

Magnetic Theremin Kit

Assembly Instructions

Operating Instructions

Circuit Description

muTator 5000 Magnetic Theremin Kit

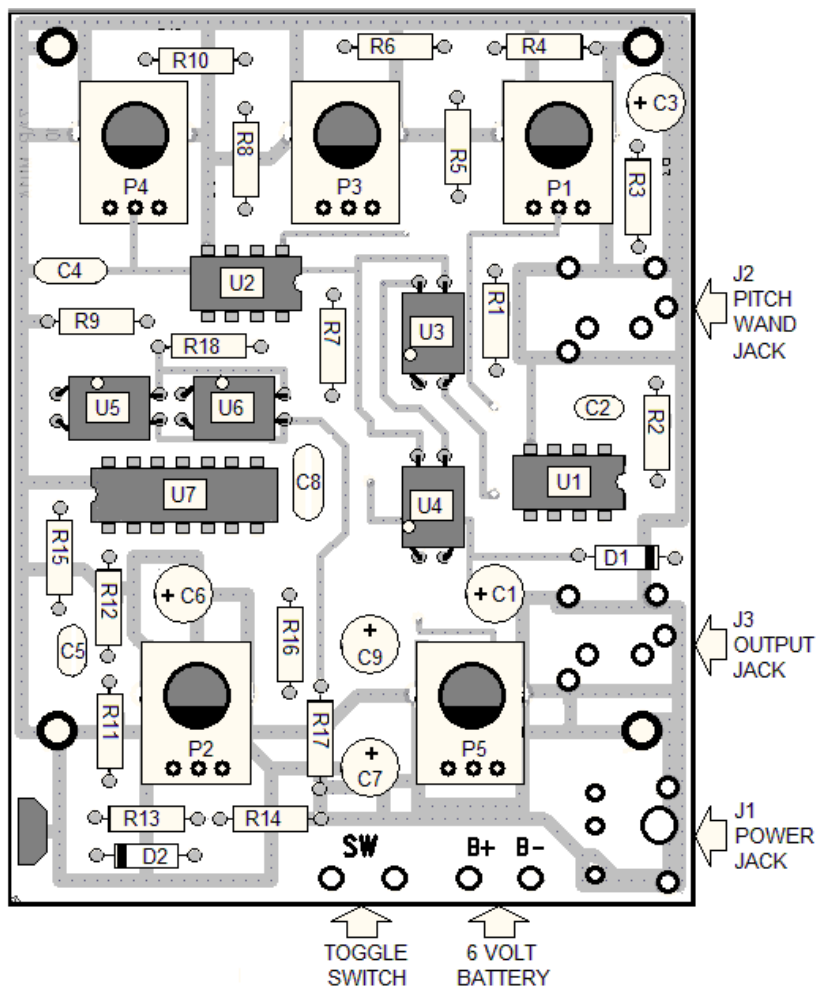
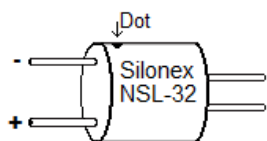
ZAP Studio LLC UPC 685248250013

Assembly Instructions

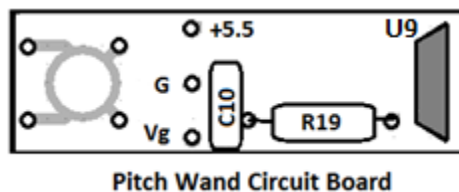
Electronic assembly and soldering experience is required for this kit. Use a 25 watt soldering iron with a clean sharp tip. Use rosin core solder. Double check part values, locations, and orientation before soldering.

1. Carefully install and solder ICs U1 through U7. Observe component orientation, especially U3, U4, U5, and U6: note that the leads are farther apart on one side and the location of the dot on the side of body.
2. Carefully install and solder resistors R1 through R18 and diodes D1 and D2. Observe polarity of the diodes. Cut excess leads after soldering.
3. Carefully install and solder capacitors C1 through C9. Observe the polarity markings on the electrolytic capacitors. Cut excess leads after soldering.
4. Carefully install and solder potentiometers P1 through P5. Before soldering, make sure that the potentiometers are seated firmly on the board with their shafts perpendicular the board.
5. Carefully install and solder jacks J1 through J3. Before soldering, make sure that the jacks are seated firmly on the board. A picture of the assembled pc board is shown on the next page.

