), E500024
R4,R10	(2)	Res, 100k 5% (brn,blk,yel), E500006
R1, R7	(2)	Res, 6.8k 5% (blu,gray,red), E500115
R8,R12	(2)	Res, 22.6k 1% (red, red, blu, red, brn), E500175
R13, R14	(2)	Res, 10 k 5% (brn, blk, org), E500015
R15,R16,R17,R18	(4)	Res, 22K 5%, (red,red,org), E500090
R20	(1)	Res., 47K 5% (yel,vio,org), E500067
C1, C3,C5,C7	(4)	Mono Cap, 0.22uF (224), E530079
C2,C4,C6,C8	(4)	Poly Cap, 0.01UF (103), E530009
C9, C10	(2)	Electrolytic Cap, 22 µF E530143

D1 (1) Red LED, round, E570025
R19,R21 (2) 10k Pot, E520005
S1 (1) Miniature slide switch, E640009
JP1, JP2 (2) 3-pin header, E620053
J1 (1) RCA Connector, E620057
U1, U2 (2) LMC6842AIN, E600011
Q1,Q3 (2) Transistor, 2N3904, E580017
Q2,Q4 (2) Transistor, 2N7000, E580002

(1) 2T-gen Printed Circuit Board, E100256
(4) Self-adhesive mounting feet, E700024
(2) 2-pin jumper block, E620055
(2) 4-40x5/16 machine screws, E700077
(2) #4 internal tooth lockwashers, E700010
(2) 4-40 machine nuts, E700011
(1) Battery Holder, E980074

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 “2T-gen” at the upper left.
- ❑ Install the following resistors in their indicated positions, starting at the top of the PC board and working down and right. (Complete the left column, below, then the right column.)

__ R10, 100k, 5% (brn,blk,yel)
__ R16, 22k, 5% (red,red,org)
__ R11, 1M, 5% (brn,blk, grn)
__ R8, 22.6k, 1% (red, red, blu, red, brn)
__ R7, 6.8k, 5% (blu,gry,red)
__ R9, 3.3k,5% (org,org,red)
__ R12, 22.6k, 1% (red, red, blu, red, brn)
__ R15, 22k, 5% (red,red,org)
__ R14, 10 k, 5% (brn, blk, org)
__ R17, 22k, 5% (red,red,org)

__ R5, 1M, 5% (brn,blk, grn)
__ R18, 22 k, 5% (red,red,org)
__ R13, 10 k, 5% (brn, blk, org)
__ R2, 8.25k, 1% (gry,red,grn,brn,brn)
__ R1, 6.8k, 5% (blu,gry,red)
__ R3, 3.3k,5% (org,org,red)
__ R6, 8.25k, 1% (gry,red,grn,brn,brn)
__ R20, 47 k, 5% yel,vio, org)
__ R4, 100k, 5% (brn,blk,yel)

- ❑ Install the mono ceramic capacitors listed below:

__ C7, .22µF (224) __ C5, .22µF (224) __ C3, .22µF (224) __ C1, .22µF(224)

- ❑ Install the poly capacitors listed below:

__ C6, .01µF (103) __ C8, .01µF (103) __ C2, .01µF (103) __ C4, .01µF (103)

- ❑ Install the electrolytic capacitors listed below, Insert the **long** lead into the **square** pad.

__ C10, 22uF 25 V __C9, 22uF 25 V

- ❑ Install the Red LED at D1. Insert the **long** lead into the **square** pad.
- ❑ Install R19, a 10k (103) pot, on the left edge of the board as shown by its outline.
- ❑ Install R21, a 10k (103) pot, on the left edge of the board as shown by its outline.
- ❑ Install J1, the RCA connector, on the left edge of the board as shown by its outline.
- ❑ Install switch S1, on the left edge of the board as shown by its outline.
- ❑ Install the headers, JP1 and JP2 near the top and bottom edge of the board.
- ❑ Install U1 and U2 in their indicated positions. Align the notch in the top of the package with the outline on the printed circuit board.
- ❑ Install Q1, Q2, Q3, and Q4 in their indicated positions. Align the flat side of the package with the outline on the printed circuit board.
- ❑ Install the jumper blocks on the pins marked “T” on JP1 and JP2.
- ❑ Install the battery holder at BT1. Use 4-40 hardware
- ❑ Install 4 mounting feet on the back side of the board as shown in the photo on page 7.

