Miniature Audio Oscillator (Miniosc)

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PCBs will be made available for this project if demand is sufficient. Please send an e-mail to ESP to register your interest

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Introduction

The Miniosc is designed as a pocket sized high performance audio oscillator. Some time after another design was published, it occured to me that an even simpler, battery operated version was possible and could be made at very low cost as well by using one quad op-amp to provide the entire active circuitry. Employing a nine volt battery supply would put a lower limit on the maximum output level, compared with a mains powered oscillator, meaning that about one volt or so output should still be available.

The mini version of the original Low Distortion Oscillator has been fitted into a pocket sized instrument case including a nine volt battery in its own compartment, and has level and frequency control pots on top with range and mode switches on the sides allowing one handed operation of all controls, a very useful feature.

A mini sized, battery powered sine and square wave source is invaluable for on site testing of all sorts of audio equipment and even workshop use where the item to be tested may not fit on the workbench, for example a 24 channel mixing console or a large powered loudspeaker system.

Description

The oscillator circuit (see Figure 1) involves two unity gain phase shift stages, A1 and A2, in tandem and a gain stage, A3, with back to back diodes and resistor network providing non-linear negative feedback. At a particular frequency (determined by RT and CT - the timing components) A1 and A2 provide 90 degrees phase shift each, 180 degrees in total and the circuit begins oscillating, since A3 and its non linear network has more than unity gain for small signals. As the oscillation level increases the diodes conduct and limit the gain of A3 stabilising the output at the desired level, in this case a little over 1V RMS. However, some distortion of the sine wave peaks is caused by the diodes.

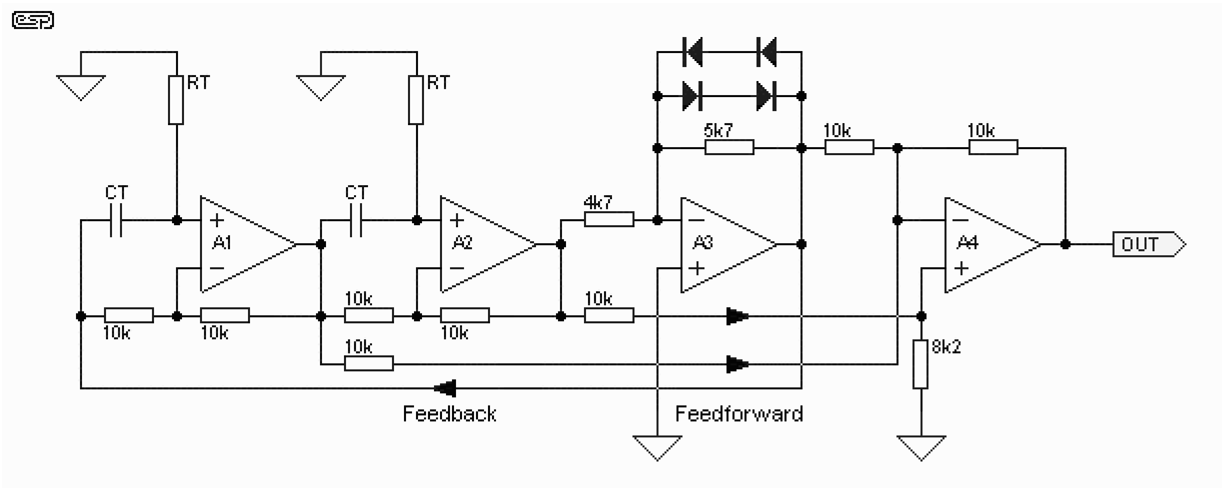

Figure 1 - Basic Oscillator Principle

The fourth stage, A4, is the real secret of the design since it combines the outputs of the three preceding stages using a feedforward* approach. This is done in such a way as to reduce the third and higher odd harmonic distortion products generated in those stages due to the back to back diodes used for level stabilisation. Because the diodes are symmetrical in their effect they cause only third and higher odd harmonics of the sine wave output.

> * Note that the term "feedforward" is not used in the strictly traditional sense here, but refers to the fact that parts of the signal are fed forwards to the final stage. This is more by way of a simple explanation than an attempt to redefine the term (just in case any of the engineering types were planning on taking me to task for my "misuse" of the word :-)

The net effect of A4 is to remove at least 90% of these unwanted harmonics from the output over the operating range of the oscillator. The prototype measured only 0.16% THD at 1kHz, somewhat less at lower and more at higher frequencies. At these levels the distortion is barely audible and presents a visually perfect sine wave on an oscilloscope screen. Overall, this represents a much better performance than a typical function generator.