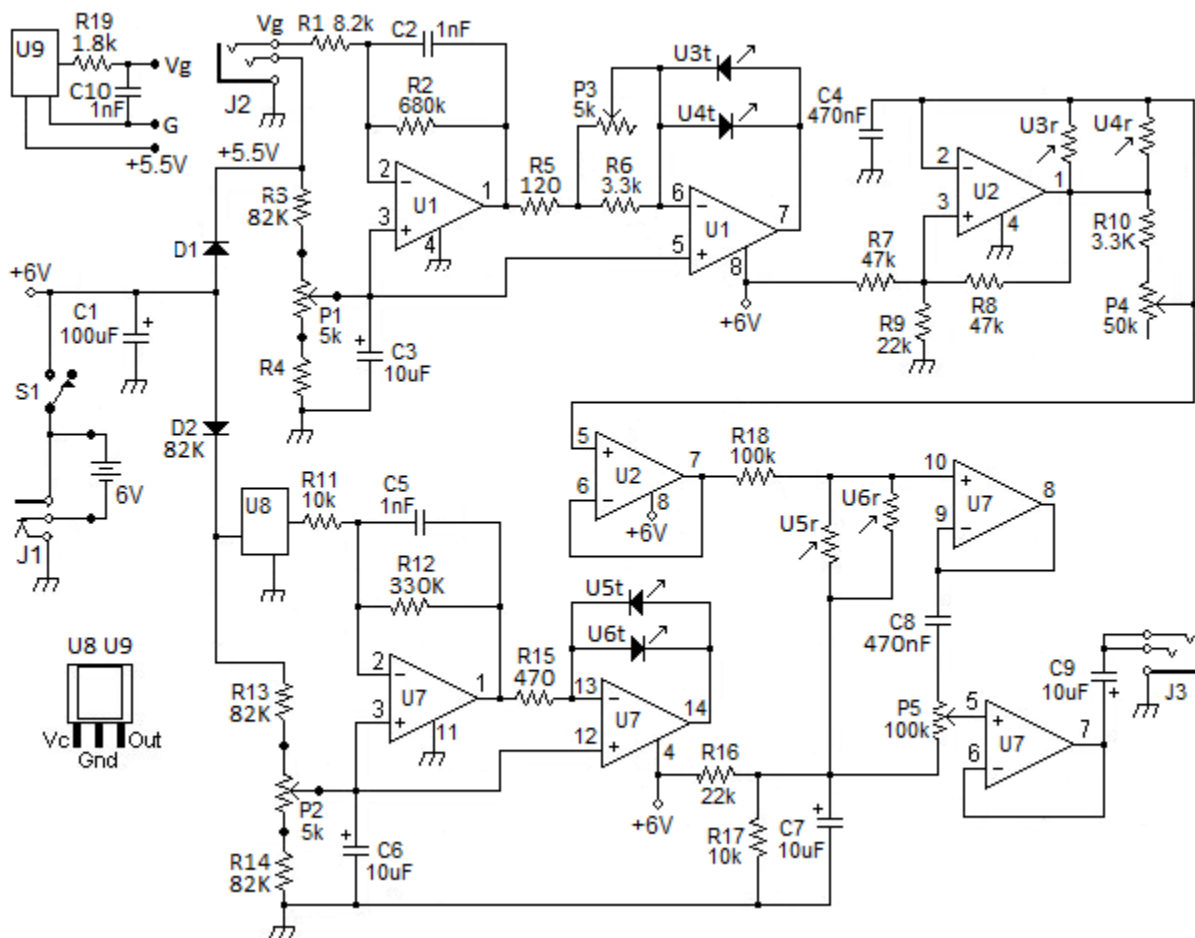
U1, U2: LM358
 U3, U4, U5, U6: NSL-32
 U7: LM324
 U8: SS495A2
 D1, D2: 1N4148
 R1: 8.2k
 R2: 680k
 R3, R4, R13, R14: 82k
 R5: 120
 R6, R10: 3.3k
 R7, R8: 47k
 R9, R16: 22k
 R11, R17: 10k
 R12: 330k
 R15: 470
 R18: 100k
 C1: 100 μ F, 16VDC
 C2, C5: 1nF
 C3, C6, C7, C9: 10 μ F, 16VDC
 C4, C8: 470nF
 P1, P2: 5k, Linear Pot.
 P3: 5k, Log. Pot.
 P4, P5: 50k, Log. Pot.



