
LumiDax Electronics LLC Bakerboard Analog Trainer

Operator's Guide with
Example Projects

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Introduction

The LumiDax ® Bakerboard Analog Trainer is an all-in-one electronics lab. It features three power supplies, a function generator, an oscilloscope, and a spectrum analyzer - all conveniently attached to a large-surface breadboard for prototyping your projects. With this system, analog circuits such as operational amplifiers can be constructed easily and tested for proper function.

Main Features

The Bakerboard is equipped with several useful pieces of test equipment in one convenient package.

Figure 1, shown below, is a diagram showing the layout of the Bakerboard Analog Trainer.

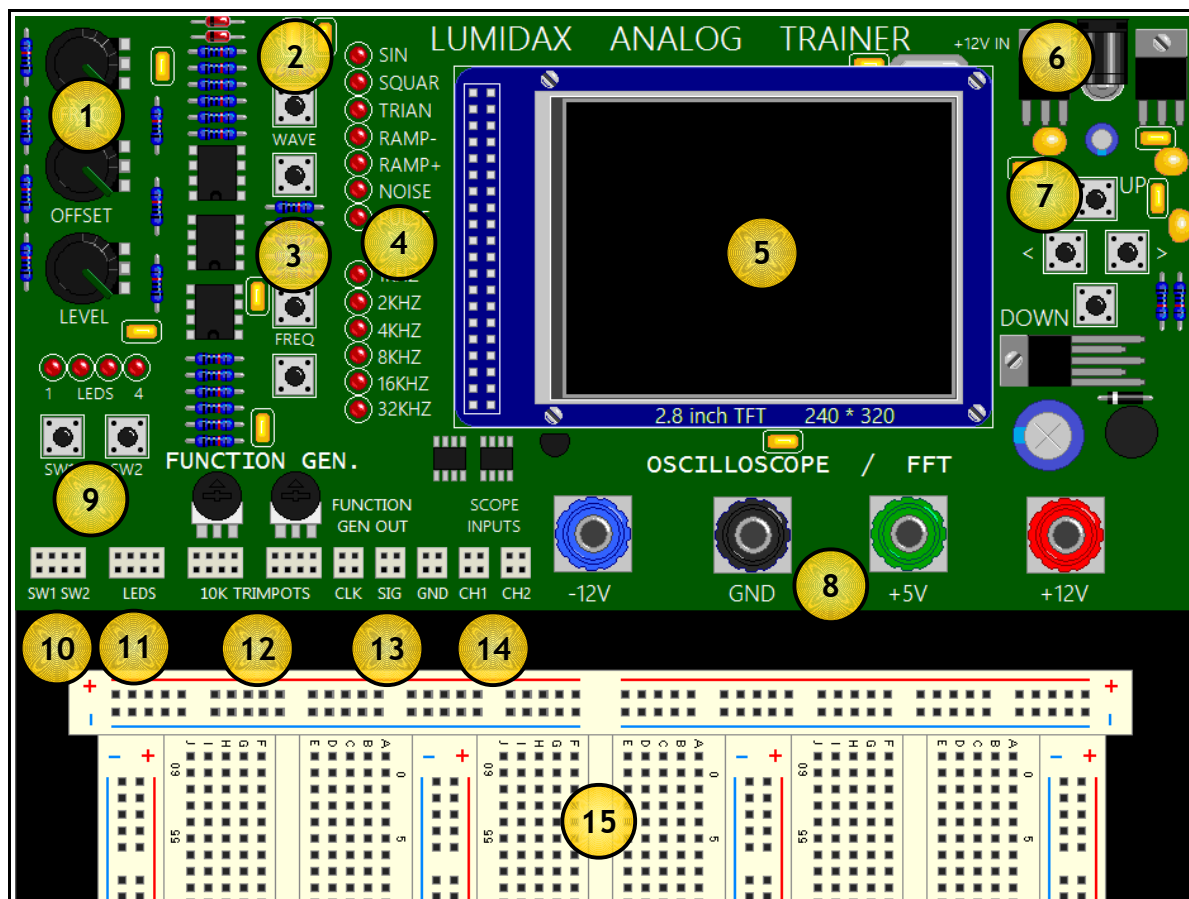


Figure 1: A tour of the LumiDax ® Bakerboard features.

- | | |
|--|---|
| 1) Function Generator control knobs. | 9) Project LEDs, switches, and potentiometers. |
| 2) Function Generator waveform select keys. | 10) Quick-connects for project switches. |
| 3) Function Generator range select keys. | 11) Quick-connects for project LEDs. |
| 4) Function Generator waveform, range indicator. | 12) Quick-connects for project potentiometers. |
| 5) Full color 2.8" TFT display. | 13) Function Generator signal and clock output. |
| 6) DC jack for power supply (included.) | 14) Oscilloscope inputs for Channel 1, Channel 2. |
| 7) Oscilloscope / Spectrum Analyzer cursor keys. | 15) Solderless breadboard for prototyping circuits. |
| 8) Built-in power supplies for -12V, +5V, +12V. | |

Solderless Breadboard

One of the most useful features of the Bakerboard is the solderless breadboard, which allows you to build and test circuits without the need for solder and soldering irons. The solderless breadboard is designed such that the holes will accept leads for most electronics components and wires, holding them firmly and securely. Simply bend the leads, trim them with a pair of diagonal cutters, and push the wires into the holes. Removal is easy too - just gently pull. Take a look at **Figure 2**, shown below.

