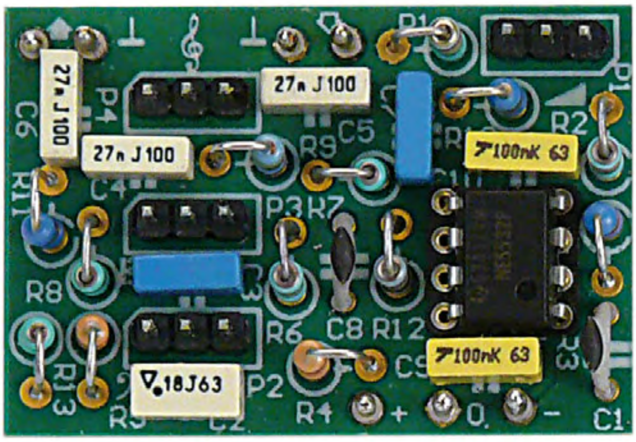
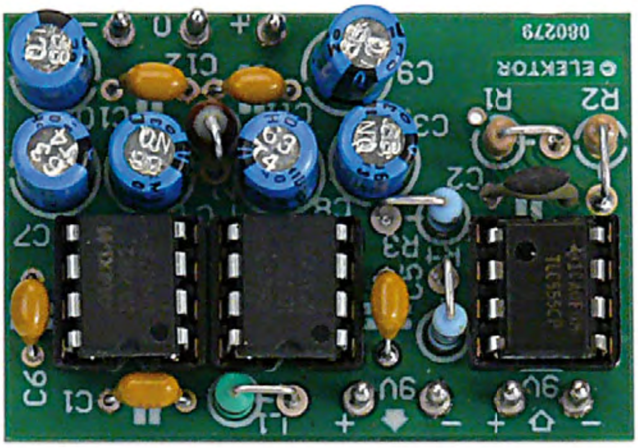
Pocket Preamp

Part 2: a simple preamplifier with tone control





By Ton Giesberts (Elektor Labs)

The PWM power stage discussed in the previous instalment (June 2009) can be used perfectly well on its own. But a matching preamplifier with power supply would complete this amplifier nicely. That is why this month's Mini Project presents the sequel: the Pocket Preamp.

In the June 2009 instalment of this series of articles we described a small PWM amplifier. What is missing from this are tone and volume controls. Since most people are spoilt these days with surround sound systems equipped with an equalizer as an absolute minimum, we made this preamp with a 3-way tone control, instead of the more customary bass/treble control.

Main Specifications

- 3-band tone control
- Symmetrical supply
- Compact
- Connector layout matched to associated boards

Tone control

The tone control has an adjustment range of ±12 dB for the low and high frequencies and ±9 dB for the mid frequencies. The latter is more than enough, because our ears are more sensitive to mid-range frequencies. The circuit will also remain reasonably straightforward with these values. If these adjustment ranges are too small then there is very likely something wrong with the loudspeakers.

A control range of 12 dB means that, because of the relatively limited power of the output stage, there is an imminent danger of overdriving it, particularly for the low and middle frequencies. After all, an increase of 12 dB implies an increase in power by a factor of 16!

The circuit

The volume control (P1) is connected directly tot the input of the preamplifier (see **Figure 1**). This is the best place to prevent the tone control stage from being overdriven. The first amplifier stage (IC1a) is non-inverting and has a gain of 4 times as calculated from

R3 / R2+1

At a supply voltage of ±9 V, a signal of more than 1 V (i.e. a little over 1.2 V_{eff}) can be processed without distortion, when the tone controls are in their centre positions. It will be obvious that when either the high or the low tone control is at its maximum value, the maximum permissible input signal is a lot smaller at only 300 mV (for the applicable frequencies, of course). At this point the output of the tone control is just below the point of being overdriven (but it will already overdrive the power amp, so take care!).
The operation of the tone controller is not all difficult to understand. The part

around IC1b is an inverting amplifier with three feedback circuits connected in parallel for the tone control. Resistor R12 ensures that the output cannot swing to the power supply rail in the event of contact bounce by the wiper of P2. Incidentally, R1 functions in a similar way for volume control P1. C8 and C1 suppress RF (high frequency) interference.