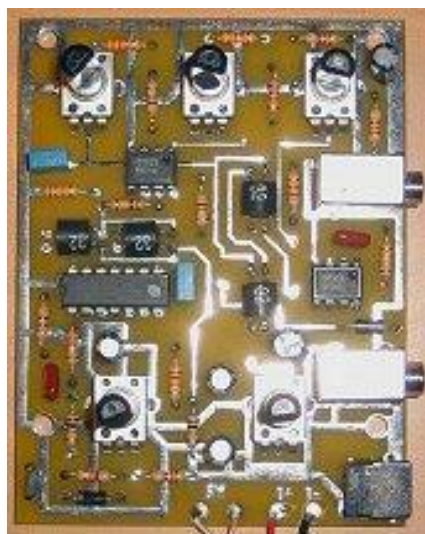
6. Assemble the pitch wand board as shown on the right. A 3-foot stereo cable with a 3.5mm plug on one end is soldered to the left side. See picture on the next page. Note that the tip of the plug goes to +5.5V, which is the white wire. The red wire goes to Vg and the shield goes to G. The cable is clamped to the pc board with wire.



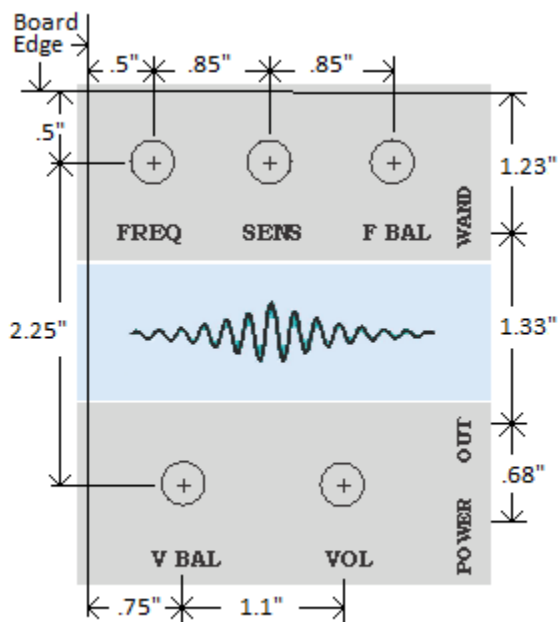
Circuit Diagram



Pitch Wand Board



Instrument Board



CONTROL & JACK TEMPLATE

Operating Principles and Instructions

Introduction

This magnetic Theremin produces a tone whose pitch and volume are controlled by magnetic fields. The term “pitch” refers to the frequency of a tone in cycles per second. The music tone “middle A” has a pitch or frequency of 440 cycles per second. The scientific unit for cycles per second is “Hertz” which is abbreviated “Hz”. So 440 cycles per second is usually expressed as 440Hz.

This instrument can produce frequencies from less 20Hz to greater than 6000Hz. The frequency can be controlled by magnetic fields over a range of at least three octaves. The lowest frequency is set with a frequency control when the magnetic field is zero. The frequency can then be increased by magnetic fields to a value at least 3 octaves above the lowest frequency. For example, if the lowest frequency is set to 220Hz, the frequency can be varied magnetically up about 1760Hz.

Frequency is controlled by the strength of the magnetic field sensed by the instrument’s “pitch wand” . Moving the pitch wand in a magnetic field, such as that produced by a magnet, causes a variation in frequency. The instrument’s sensitivity is adjustable with a sensitivity (**SENS**) control. At maximum sensitivity moving the pitch wand in the earth’s magnetic field will cause the frequency to vary.

The volume or amplitude of the instrument’s output is controlled by the strength of the magnetic field sensed on the left side of the circuit board. The instrument’s maximum output amplitude (volume) can also be adjusted with a master volume control.

Functional Block Diagram

The block diagram on the right shows the functional blocks of the instrument and controls associated with each block.

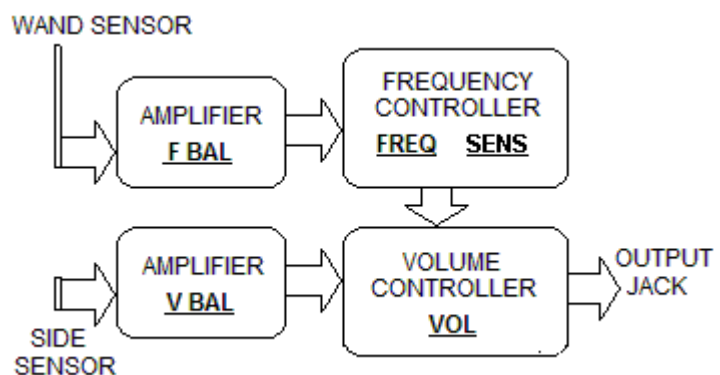
F BAL: Frequency balance control.