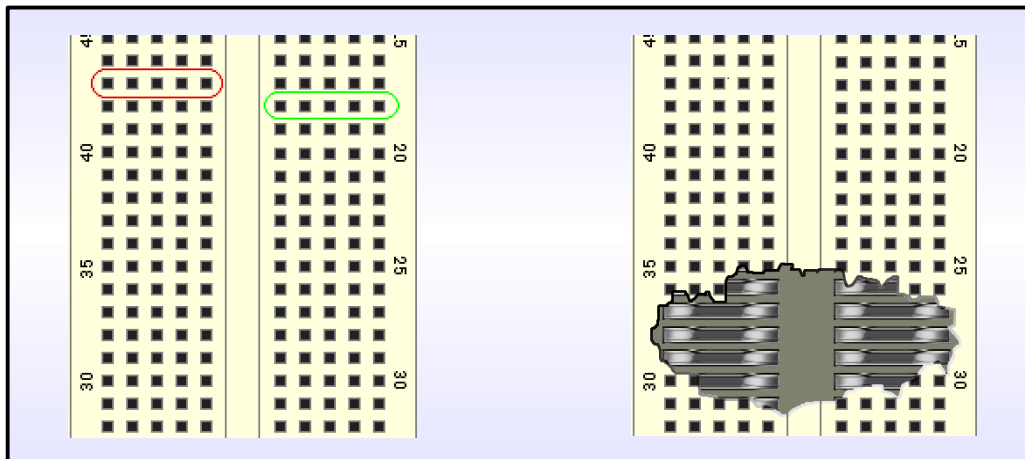


Figure 2: Solderless breadboard tie-points and how they work.

In the figure above, we can see that the breadboard has rows of tie-points. The gap that runs down the middle is just the right width to place integrated circuits. The breadboard has rows of five holes on either side of the gap in the middle. Each row of five tie-points is connected horizontally, so plugging wires and leads into the same row makes an instant connection. As shown in the above figure on the left, one row is circled in red, and another separate row is circled in green. The diagram on the right shows how the metal prongs are arranged internally.

The prongs that make the tie-points are spring-loaded, and can accept wires up to 22 AWG wire. They will work for lead thicknesses of most components. However, it is important that you be gentle when inserting wire into the tie-points. Components such as high-current rectifier diodes have leads that are thicker to handle the higher current. But if the lead won't fit, rethink how to attach it to your circuit. Repeatedly forcing large leads into the holes will force the spring-loaded prongs apart over time, and your wiring connections will be loose and unreliable.

Warning 🥲

Don't try to force wires and leads larger than the breadboard can handle. You risk causing damage to the breadboard.

There are also power distribution strips provided for convenience. These are located on the top of the breadboard, and running down the sides and between the breadboard panels. They are identified by the red and blue markings indicating plus and minus, respectively. **Figure 3** shows a power distribution strip.

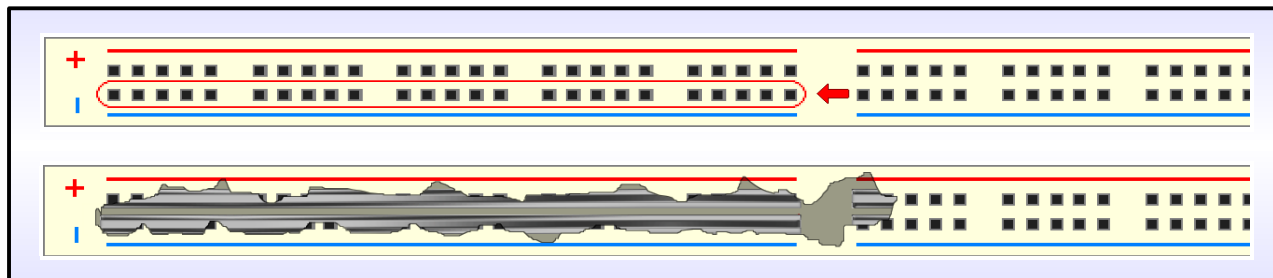
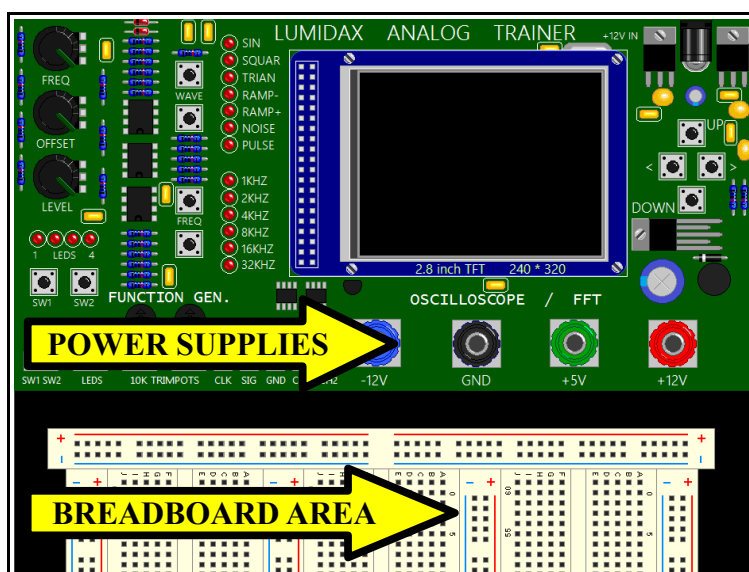


Figure 3: Power distribution breadboard strip.