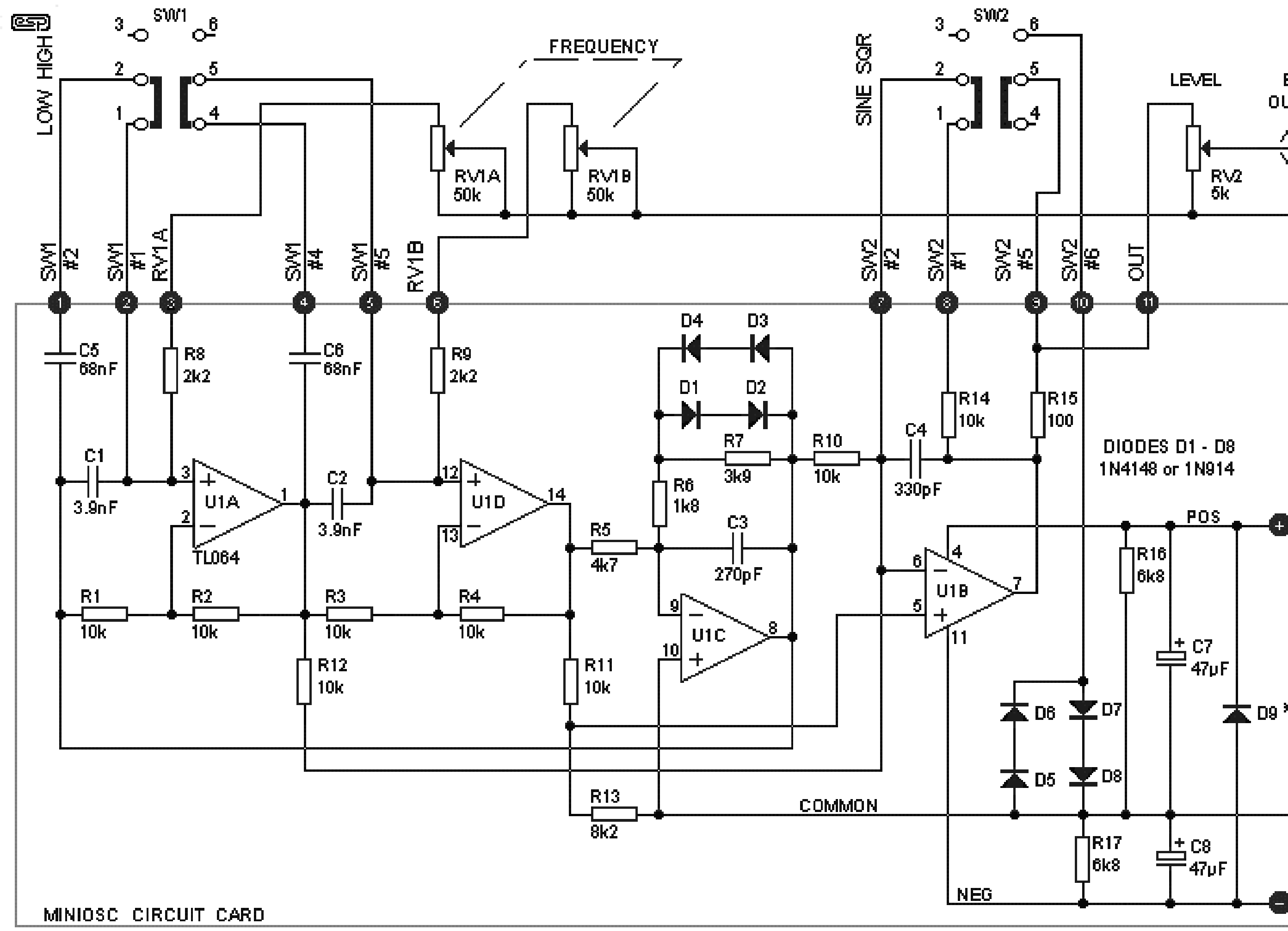

Figure 2 - Complete Schematic of MiniOsc

Refering to the main circuit (Figure 2) there are only two control pots (RV1 and RV2) and two DPDT switches. The output level pot includes an on-off switch and is of logarithmic taper to allow easier setting at low (i.e. millivolt) levels. This pot is directly coupled to A4's output to minimise response errors, provided that the load impedance is constant or quite high compared to the output impedance provided by Miniosc.

> Note: Since switched pots may be quite difficult to obtain these days, a separate on/off switch will probably be needed. This should be the same type as the others specified.

The frequency sweep control (RV1A/B) has a range of about 24:1 and in combination with the High-Low range switch having a 18:1 ratio, the audio band is covered (with the exception of the lowest octave) in two overlapping ranges. The possibility of a single sweep of the audio band without the range switch was tried out and later dropped in preference to the present design.