P2 is the bass control. C2 determines the frequency range that will be controlled. Simply put, at higher frequencies, C2 effectively shorts out P2. The amplification is then determined by the ratio of R5 and R4. The ratios of P2 to R4 and R5 determine the minimum and maximum control range respectively. The maximum gain for example is

(P2+R5) / R4

and amounts to about 5.5 times (15 dB, DC). R6 is necessary so that the other frequencies can be adjusted with P3 and P4. C7 primarily determines from which frequency the high tone control operates. C5 and C6 ensure that the tone control has a steeper response.
Components R9 and C4 have the same functions for the mid frequency control as R6 and C7 for the low and high controls. C3 has the same function as C2, but filters the high frequencies much later. Together with C4 it sets the range of the mid control. In the end, the control ranges of the mid and high adjustments are not only determined by, for example, the ratio of P3 to R7 and R8, but the other components in the feedback circuit also play a role. That is why the ratios between P3 and P4 to R7/R8 and R10/R11 are greater than would be expected from the actual control ranges.

The low tone control has quite a wide bandwidth, because we assume that small loudspeakers will be used. If this tone control is going to be used with a larger amplifier and ditto speakers a larger value for C2 may result in a better sound. Output resistor R13 prevents problems in the event an excessive capacitive load is connected.

Power supply

The power supply is symmetrical. This way we can avoid relatively large coupling capacitors and their detrimental effects on sound quality. The disadvantage is that a negative supply voltage is required. The easiest solution is a circuit that inverts the positive power supply.

We selected a DC/DC converter from Maxim, the ICL7662 (see **Figure 2**). This IC works as a charge pump and can operate with voltages up to 20 V. Pin-wise and functionally the IC is compatible with the more common ICL7660, which can operate up to 10 V (the 'A' version can handle voltages up to 12 V). These parts can also be used here without any problems. The biggest advantage of this is the simplicity; only two external capacitors are required. A small disadvantage is that the output voltage is not regulated.
The unloaded output voltage is equal to the input voltage, but negative. As the output current increases the output voltage will reduce however. To increase the stability of the output voltage two ICs are connected in parallel. If you load a single IC powered at 9 V with a resistance of 100 Ω, the output voltage drops to about –4.6 V. With two ICs in parallel this drops to only