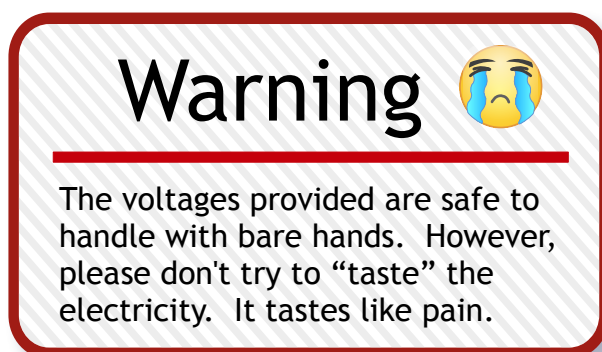
The power distribution strips on your breadboard are different from the row connectors in **Figure 2**. The difference is that the tie-points are all connected in a line. There are red and blue markings on the power distribution strip to help you understand how they are connected internally. The red and blue lines show common connections. The arrow in the top drawing of **Figure 3** points to a strip of tie-points that are all connected. Notice that the red and blue lines are broken in the middle of the power distribution strip. In **Figure 3**, the bottom drawing shows an inside-view. That broken line means that the connections do not run all the way down. Don't forget this gap in the future, as this knowledge will save you from much confusion later. Power is not automatically provided on these distribution strips.

Power Supplies

The LumiDax ® Bakerboard is equipped with three regulated DC power supplies. These are +5V, -12V, and +12V, and all share a common ground. The +5V power supply is ideal for digital circuits, while the -12V and +12V supplies are great for op-amp circuits, which require dual power supplies. The +5V and +12V power supplies can deliver up to one amp of current, and the -12V supply can deliver a maximum of 0.5 amps. A desktop power supply cord is provided with the kit for powering your trainer. **Figure 4** shows the power supplies, located near the top of the breadboard area. The binding posts can accept banana jacks, or wires can be secured by screwing the binding post down onto your wires. As shown below, the blue binding post provides -12V, black is the common ground, green is +5V, and red is +12V.



4: Breadboard area and power supply positions on the Bakerboard.



There are certain things to keep in mind when using these power supplies:

- Do not ever connect the power supplies together directly, or connect them directly to ground. This will cause damage to your power supplies.
- Make sure your components can handle the power they are trying to dissipate. If a part gets hot on your breadboard, it may melt the plastic and cause an unsightly burn...not to mention permanently damaging your unit. The +12V supply can deliver up to 12 watts of power, which is more than enough to smoke a part. Also, resistors smell really bad when they burn.
- These voltages are safe to handle with bare hands. Even so, please use caution. Don't poke around with screwdrivers, or wear watches, rings, or necklaces. This may cause shorts.
- Don't spill liquids on the unit or expose to high levels of moisture.
- Do not EVER use power supplies other than those provided with your unit. If you use a higher voltage or current power supply, you risk damaging the test equipment, the breadboard, and your health. It may be tempting to make a 120V relay circuit to control your lights, but please don't do it.
- Try to keep your wiring neat. Loose wires and leads that are too long will encourage shorting.
- When removing integrated circuits (ICs,) use an IC puller. Using a screwdriver may appear to work, but you will also damage the breadboard.
- Don't eat over the Bakerboard Analog Trainer. Food will enter the tie-point holes, and will be very hard to clean.
- Try to keep the Bakerboard Analog Trainer in a safe place. A fall may damage the unit.
- If you get a white screen, you have a short. Quickly unplug the unit and check your circuit.

Function Generator

The Bakerboard Analog Trainer features a function generator that can provide seven different waveforms, in six different frequency ranges. Not only can the function generator create familiar sine, square, and triangle waveforms, but also ramp waves, narrow pulses, and white noise. This makes the function generator ideal for testing audio amplifiers and filters.

The function generator can provide an output signal between -10 V and +10 V. The frequency, DC offset, and amplitude are all fully adjustable via the control knobs located on the left side of the Bakerboard Analog Trainer, marked **FREQ**, **OFFSET**, and **LEVEL**. **Figure 5** shows the positioning of the control knobs. The **WAVE** keys and the **FREQ** keys control the waveform type and the output frequency range, respectively. Red LED indicators display what waveform and range have been selected. Do not overload the output of the function generator. Drive loads at or above 1 K Ω for best results.

The outputs of the function generator are the white tie-point blocks marked **CLK**, **SIG**, and **GND**. These are clock output, signal output, and ground, respectively. The **CLK** output is an LVTTTL output that indicates when the waveform has a positive half-cycle with a logic high output. This clock can be used to test digital circuits, or for synchronization. LVTTTL should be able to drive a standard TTL input without issue.

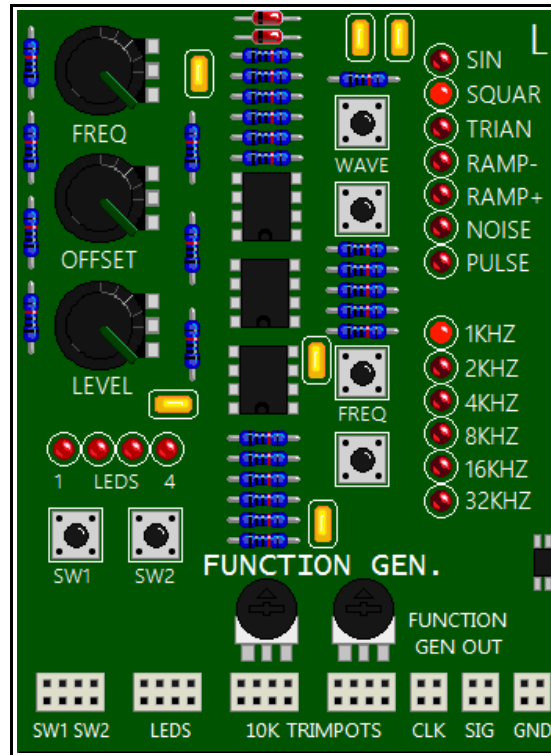


Figure 5: The function generator part of the Bakerboard Analog Trainer.