FREQ: Frequency range control.

SENS: Sensitivity control.

V BAL: Volume balance control.

VOL: Master volume control.



Control Functions

F BAL: This control is usually adjusted to produce the lowest pitch when the magnetic field strength sensed by the instrument’s pitch wand is minimum.

FREQ: This control adjusts the range of pitch produced by the instrument. It is usually adjusted to produce the lowest desired pitch when the magnetic field strength sensed by the pitch wand is minimum. An increase in the magnetic field strength will cause the pitch to rise.

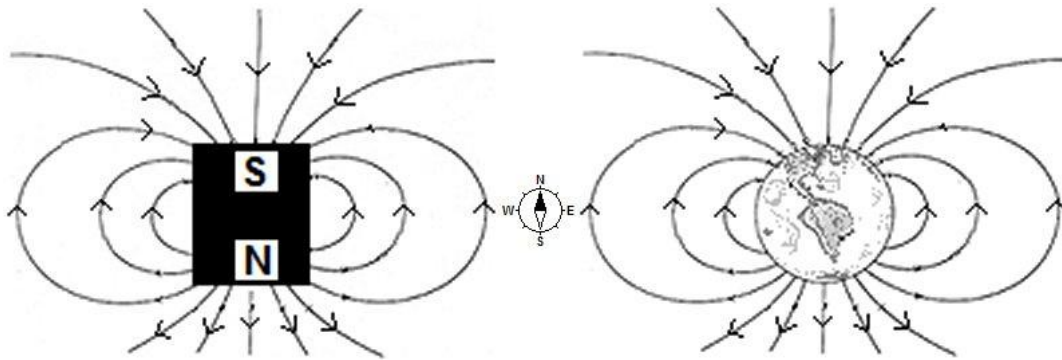
SENS: This control adjusts the instrument’s sensitivity to a magnetic field change. When set to maximum moving the pitch wand in the earth’s magnetic field can produce a change in pitch of about three octaves. When set to minimum the effect of the earth’s field will be insignificant and a magnet will be needed to produce a change in pitch.

V BAL: This control is usually adjusted to produce the highest volume (amplitude) when the magnetic field strength sensed by the instrument's side sensor is minimum. An increase in the magnetic field strength will cause the volume to decrease.

VOL: This is the master volume control. It determines the maximum volume or amplitude that the instrument will produce.

Magnetic Fields

This instrument can operate using any magnetic field, such as produced by a magnet or the earth. The strength of the field is typically measured in "Gauss" or "Teslas" (1Tesla = 10,000 Gauss). The strength of the earth's surface magnetic field varies with location and has an average value of about 0.5 Gauss. Permanent magnets may have magnetic field strengths greater than 1000 Gauss up to about 14,000 Gauss.



Magnetic fields may be visualized as "lines of magnetic force" as shown in the diagrams above. The field is strongest in the direction parallel to the field lines and zero in the direction perpendicular to the field lines. Also, the field is stronger where the field lines are closer together.

The diagram above on the left shows the field lines produced by a magnet. The field lines are directed out of the north pole and into the south pole. The magnetic field is strongest at the poles and decreases with distance from the poles.

A magnetic compass needle aligns itself parallel to the field lines and its north pole points to the magnet's south pole, as shown in the middle of the diagram above. The diagram on the right shows the earth's magnetic field is similar to that of a magnet and that its geographic north pole is actually a south magnetic pole.

Pitch Wand Sensor and Volume Wand Sensor

This instrument has two magnetic field sensors. One is in the tip of the pitch wand. Its sensitivity is the greatest when the wand is aligned parallel to the magnetic field lines and almost zero when it is perpendicular to the field. Since this wand controls the pitch, changing the angle of the wand in the field or moving the wand in and out of the field results in a change of pitch.