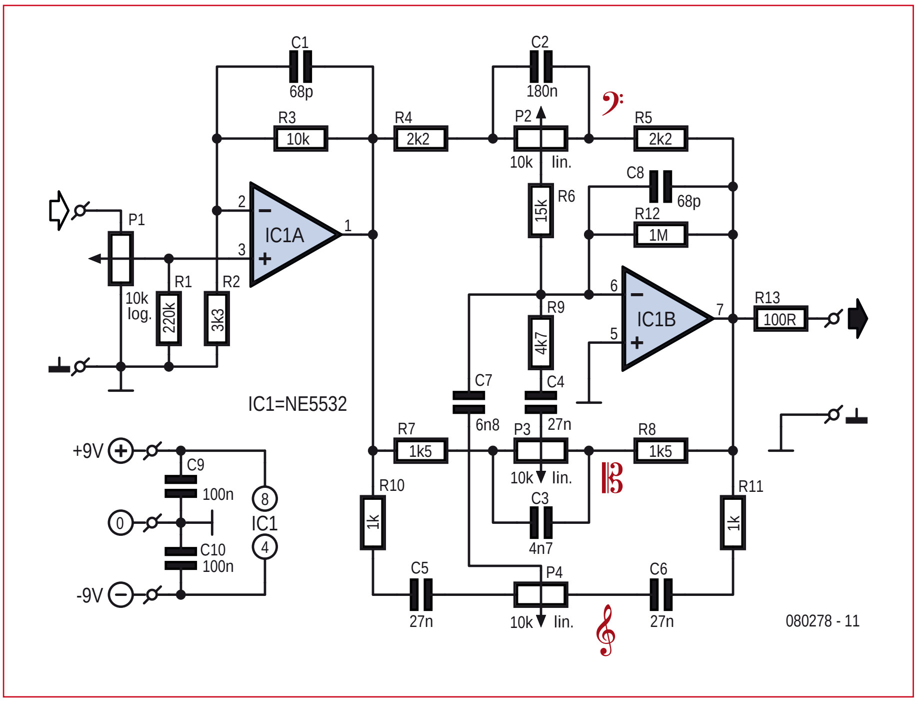


Figure 1. The preamplifier is quite straightforward for a volume control with triple-band tone control.

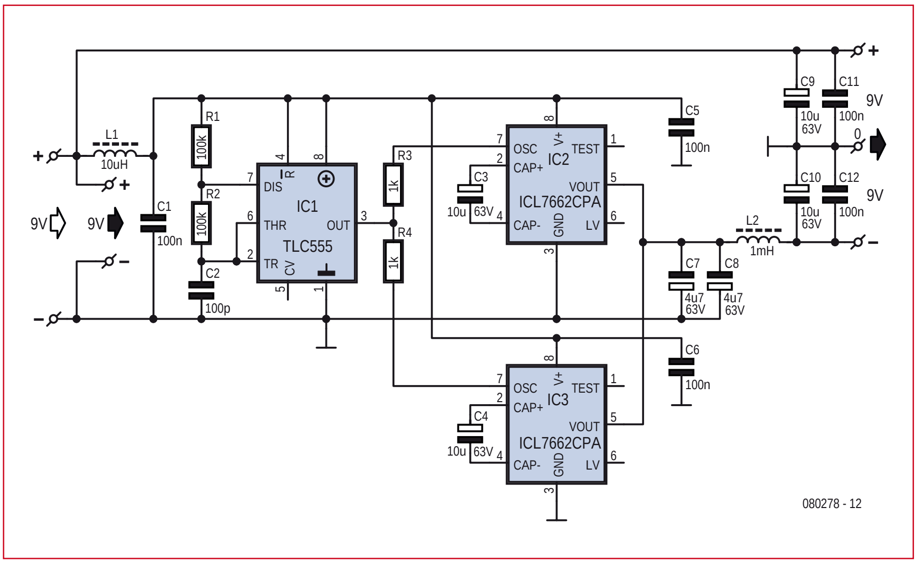
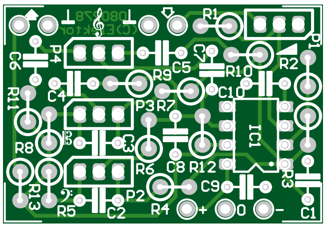


Figure 2. A voltage converter is used to convert a single power supply voltage into a symmetrical power supply.