Project Switches, LEDs, and 10 K Ω Trimpots

Two momentary push-button switches are provided for convenience. Each switch has two vertical columns of tie-points corresponding to the terminals of the switches. SW1 is on the leftmost two columns, and SW2 is on the rightmost two columns. There are four LEDs, which have dropping resistors. These LEDs have their cathodes connected to ground. Therefore, to light an LED, use a positive voltage (up to +12 V.) Finally, there are two trimmer potentiometers at 10 K Ω each. They have their middle tab connected to the two middle columns of the tie-point blocks.

Oscilloscope

The Bakerboard Analog Trainer features a dual-channel 32 KHz oscilloscope. It is ideal for testing audio circuits, despite the limitation in bandwidth. It has an advanced front-end filter that prevents aliasing, or artifacts due to signals being outside the selected range. **Figure 6** shows the position of the oscilloscope.

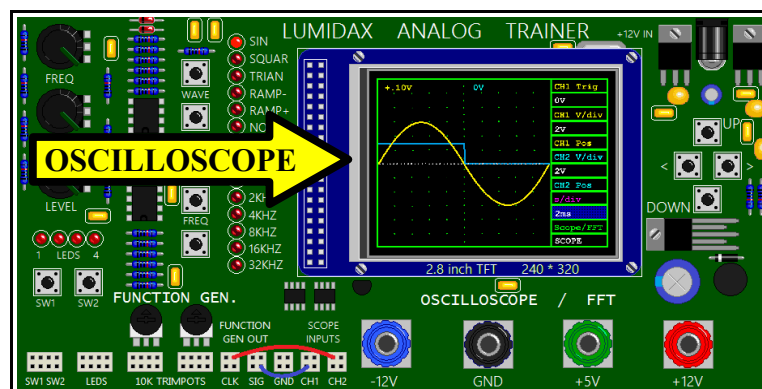


Figure 6: The oscilloscope on the Bakerboard Analog Trainer.

The oscilloscope features a full-color 2.8" TFT module with a bright backlight. To the right of the screen is a keypad consisting of four keys. Use the up and down keys to move the blue cursor, which highlights the window of interest on the right hand side of the screen. Once highlighted, the left and right keys can be used to change settings. **Figure 7** shows a breakdown of the various settings.

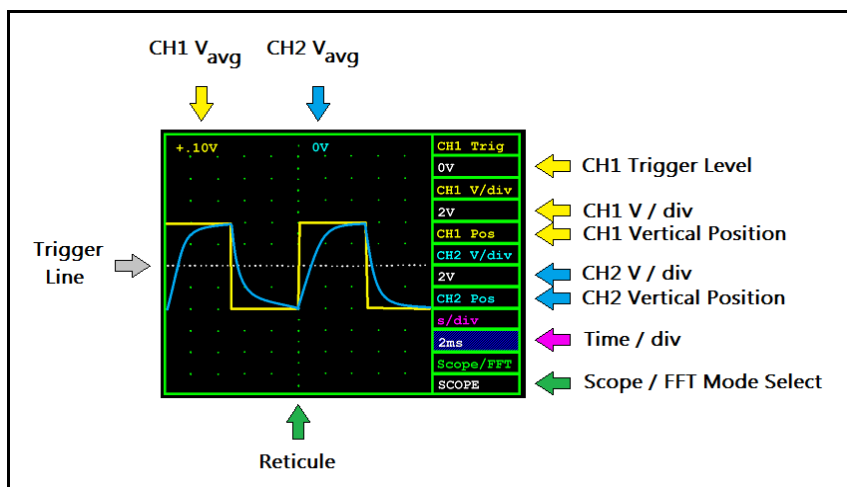


Figure 7: The layout of the oscilloscope window.

Traces

The CH1 (Channel 1) input of the oscilloscope is color-coded yellow, and the CH2 (Channel 2) input of the oscilloscope is color-coded light blue. This makes it easy to distinguish which controls are associated with the channels. At the top of the screen, the signal average voltages are displayed for CH1 and CH2. These are just for rough estimate of the average voltage on these channels, accurate to within 0.1 V.

Trigger Level

The trigger level, which appears on the screen relative to the CH1 trace (yellow,) allows for selecting the automatic trigger level. That is, the oscilloscope auto-triggers on the CH1 input. Set the trigger line to stabilize the CH1 trace. If the oscilloscope cannot obtain a signal lock, it will time out and simply display the signal asynchronously.

CH1, CH2 V / div

The volts per division setting is 2 V / div by default. However, the oscilloscope offers two levels of software gain to make it easier to see smaller signals. Therefore, 1 V / div and 500 mV / div are also offered for magnification of the signal amplitude.

CH1, CH2 Vertical Position

The vertical position of the traces can be adjusted to make reading the oscilloscope easier. It does not have any bearing on the input signal levels, and merely moves the trace on the display vertically. Press the left or right keys to “bump” the trace up and down.