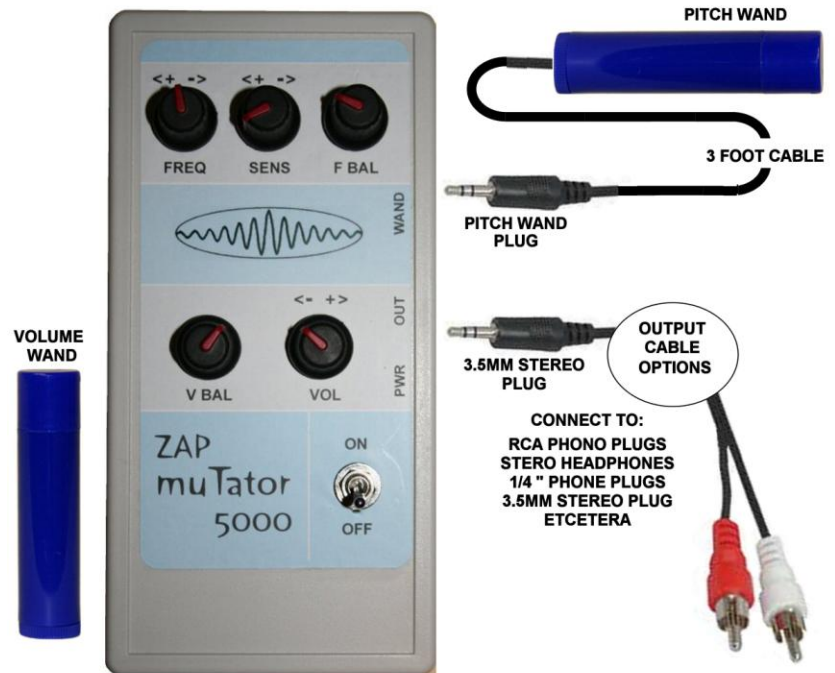
The other sensor is located on the left side of the instrument's pc board near the **V BAL** control. Increasing the strength of the magnetic field sensed by the side sensor results in a decrease in volume. The volume can be controlled by moving a small magnet or volume wand near the side sensor.

Instrument Set Up

The picture on the right shows one configuration of the instrument. Insert 4 AAA batteries into the battery compartment and/or connect a 6 volt regulated wall adaptor to the power jack.

Plug the pitch wand into the wand jack and plug in earphones or an amplifier into the output jack. Refer to the illustration on the right.

Earphones may be plugged directly into the output jack. The output can also be connected to an amplifier, effects device, or PA system by using the appropriate adaptor cable.



Initial Operation

1. Turn on the power switch. Turn the master volume control (**VOL**) maximum counterclockwise (-). Set the other controls midway (12 o'clock), slowly increase the volume. You should be able to vary the instrument's frequency with the **F BAL** control and volume with the **V BAL** control.
2. The **V BAL** control is normally set by adjusting it to produce the highest volume in the absence of a magnetic field. The volume should increase considerably at the balance point. Set **V BAL** for maximum volume and then adjust the volume (**VOL**) control for the desired zero field volume.
3. The **F BAL** control is normally set by adjusting it to produce the lowest frequency in the absence of a magnetic field. If the sensitivity (**SENS**) control is set high (+) the instrument's wand should be aligned perpendicular to the earth's field when making this adjustment. The lowest zero field frequency can be adjusted with the frequency (**FREQ**) control.

The settings of the controls depend on the application as well as the operator's preference and experience.

4. Summary: Adjust the **V BAL** control for the maximum volume and the **F BAL** control for the lowest frequency. Set the frequency (**FREQ**) control for the desired lowest pitch. Move the wand near a magnet and note the resulting change in pitch. The **FREQ** control setting will also vary the frequency or pitch range produced by moving the wand. The **SENS** control will change the distance over which the frequency or pitch changes.
5. The volume can be decreased by moving a magnet or magnetic wand near the left side of the instrument (near the **V BAL** control)
6. Experiment with the settings of the controls. The results will vary with the magnet used and its orientation. Increasing the gain will cause the wand to respond to the earth's magnetic field. The

The **F BAL** control should be adjusted for the lowest frequency when the wand is oriented perpendicular to the earth's field. A compass may be used to determine this, or carefully moving the wand to produce the lowest pitch while adjusting the **F BAL** control will also work.

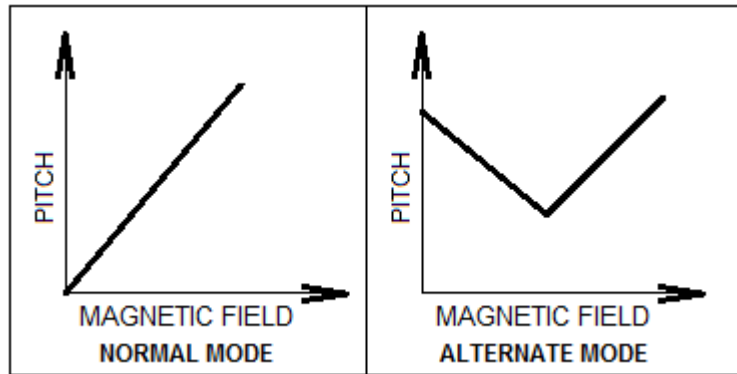
It is possible to increase the sensitivity of the instrument so that very small wand movements as well as environmental effects will cause a noticeable "waver" in the frequency. If this happens, the **SENS** control needs to be decreased (-) a little.