The square/sine wave switch works by disconnecting the negative feedback around A4 allowing the op-amp to run "open loop". In this condition it is overdriven by the oscillator stage causing its output to saturate at the positive and negative supply voltages producing a squared waveform. The additional four diode network which is switched across the output of A4 and voltage limits the output level in square wave mode to match the sine wave level and at the same time regulates against variations in the battery voltage.

The actual operating level of Miniosc is limited by the use of a single nine volt battery. The discharge curves for various types show a voltage variation of from 9.5 volts down to 6.3 volts is to be expected from "fresh" to "flat". The miniosc operates as specified over this range with a maximum output level of 1.27 volts rms sine and 1.45 volts square. The battery drain in sine wave mode is a miniscule 1.7mA increasing to about 4.7mA in square wave mode. This very low drain is mainly the result of using the Texas Instruments TL064 low power quad FET op-amp which is ideally suited to the design.

Types like the TL074, TL084, LF347 and LF444 and other quad op-amps with compatible pin outs are not recommended for use due to both the increased battery drain and reduced margin of minimum operating voltage. The TL064 is alone in having operation specified down to a plus and minus 3 volt supply.

Power from the standard nine volt 216 style battery feeds a voltage divider (R16 and R17) to provide an artificial centre tap with bypass capacitors and a 1 amp diode to protect the IC from inadvertant reverse connection of the battery. Even a momentary reversal of a good battery would easily destroy the TL064 IC and any of its relatives. Creating balanced plus and minus 4.5 volt supply rails like this allows direct coupling between all the op-amp stages (including the output level control), and also reduces the number of components.

Performance

The Miniosc is ***not*** a toy oscillator. It is capable of serious work testing domestic or professional audio equipmemt of all types and will verify normal operation, allow levels to be set, channels to be matched and response curves measured.

Low distortion combined with a particularly high "envelope stability" of 0.1 dB, even when rapidly swept, is a feature lacking even in many high grade oscillators. Battery operation eliminates the possibility of mains hum in the output and also allows connection to either floating transformer or actively balanced input circuit. Direct coupling of the output circuit eliminates any response errors caused by connecting low load impedances to Miniosc.

Note: The lowest octave of the audio band has been designed deliberately out so as to avoid damaging speakers when using the Miniosc. There are few speaker systems that can safely accept full power input at 20 Hz!

The square wave function has been included because it is so useful. The rise and fall times are relatively slow, however there is very good waveform symmetry across the audio range.

Construction Details

The suggested case has a removable top panel which should be carefully drilled for the two pots and BNC socket to be fitted. There is just enough room so measure twice and cut once! The pots may need the last few millimeters of their shafts removed to allow the knobs to sit flush as on the prototype. Use a hacksaw and file delicately to achieve this, also pack the slot in the shaft while cutting.

Figure 3 - Photo of Completed MiniOsc

The two (or three, if a slide switch is used for power) slide switches fit into slots which are cut with a nibbling tool in the sides of the case and then filed to size. Cut only enough plastic to permit full travel of the actuator. Two small holes will also need to be drilled to mount these switches. Mark their positions using a switch as a template and a sharp point or scriber. Four 2mm x 10mm long mounting bolts will also need to be purchased as they are not normally supplied with the switches.

The PCB may now be loaded (when available and if purchased, the details will be available in the secure section). This work should be done carefully to avoid solder bridges and prevent overheating the components. Use a small conical tip soldering iron at a moderate temperature (about 320 degrees C). The resistors are mounted vertically and the diode networks require pairs of diodes to have their leads twisted together and soldered before installation in the board. Take particular care with the polarity of the diodes and orientation of the IC.

MKT type PC mount capacitors have been specified for the Miniosc as they are now widely available but no other miniature components are needed despite the very small PCB and case.

Tip: Be wary of 1% metal film resistors with four band colour codes, it is more reliable to measure them with your multimeter than try to decipher the codes.

Small areas of the PCB may need to be removed near the corners to fit into the case and a hole drilled to secure the board with a 2.5 mm (or 6BA) bolt, nut and insulating washer.

Link the pots and switches to the appropriate points on the PCB with short lengths of light guage hook up wire which should be attached to the PCB first if not using pins. Last, wire the battery snap via the on-off contacts on the level pot. It doesn't matter which lead (red or black) goes to the switch but red is traditional.

Lastly, glue a small piece of foam plastic in the battery compartment to prevent the battery rattling about.

BNC Output Connector

The BNC output socket has been specified for the simple reason that the mating plug locks in place. An RCA socket was tried at first but proved unsatisfactory since the Miniosc could not be left dangling on its output lead without risk of disconnection followed by the unit going bang on the floor! Using the BNC overcomes this problem and various adaptor leads allow conversion to RCA and jack plug when required.

Commissioning

Once assembly is complete, double check all wiring and soldering especially for bridges between tracks or IC pins.