Time / div

The time per division setting may be adjusted from 10 ms / div down to 100 us / div. If artifacts or aliasing are seen on the traces, use the time / div setting to adjust for better viewing of your signals. You should be able to see at least three or four full cycles on the display.

Scope / FFT Mode

The oscilloscope may be changed to FFT mode for measuring signals in the frequency domain. The FFT (Fast Fourier Transform) plot displays signal intensity on the vertical axis and frequency on the horizontal axis. Since sine waves are pure, they will appear as sharp peaks on the plot. When switching to FFT mode, the oscilloscope settings are saved automatically.

Spectrogram

The spectrogram (FFT) mode allows the user to view signal strength vs frequency. This mode can be used to measure frequency as well as relative amplitude for signals up to 50 KHz. **Figure 8** shows the basic linear spectrogram screen. Only CH1 is used for input to the spectrogram.

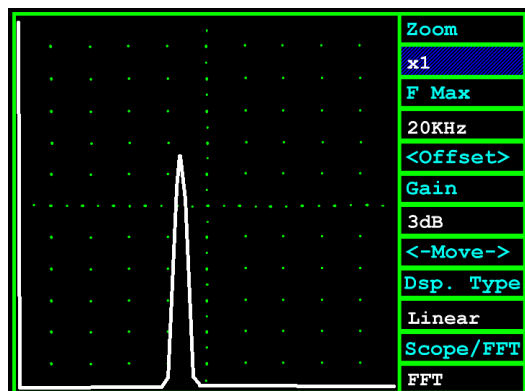


Figure 8: Linear spectrogram Mode.

Zoom

The horizontal zoom factor is x1 by default. If there is an area of interest that is too difficult to see, the zoom factor may be changed to stretch the spectrogram in the horizontal direction. Keep the zoom factor in mind when measuring your signal.

F Max

The FFT sample rate can be changed. A frequency of 0 Hz corresponds to the leftmost position on the screen, with the rightmost position in the window corresponding to the maximum frequency. For example, the frequency peak shown in the above figure is 8000 Hz with the given settings.

OffsetScope / FFT Mode

The offset control raises or lowers the FFT trace. This is more useful in the waterfall mode, which will be covered shortly.

Gain

Two levels of software gain are provided. These are 3dB (x2) and 6dB (x4.) This is software gain only (the image will be stretched in the vertical direction for easier viewing.)

Move

The move function is used in conjunction with the zoom setting. If the zoom factor is greater than x1, the move function can show parts of the zoomed FFT that lie off the screen. Returning the FFT to x1 zoom will display the entire FFT plot.

Disp. Type

A linear FFT display is the default setting. Switching to waterfall mode gives a real-time view of the signal using a color-coded display. The higher the signal intensity, the brighter the color. **Figure 9** gives an example waterfall display. The signal from **Figure 8** is the same signal input used for the display in **Figure 9**. Notice that instead of a linear graph, that a column of color is shown. The green part corresponds to the highest intensity. The orange and red parts are where the signal intensity is relatively lower.

Scope / FFT Mode

When in FFT mode, you may once again return to oscilloscope mode by using this function. Your FFT screen settings will be saved automatically.

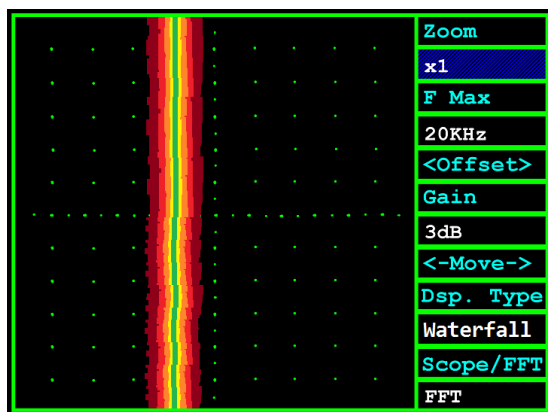


Figure 9: Waterfall display with the same input as in Figure 8.

Important Points for Using the Oscilloscope and Spectrogram

- Do not use the oscilloscope to measure signals outside of the range of -10 V to +10 V.
- There are front-end filters for preventing aliasing on the oscilloscope. If the amplitude of your signal looks too small, or the trace is unreadable, try a different range.
- Some signals have multiple harmonics, such as square waves. If you see multiple peaks on the FFT output, this is due entirely to harmonic components.
- If you try to measure a signal on the FFT plot that is higher than F Max, the signal will alias. If this happens, go to a higher range.
- If the FFT plot has a “notch” in the peak, try setting the signal amplitude lower. Over-driving the FFT will give unpredictable results.

Example Project

This lab project demonstrates the capabilities of the Bakerboard Analog Trainer.

Materials

The materials required for this lab are listed in the table shown below.

Example Project – Parts List	
Quantity	Item
2	47 μ F electrolytic capacitor
2	0.1 μ F ceramic disc capacitor
4	10 K Ω $\frac{1}{4}$ watt resistor (brown, black, orange, and gold striped)
2	560 Ω $\frac{1}{4}$ watt resistor (green, blue, brown, and gold striped)
2	2N3904 or 2N2222 transistors
2	LEDs of your favorite colors
1	LM741 or pin-compatible operational amplifier
1	LumiDax $\text{\textregistered}$ wiring kit
1	LumiDax $\text{\textregistered}$ Bakerboard Analog Trainer
1	Pair of wire cutters

Procedure

Make sure power is not applied to the trainer until your circuit is wired and ready to test.