Initial Test

- ❑ Set S1 (small slide switch) to the OFF position.
- ❑ Install a 9V battery into its holder.
- ❑ Connect the output of the 2T-gen to the input of a sound system or to headphones using a suitable adapter cable.
- ❑ Set R19 and R21 to about mid-range.
- ❑ Turn on the 2T-gen. The round red LED will light.
- ❑ The 2T-gen output should be heard on the sound system or headphones.
- ❑ Place the jumper block over the "NT" pins or JP1 and JP2 in turn and confirm that only a single tone is heard when the jumper block is in place.
- ❑ Return the jumper blocks to the "T" position.
- ❑ This completes the initial test. Turn off the 2T-gen to conserve the battery

Using the 2T-gen

Controls and indicator LEDs

- ***Power-on LED (red)***: Turns on when the 2T-gen is in use.
- ***Output Level Adjust:*** Allows adjustment of the output level to the desired level.
- ***Balance:*** Allows adjustment of the two tones to produce equal transmitter output power.
- ***JP1 and JP2:*** Provide control of the oscillators. Placing a jumper block over the "NT" pins will turn off the associated oscillator. Placing a jumper block over the "T" pins, or removing it entirely, will turn on the associated oscillator. JP1 controls the 700 Hz oscillator and JP2 controls the 1900 Hz oscillator.

Applications

The 2T-gen has been designed to provide a 2-tone signal source for testing of SSB transceivers and associated amplifiers. This type of testing is almost universally used as a measure of transmitter linearity for amateur radio equipment. Results of 2-tone IMD tests can be found in every ARRL review of new transceivers and power amplifiers.

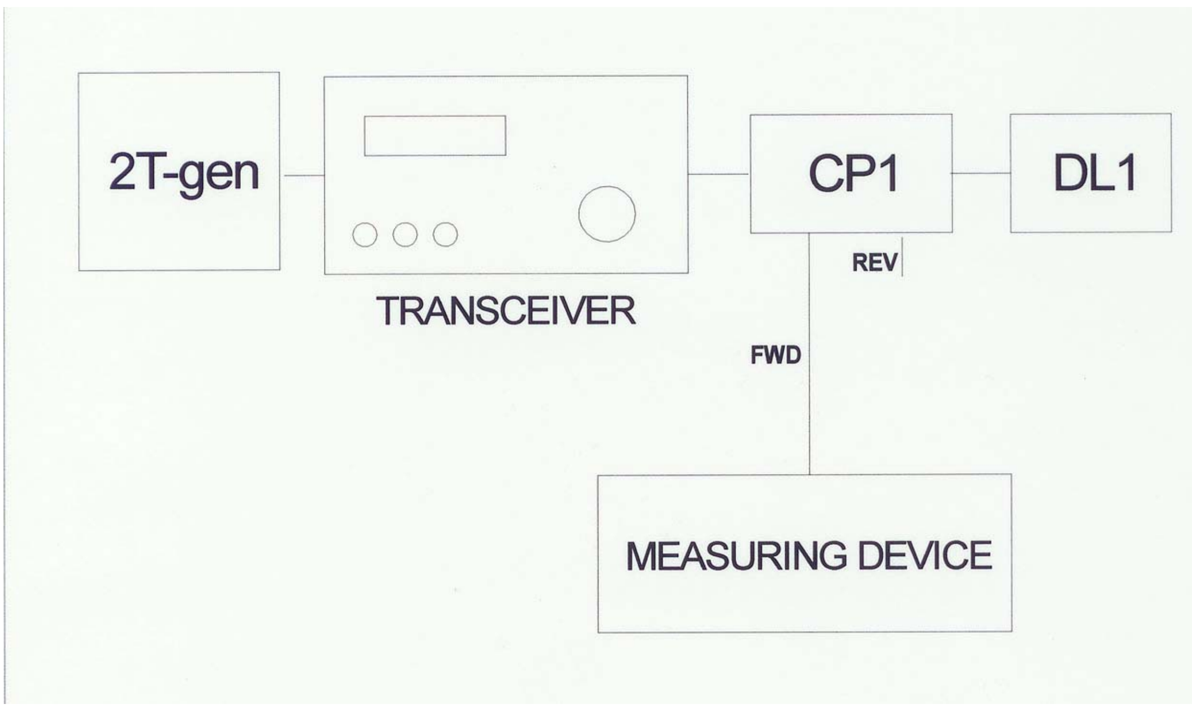
When connected to the 2T-gen, the ideal SSB transmitter will produce an output that consists of only two frequencies, for USB these will be the carrier frequency plus 700 Hz and the carrier frequency plus 1900 Hz and for LSB the frequencies will be carrier minus 700 Hz and carrier minus 1900 Hz.