Alternate Modes of Operation

The difference between the normal mode of operation and alternate mode is illustrated on the right. This also applies to the volume controller.

In the standard mode, the frequency will always increase as the magnetic field strength is increased.

In the standard mode, the volume will always decrease as the magnetic field strength is increased.



In alternate modes the **F BAL** control can be set so that the lowest frequency is not produced when the magnetic field strength is at minimum. Experiment by setting the **F BAL** control for lowest frequency with the wand at various distances from the magnet.

In alternate modes the **V BAL** control can be set so that the highest volume is not produced when the magnetic field strength is at minimum. Experiment by setting the **V BAL** control for highest volume with the magnet or magnetic wand at various distances from the side sensor.

A variety of effects can be produced by this instrument in addition to its Theremin like capabilities. For example, the pitch produced by the wand can be modulated by a varying magnetic field.

A link to a **muTator 5000** demonstration video is posted at: www.zapstudio.com

Magnet and Wand Information

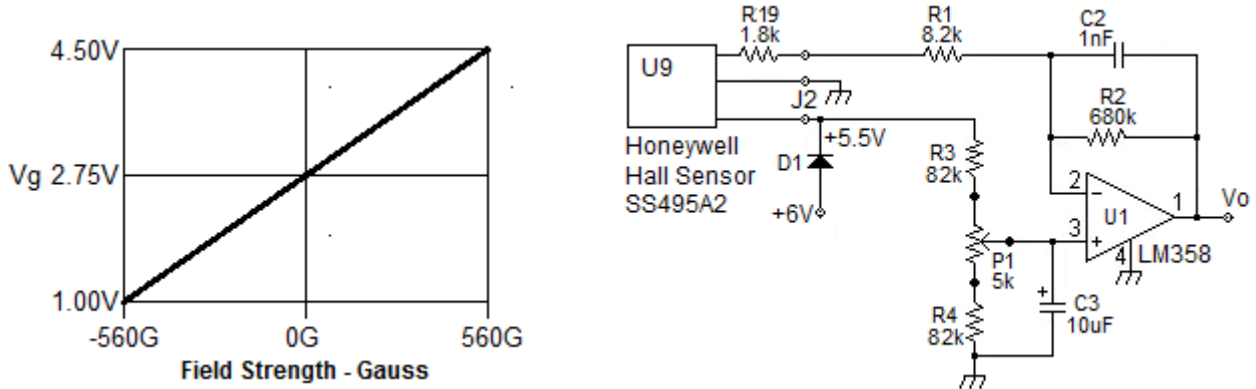
Although any type of magnet may be used, neodymium rare earth magnets are recommended. An effective magnetized "volume wand" can be made using a 0.5 inch diameter by 0.5 inch long neodymium rare earth magnet in its tip. The earth's magnetic field or any magnet can be used to provide the magnetic field for the pitch wand, including loudspeakers and electric guitar pickups.

The "pitch wand" uses a magnetic field sensor in its tip. It is aligned so that it is most sensitive to magnetic field lines parallel to the wand. Note that the instrument's pitch can be varied by changing the angle of the wand in a magnetic field. This is the primary operating mode when using the earth's magnetic field. The variation in pitch caused by moving the wand in the field of permanent magnets depends largely on the size and strength of the magnets used and on the ingenuity of the operator.

How It Works

Pitch Wand, Hall Sensor, and Amplifier

The pitch wand uses a Hall effect sensor with a magnetic field sensitivity of about 3.125mV per Gauss. Its zero field output is one half of its supply voltage. Its output voltage increases or decreases according to the field strength and polarity. A graph of the sensor's output is presented below on the left. The schematic diagram of the sensor and amplifier circuit is below on the right.