1. We will first build a cute little LED flasher by using the multivibrator circuit shown in **Figure 10**. This circuit will flash two LEDs alternately at a rate of about 1 Hz to 3 Hz. Use the pictorial diagram in **Figure 11** to get an idea of what your breadboarded circuit should look like.

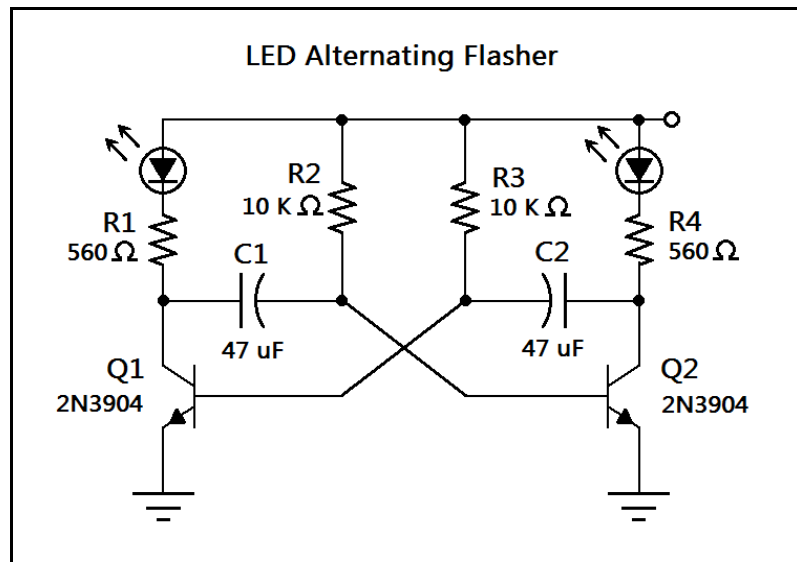


Figure 10: LED flasher circuit.

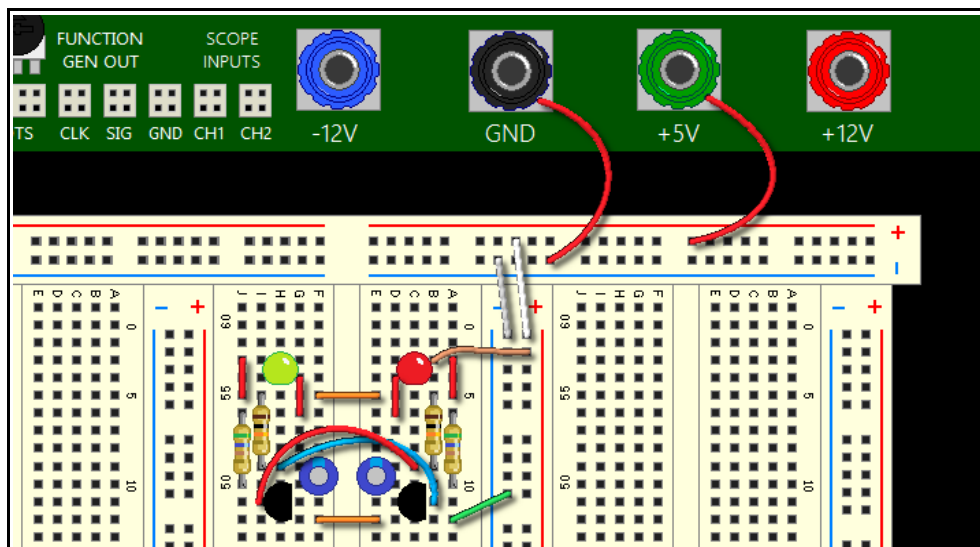


Figure 11: The LED flasher circuit on the breadboard.

2. Apply power to the LED flasher. Are the LEDs blinking alternately? The rate of flashing should be slow enough to see with your eyes.

3. Remove the power and dismantle the circuit. We will now build our first amplifier, the inverting op amp. We will use the function generator and the oscilloscope to try some experiments. Wire the schematic shown in **Figure 12**. Use the pictorial diagram in **Figure 13** as a guide.

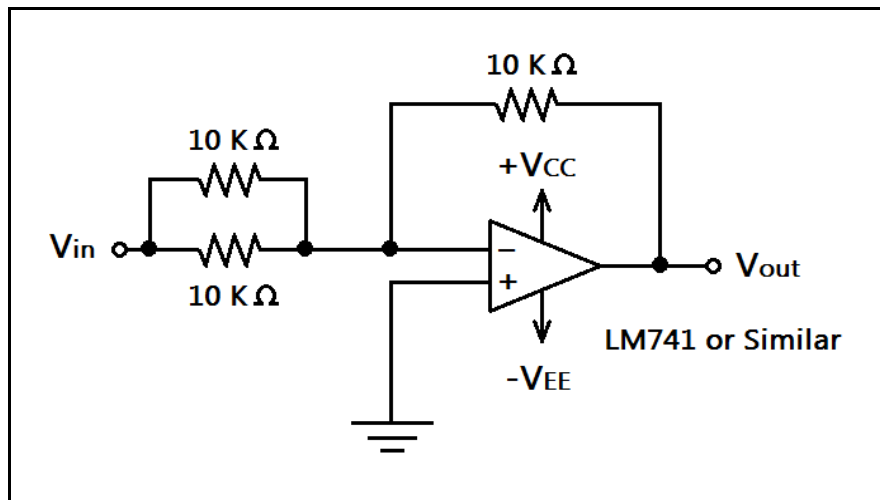


Figure 12: An inverting amplifier with a gain of two.