Actual transmitters will produce spurious output at additional frequencies as a result of nonlinearity. The highest amplitude spurious output will normally be the third-order product and the next highest will be the 5th order product. Higher-order products may also be present at lower amplitudes. These spurious products are referred to as the intermodulation distortion (IMD) products.

The 3rd order product will appear at a frequency offset from the carrier by $2F_2 - F_1$ and the 5th order product will be offset from the carrier frequency by 3xF2-2xF1. For the 2T-gen, F1 is 700 Hz and F2 is 1900 Hz, which results in a 3rd order product of 3100 Hz and a 5th order product of 4300 Hz. The amplitude of these undesired outputs is usually increased as the transmitter output is increased, and is caused by various transmitter amplifier stages beginning to operate in compression. A properly operating transmitter should produce third-order IMD products that are 27 to 30 dB or more below the PEP output power. The PEP output power is 6 dB higher than the output power produced by the 700 Hz and 1900 Hz tones.

Test Setup

In order to make IMD measurements on a transmitter a test setup must be established that allows the signals from the 2T-gen to be connected to microphone input of the transmitter under test and provides for a sample of the RF output to be connected to a measuring device that is capable of examining the transmitter output signal. A typical test setup for a low power transceiver is shown in the drawing below.



Several years ago, the most common measuring device was an oscilloscope or transmitter output monitor. While observing the transmitter output envelope, the 2-tone input was increased until "flat topping" was observed as an indication of transmitter compression. This procedure is well documented in older ARRL Handbooks. This procedure provides only an approximate indication of transmitter overload, but it is useful if more precise instruments are not available.

Another measuring device is a receiver with sufficient selectivity to separate the sidebands produced by the transmitter. The receiver can be connected in series with a variable attenuator and the relationship between the desired sidebands and those produced by IMD can be measured by tuning to each in turn and adjusting the variable attenuator to produce an equal S-meter reading. The ratio between the sidebands is the difference in attenuator readings.