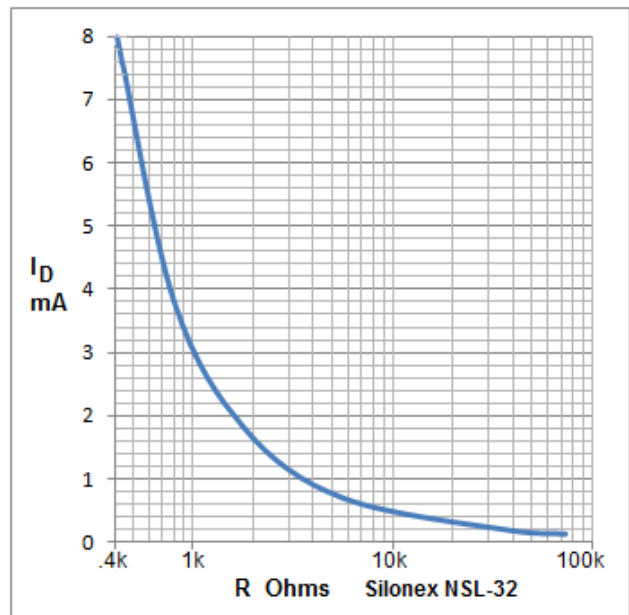
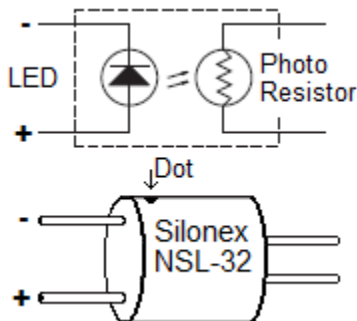
U1 amplifies the output of the sensor by 68 (680k/10k), increasing the magnetic field sensitivity to 212mV per Gauss. Its output voltage, V_o , is offset by 2.75 volts by the “balance” potentiometer, P1. A voltage divider consisting of R2, P1, and R4 is used to apply 2.75 volts to U1, pin3. The capacitor C2 in conjunction with resistor R5 provides low pass filtering.

P1 is used to set the zero Gauss offset voltage to one half of the supply voltage. In operation, this is done by adjusting it for the lowest pitch in absence of a magnetic field. The output voltage V_o drives a voltage to current converter which is described next.

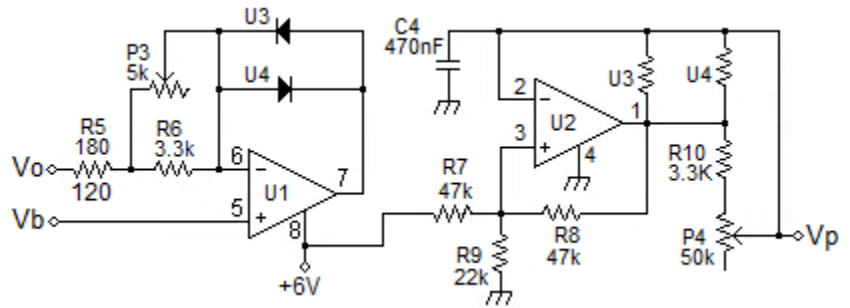
Voltage to Current Converter and Photo-Resistor Output Opto-Couplers

The voltage to current converter is used to vary the current through the LEDs of photo-resistor output opto-couplers. Increasing the LED current increases the LED brightness which in turn decreases the resistance of the photo-resistor.

A graph of typical LED current and resistance is presented on the right for the Silonex NSL-32 Opto-coupler. The diagram and drawing is presented below.



U1B in the circuit on the right drives current through the LEDs U3t and U4t. The current is proportional to the difference in the voltages V_o and V_b . The LEDs are the transmitter part of the photo-couplers. The corresponding receivers are the photo-resistors U3r and U4r in the circuit of U2A.



The input resistance to U1B is the net resistance of the combination of the resistors R5, R6, and P3. The net resistance can be varied from 120 ohms to 2310 ohms with the P3, the sensitivity control. The voltage difference, $V_o - V_b$, ranges from -2 to +2 volts, depending on the magnetic field strength and polarity. Applying Ohm's law, the range of current through the net resistance is -17mA to +17mA.

When $V_o - V_b$ is positive, the current will flow through U4t (U3t is reverse biased). When $V_o - V_b$ is negative, the current will flow through U3t (U4t is reverse biased). Since U3r and U4r are in parallel, either U3 or U4 will cause a change in the pitch. This makes the pitch independent of magnetic polarity. Magnetic north will cause the same pitch change as magnetic south.