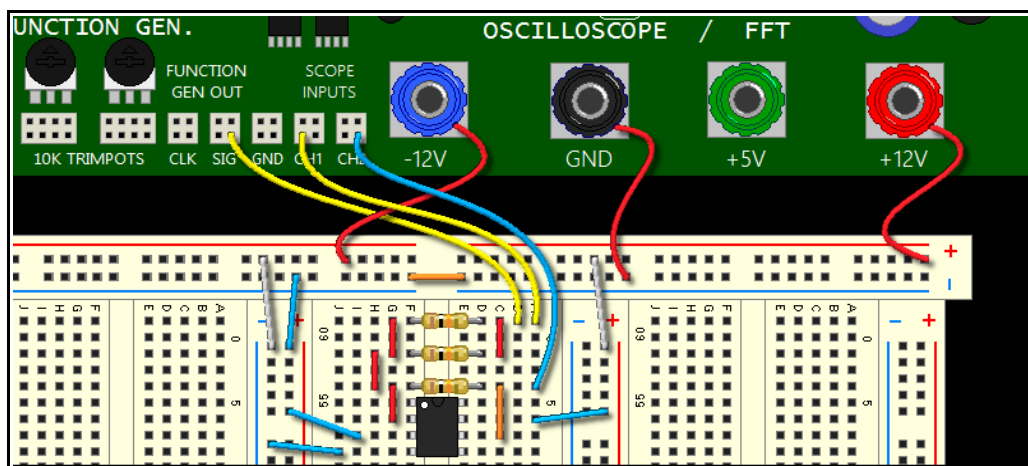


Figure 13: Inverting amplifier pictorial diagram.

4. Notice the input resistors on the input in parallel. The equivalent resistance for the input is half the resistance of the feedback resistor. What is the gain? Adjust the function generator offset to center the waveform, and select sine wave output. Make the sine wave amplitude $2 V_p$. Verify your gain calculation by comparing the output voltage to the input. **Figure 14** shows how the output should appear.

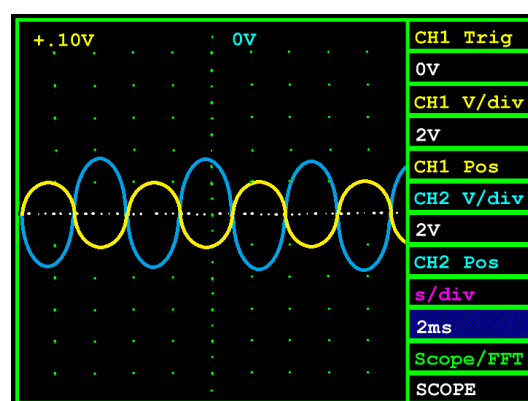


Figure 14: Example output for the inverting amplifier.

5. Now disconnect the feedback resistor (the 10 K Ω resistor closest to the op amp in **Figure 13**.) What happens to the output waveform? By removing the feedback resistor, the gain of the circuit goes to about one million. This circuit is now nothing more than a comparator with a series input resistor.

6. Select the triangle waveform on the function generator. Use the level control on the function generator to move the triangle wave up and down slightly around the center line. What happens to the output waveform? Can you control the duty cycle this way? **Figure 15** shows how the output should appear.

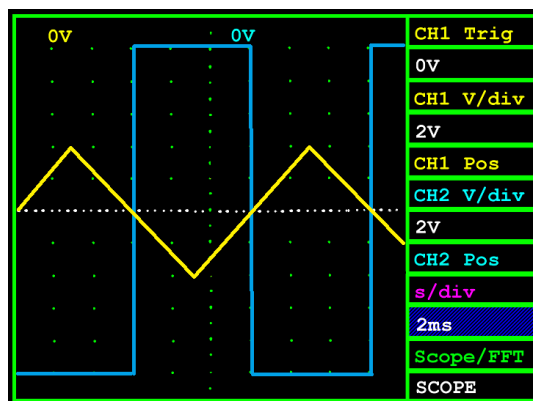


Figure 15: Comparator output converting a triangle wave to a square wave.

7. Power off the trainer and dismantle the circuit. We will now make a low-pass Sallen-Key 2nd order filter. This filter will have a cutoff frequency around 150 Hz. Use 10 K Ω resistors for R_1 , R_2 , R_3 , and R_4 , and 0.1 μ F for C_1 and C_2 . Wire the circuit shown in the schematic in **Figure 16**, and use the pictorial diagram in **Figure 17** as a reference for breadboarding.