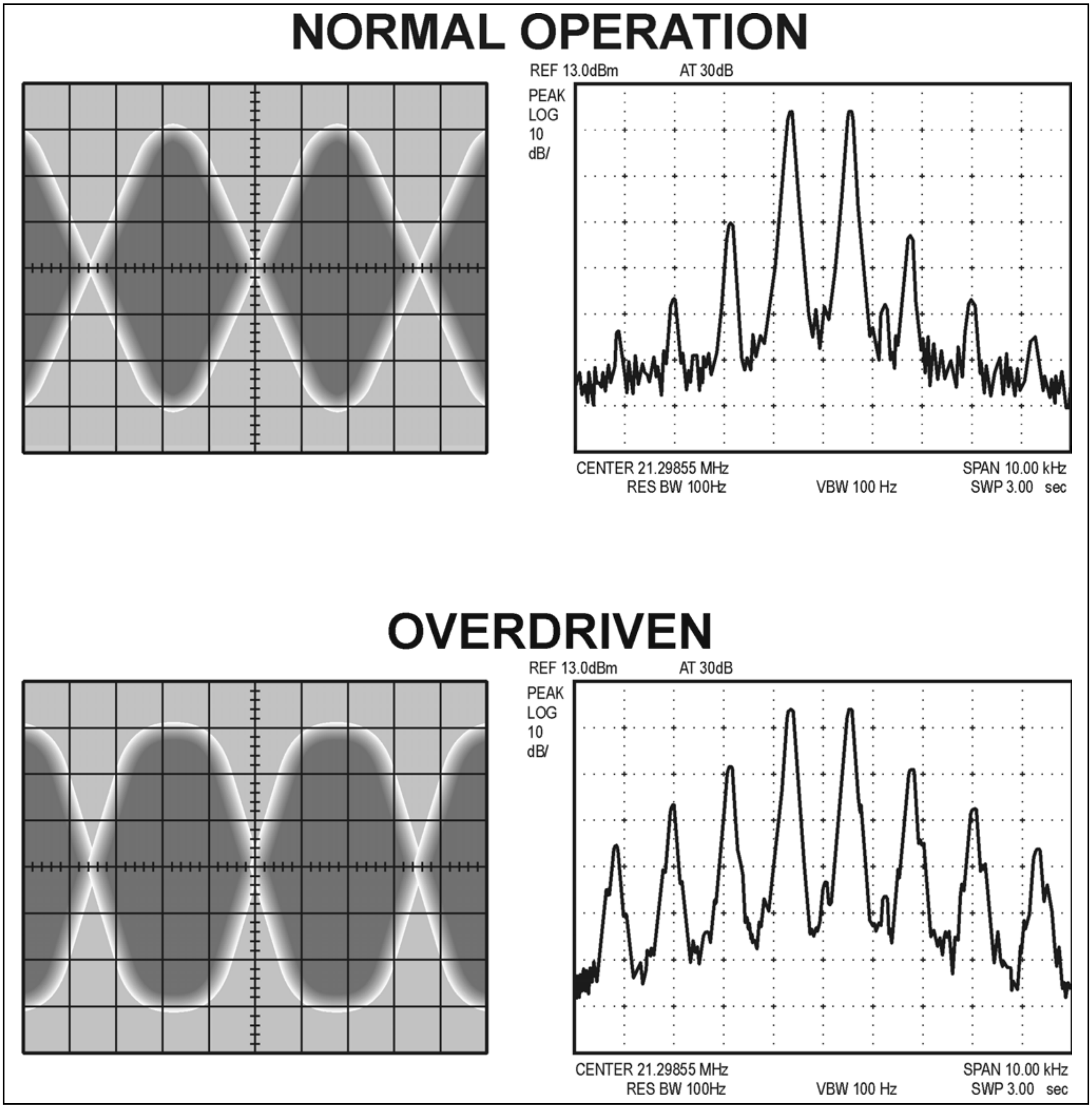
In recent years, a much more convenient measuring device has become available at reasonable prices. A used spectrum analyzer can be purchased at flea markets and used test equipment dealers for very reasonable prices. Several PC-based spectrum analyzers have been designed and published also. The relationship between the desired sidebands and those produced by IMD can be observed in real time using a spectrum analyzer for a measuring device and performance can be easily related to the measurements of IMD published by the ARRL as part of their equipment reviews.

Most transmitters will produce different output power from equal level audio input at 700 Hz and 1900 Hz. This can be the result of audio shaping networks in the transmitter microphone input circuit or from ripple in the SSB filter or both. The Balance control is provided account for this difference by adjusting the ratio of the tone outputs over about a +/- 3 dB range. The first step in using the 2T-gen is to adjust the Balance control to account for this difference in the transmitter under test. This is easily done by connecting the 2T-gen as shown and keying the transmitter and adjusting the transmitter microphone gain or the 2T-gen **Output Adj** for a convenient output power. If you are using a spectrum analyzer as a measuring device, next set the 2T-gen **Balance** control for equal level the two outputs resulting from the 700 Hz and 1900 Hz tones.

If you are using an oscilloscope or receiver as a measuring device you will not be able to view the transmitter outputs resulting from the two tones simultaneously. In this case use a power meter and set the transmitter for some convenient output. Then disable one of the two tones with **JP1** or **JP2**. If the **Balance** control is set correctly the output power will decrease to half of the original reading. If this is not the case, adjust the **Balance** control until the power output with both tones is twice the power with one tone. This is an interactive adjustment and will have to be repeated several times to achieve the desired result. It may be necessary to repeat this procedure for the opposite sideband because the transmitter SSB filter characteristics may be different for the upper and lower sidebands.