Connect a battery and switch on. If you have an oscilloscope available then a full performance check can be done otherwise simply connect Miniosc to your stereo amplifier and operate all the controls to verify correct operation. The sweep should sound smooth and the pitch should increase as the knob is turned clockwise. A large increase in frequency should be heard when the range switch is operated from Lo to Hi.

The square-sine wave switch should cause a very obvious sharpening of the tone but little increase in the level. The top end of the "Hi" sweep range should just disappear into inaudibility unless you are much younger than I am!

Warning: Keep the level down for this last test as replacement tweeters can be expensive! High powered tests involving loudspeakers should always be mercifully brief.

Battery drain can be checked with a multimeter and should read around 1.7mA in sine wave mode if all is well and you are using the TL064. Excessive current drain or no oscillation will probably be due to wiring errors, solder bridges or a component or two which has not had one of its leads soldered.

Using Miniosc

Although the Miniosc is not intended to replace the usual bench audio signal generator it can at a pinch do most of the same jobs a bench model does. The fact that the output level remains particularly steady while the frequency is swept rapidly makes response testing a breeze, especially for tape recorders, equalisers, electronic crossovers and loudspeakers too if a flat response sound level meter is available.

The main use I forsee for Miniosc is on the spot tests to equipmemt where little or no other test equipment is to hand. This might mean using your ears as the output instrument, or possibly a VU meter, LED ramp or similar level display built into the unit under test. In many cases a digital or analogue multimeter can be used as an output meter providing that its response is known to be flat over the range to be measured or it has been checked first using your new Miniosc!

Note: Analogue multimeters and VU meters will normally read accurately over the audio band but the same is not true of most digital multimeters where the AC readings taper off above only a few kilohertz.

Slowly turning the sweep control makes pinpointing and tracing rattles and buzzes in speaker systems very simple. Also, you can identify obvious peaks and holes in the response caused by defective drivers or passive crossover networks. Of course, be wary of rattling room heaters or window panes before you condemn the speakers.

Using Square Waves

The square wave function can be used in conjunction with an oscilloscope to examine transient responses for ringing or more likely when testing by ear when checking out signal processors and effects units like delay and reverberation, whether mechanical or electronic. You need an input signal rich in harmonics for the full sound of these units to be heard. A square wave signal contains all the odd numbered harmonics of a frequency, diminishing in relative intensity, out to beyond audibility.

Sweeping the square wave back and forth over one or two octaves will further enhances the audibility of effects, not to mention creating some wonderful sci-fi type noises.

Output Leads

A variety of output leads or adaptions may be needed. I used a BNC to jack (6.35mm) lead with an adaptor to RCA plug when necessary. Lead adaptors to XLR (Cannon) plugs may also be made for use with professional type audio equipment. In most cases pins 1 and 3 (or sometimes 1 and 2) should be linked on the "Cannon" to connect Miniosc to the input or else connect Miniosc between pins 2 and 3 for floating balanced (transformer) inputs.

Modifications

Some modifications are possible to the Miniosc circuit as it stands and there may be others you can develop.

1. Frequency limits can be altered by changing the values of capacitors C1, C2, C5 and C6. Increasing C5 and C6 for example to a value of 0.15 uF extends the range down to 20Hz. Some other values (R8 and R9) will be need altering also to prevent a gap occurring in the frequency coverage.

2. The range of the sweep control can be increased or reduced by changing the value of the end resistors R8 and R9. However, do not go below a value of 680 ohms.

3. The output level control-switch can be changed to a 1 kohm type if operation into low impedances needs to be optimised. This will make level setting more progressive than with the 5k ohm pot specified when feeding low impedance loads. (This will increase the sine wave battery load to 2.2mA while the square wave load remains at 4.7mA.)

Notes

1. The output frequency is given by ...

$$f = 1 / (2 . \pi . R . C)$$

where R equals resistance to ground from pins 3 and 12 of the TL064, and C equals total capacitance feeding R in each case.

2. The sine output level is unaffected by battery voltage variations provided the 6.3 volt minimum is available.

3. Temperature affects slightly the output level due to the effect on the diodes. An increase in temperature will cause the output to fall by approximately 0.4% per degree.

Performance of Prototype

Frequency:	Lo 41 to 1082 Hz
	Hi 735 to 18.1 kHz
Output:	1.27 volts rms sine (+4dBm) (note 3)
	1.45 volts peak square
Load:	1.0 volts rms sine into 330 ohms
Flatness:	+/- 0.1dB (1%) 41 Hz to 17 kHz
Distortion:	0.16% THD at 1kHz
Square wave:	Rise time - 5 us at 10kHz
	Symmetry - 1% up to 10kHz

Supply:	6.3 volt minimum
Consumption:	1.7 mA, sine wave
	4.7 mA, square wave