The sensitivity of the pitch wand to a change in magnetic field strength is calculated as follows:

1. Sensitivity of Hall sensor is 3.125mV per Gauss. U1A amplifies this by 68.
2. Output of U1A, V_o , changes by 212.5mV per Gauss (68 times 3.125mV per Gauss).
3. LED current changes by 1.8mA per Gauss when P3 is set to maximum sensitivity.
4. LED current changes by 0.1mA per Gauss when P3 is set to minimum sensitivity.

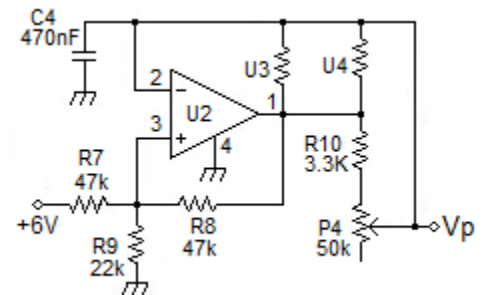
Note that the maximum change in the voltage V_o is about 2 volts. This means that the pitch wand operates in a magnetic field range of 0 to about 10 Gauss fields stronger than 10 Gauss will not produce a change in pitch.

The earth's magnetic field strength is typically between 0.3 and 0.7 Gauss, depending on location. This means that when P3 is set to maximum sensitivity moving the wand in the earth's magnetic field can produce a change in LED current on the order of 1mA, which can change the pitch frequency by several octaves..

Oscillator Circuit

U2A is a Schmitt trigger "relaxation oscillator". The Schmitt trigger is basically an analog comparator whose output switches between its high saturation voltage (about 5 volts) and low saturation voltage (close to 0 volts).

Capacitor C4 charges when pin 1 of U2A is high and discharges when pin 1 of U2A is low. When pin 1 is high, the voltage on pin 3 is about 2.66 volts. When pin 1 is low, the voltage on pin 3 is about 1.45 volts.



The capacitor charges to 2.66 volts and discharges to 1.45 volts. The rate of charge and discharge is set by the time constant of the resistance between Pin 1 and pin 2 and the value of C4. The output of the oscillator, V_p , is approximately a triangle wave with an amplitude of about 1.2 volts p-p.

The oscillator is buffered by U2B which has a voltage gain of one. Its frequency is varied by the resistance of U3r and U4r. The potentiometer P4 sets the lowest frequency and effects the frequency range of the oscillator.

Volume Wand, Hall Sensor, and Amplifier

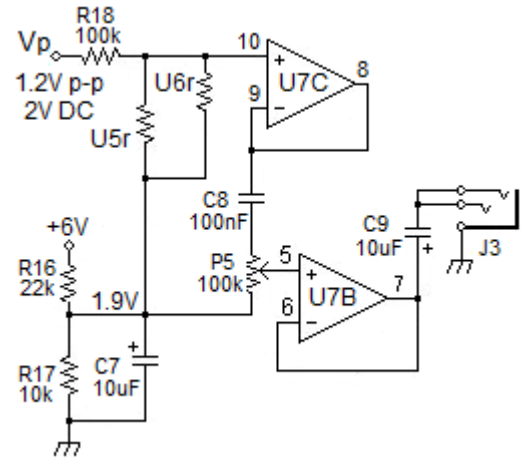
The volume wand can be any magnet. There is a Hall sensor on the side of the pc board that is used to control the output volume of the instrument. Increasing the magnetic field intensity near the Hall sensor reduces the output volume.

The amplifier, U7A, is identical to the circuit of U1A except its gain is 33. The output of U7A drives the voltage to current converter, U7D which is identical to U1B . However it has a fixed gain of about 2.1mA per volt. The total gain of U7A and U7D is about 0.22mA per Gauss.

Specifications of the NSL-32 opto-coupler indicate that its minimum photo-resistance is less than 500 ohms and its maximum (dark) photo-resistance is greater than 500k ohms.

The circuit on the right uses the opto-couplers photo-resistance in a voltage divider consisting of R18 and U5r in parallel with U6r. Calculations show that the minimum attenuation of the voltage divider is about 3dB and maximum attenuation is about 46dB.

U7C is a buffer for the attenuator. Its output is coupled to C8 and P5. P5 is the master volume control. J3 is a 3.5mm stereo jack which connects the instrument to stereo headphones or to an amplifier.



Limited Warranty

ZAP studio will replace missing or defective parts for a period of 30 days after purchase.

ZAP Studio assumes no liability for the assembly and application of this electronic kit. The assembly and application of this electronic kit is the responsibility of the buyer.

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