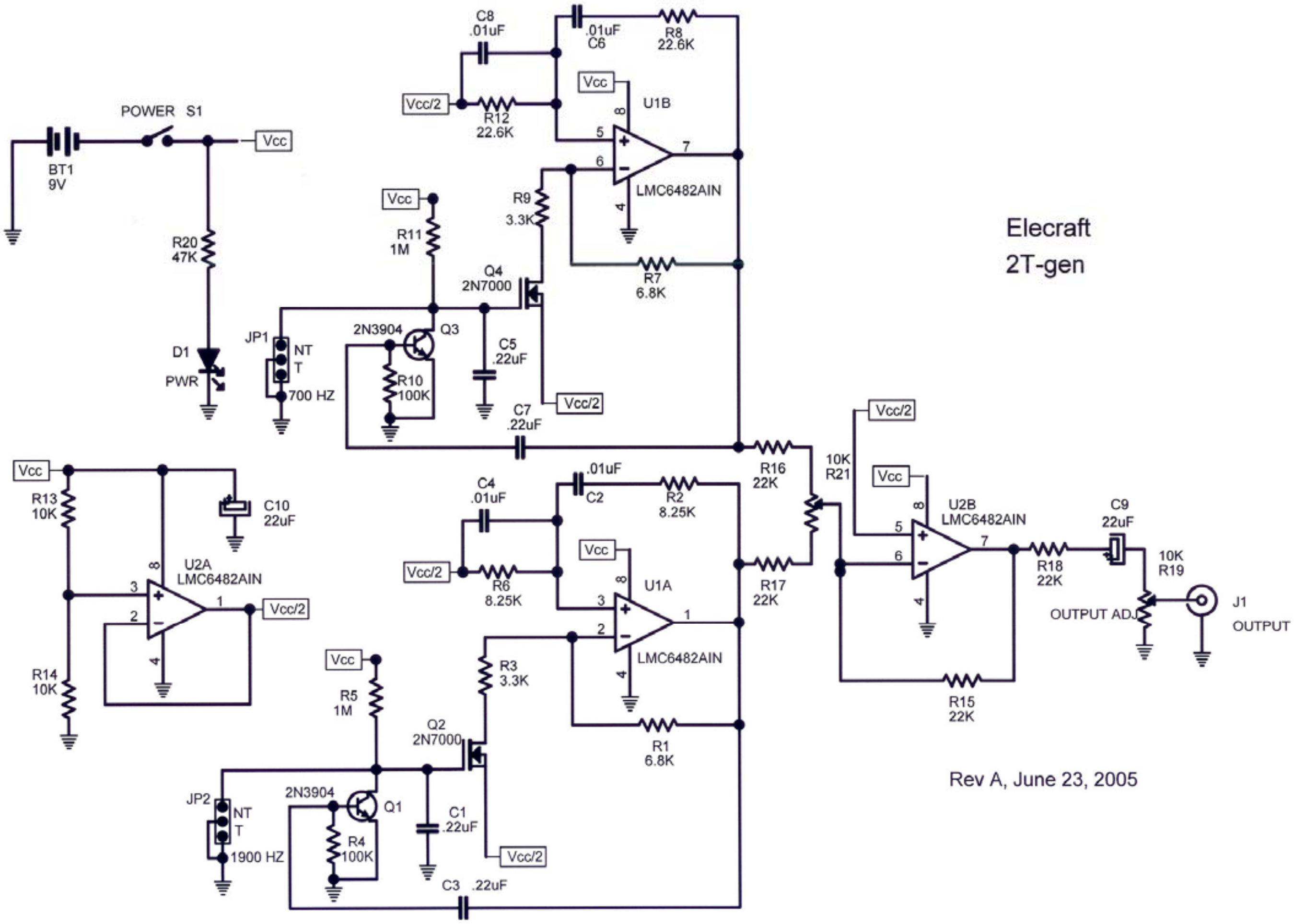
After completion of the balance adjustment, the transmitter microphone gain or 2T-gen **Output Adj** control is adjusted so that the output power produced by each tone is 6 dB below, or 1/4th the rated PEP output of the transmitter. This setting will result in the rated PEP output power when both tones are present. This is easily done by disabling each tone in turn with the jumpers on **JP1** and **JP2.**