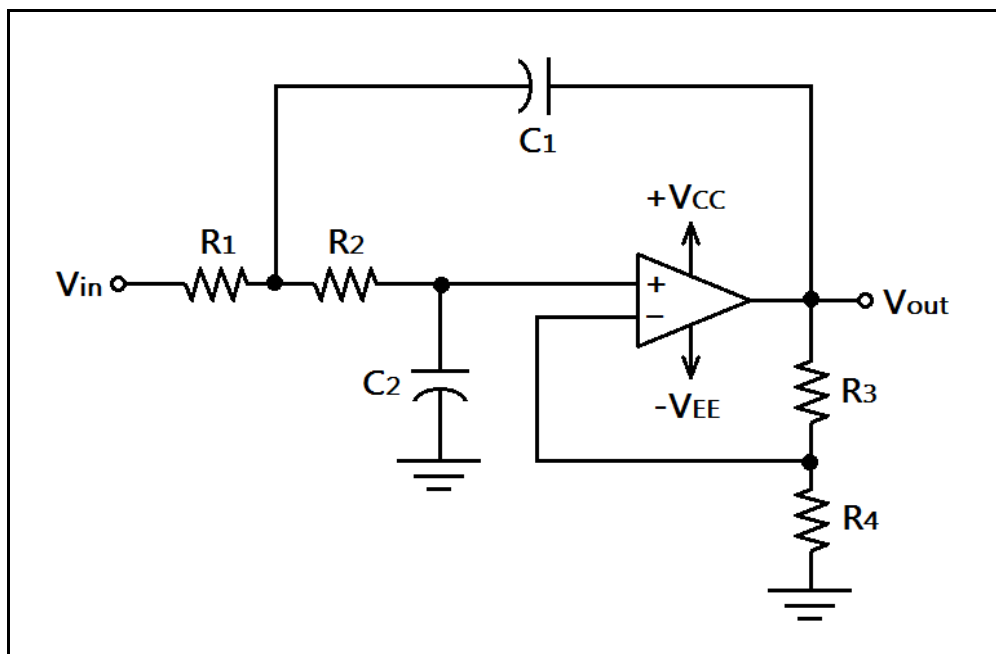


Figure 16: A Sallen-Key low pass filter.

8. Go from oscilloscope mode to spectrogram mode. Select 2 KHz as the maximum frequency, and set the gain to 3 dB. Set the graphing mode to waterfall mode. Set the function generator to the 4 KHz range. Set the waveform mode to noise, and observe the graph.

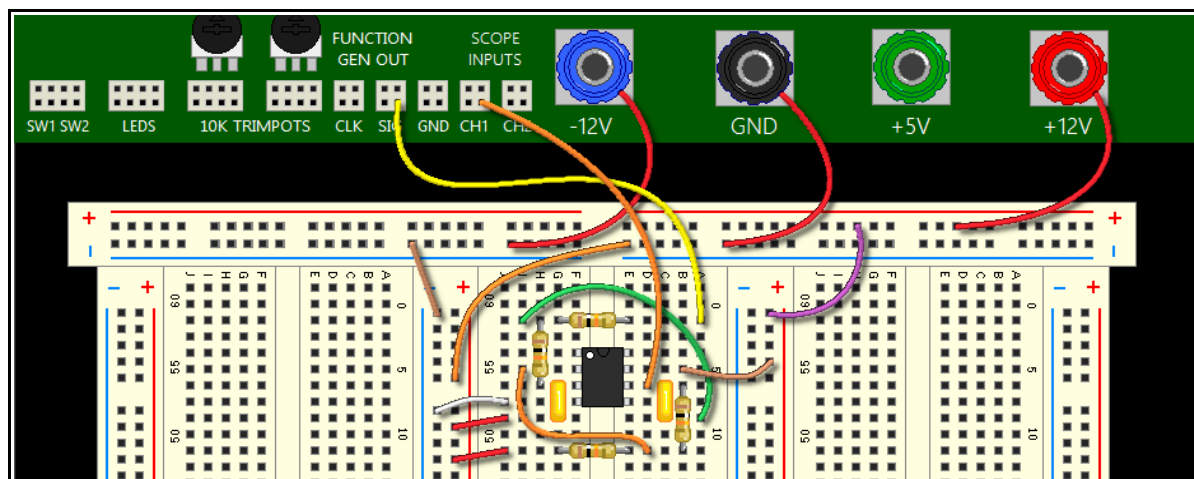


Figure 17: Sallen-Key low pass filter pictorial diagram.

9. Compare the output of the filter with the noise input to the image shown in **Figure 18**. This is a 2nd order filter, so the output will have a clearly defined cutoff frequency. Does your circuit produce the result shown in the figure?

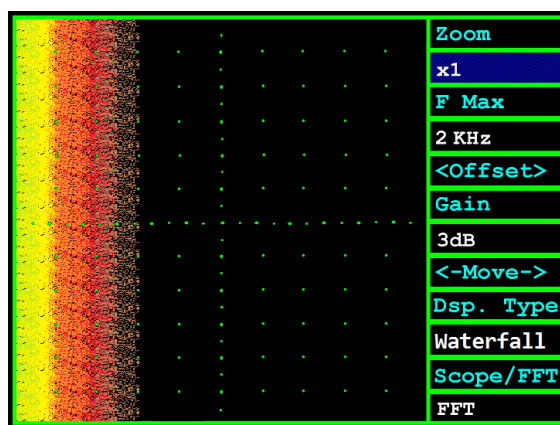


Figure 18: Waterfall display of the Sallen-Key filter output.

The above waterfall display clearly shows where the filter is active. The brighter the color, the greater the amplitude. We see the signal getting weaker with increasing frequency as we would expect for a second order, low pass active filter. We go from the area of greatest intensity (yellow) to orange, red, and finally dark red and black. Since noise contains all frequencies, it is a good method for testing filter action to input noise on the filter input and to profile the output in this way. You can see the filter action at a glance.

Conclusion

The Analog Bakerboard from LumiDax Electronics LLC ® is an all-in-one lab that can help you to prototype and test analog circuits easily. Come to our website for educational videos, and for your free ebook. The ebook is a complete course in analog electronics and is suitable for hobbyists and high school and college students alike. With more than 175 pages, over 120 diagrams, and five guided lab exercises, you'll learn about resistors, capacitors, inductors, transistors, and op amps. The book also features end-of-chapter vocabulary and design exercises with solved problems, and highlighted equations to help you find the equation you need quickly.