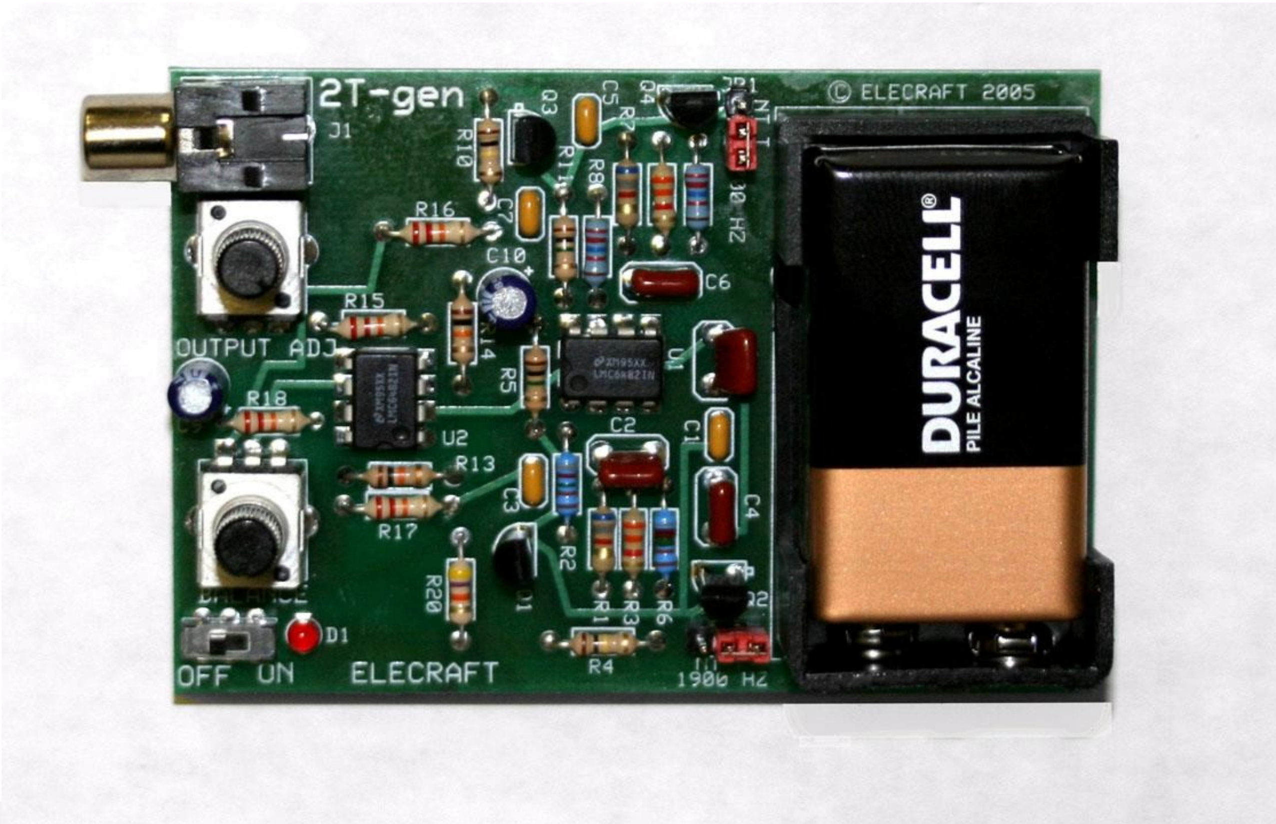
The drawings below illustrate examples of a spectrum analyzer display and the corresponding oscilloscope display.



NORMAL OPERATION
REF 13.0dBm
AT 30dB
PEAK
LOG
10
dB/
CENTER 21.29855 MHz
SPAN 10.00 kHz
RES BW 100Hz
VBW 100 Hz
SWP 3.00 sec
OVERDRIVEN
REF 13.0dBm
AT 30dB
PEAK
LOG
10
dB/
CENTER 21.29855 MHz
SPAN 10.00 kHz
RES BW 100Hz
VBW 100 Hz
SWP 3.00 sec

Schematic


Elecraft
2T-gen
Rev A, June 23, 2005
POWER S1
BT1
9V
Vcc
R20
47K
D1
PWR
C8
.01uF
.01uF
C6
R8
22.6K
Vcc/2
R12
22.6K
U1B
LMC6482AIN
R9
3.3K
R11
1M
Q4
2N7000
R7
6.8K
JP1
NT
T
700 HZ
2N3904
Q3
R10
100K
C5
.22uF
C7
.22uF
R16
22K
10K
R21
U2B
LMC6482AIN
C9
22uF
R18
22K
10K
R19
OUTPUT ADJ.
J1
OUTPUT
R15
22K
R13
10K
C10
22uF
U2A
LMC6482AIN
R14
10K
C4
.01uF
C2
R2
8.25K
R6
8.25K
U1A
LMC6482AIN
R17
22K
R3
3.3K
R5
1M
Q2
2N7000
R1
6.8K
JP2
NT
T
1900 HZ
2N3904
Q1
R4
100K
C1
.22uF
C3 .22uF


2T-gen
© ELECRAFT 2005
J1
OUTPUT ADJ
DURACELL
PILE ALCALINE
OFF ON
ELECRAFT
D1
R4
1900 HZ