COMPONENT LIST
Preamplifier board



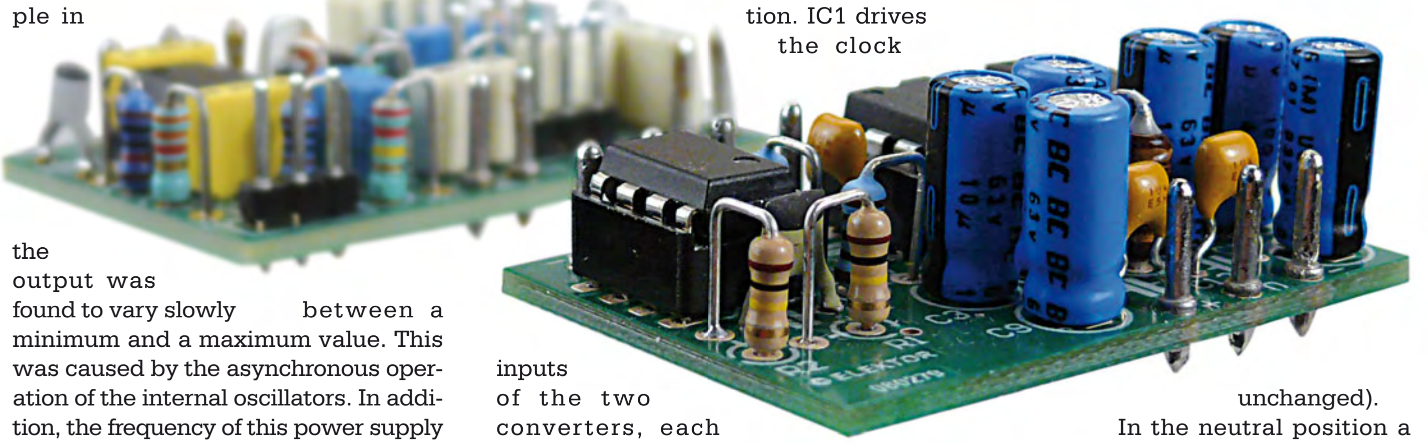
Resistors
R1 = 220kΩ
R2 = 3.3kΩ
R3 = 10kΩ
R4,R5 = 2.2kΩ
R6 = 15kΩ
R7,R8 = 1.5kΩ
R9 = 4.7kΩ
R10,R11 = 1kΩ
R12 = 1MΩ
R13 = 100Ω
P1 = 10kΩ potentiometer, logarithmic
P2,P3,P4 = 10kΩ potentiometer, linear

Capacitors
(lead pitch 5mm / 0.2”)
C1,C8 = 68pF ceramic
C2 = 180nF polyester / MKT
C3 = 4.7nF polyester / MKT
C4,C5,C6 = 27nF polyester / MKT
C7 = 6.8nF polyester / MKT
C9,C10 = 100nF polyester / MKT

Semiconductors
IC1 = NE5532 (DIP-8)

Miscellaneous
PCB, # 080278-1, from www.thepcbshop.com

–6.3 V. With your preamplifier as a load the output voltage drops only 0.35 V (the NE5532 draws about 7.5 mA). You could also use other opamps that have a lower current consumption, but their quality is often inferior; the NE5532 is an excellent audio opamp.
In our prototype we initially connected four ICs in parallel, but with three or four not much more is gained. There was however a strange effect: the ripple in the output was found to vary slowly between a minimum and a maximum value. This was caused by the asynchronous operation of the internal oscillators. In addition, the frequency of this power supply ripple was 10 kHz so it could become audible. That’s why the ICs are driven with an external clock furnished by a 555 IC. The frequency of the 555 is set to 40 kHz, so that the ripple at 20 kHz is just outside the audible range. An advantage is that the inductor in the output filter can be much smaller, which results in a much smaller resistance loss for this coil. The inductor we used for L2 has a rated series resistance of 12 Ω. L1 and L2 are standard axial noise suppression chokes, which are fitted upright here. The latter is also true for the four resistors in the circuit; this saves space.



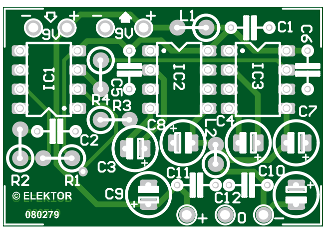
We won't dwell on the circuit around the 555. It is the standard astable configuration. IC1 drives the clock inputs of the two converters, each via a 1 kΩ resistor, to prevent potential problems at power-on (risk of latch-up). The ripple across the filter capacitors C7 and C8, which are connected in parallel for a lower series resistance, is almost completely removed by output filter L2/C10/C12. On an oscilloscope only a very small amount of the switching frequency of the power amplifier can be seen.

Test results

The most interesting test results for the tone controller are of course the individual frequency response curves for the tone adjustments. **Figure 3** shows the maximum, minimum and neutral positions (the positions of the bass and treble controls remain unchanged).
In the neutral position a slight attenuation of less than 1 dB at 20 kHz can be seen. This is mainly caused by RF suppression capacitors C1 and C8. At 20 Hz the variation in gain is ±14 dB (±12 dB at 40 Hz) and at 20 kHz it is about ±12 dB.

The distortion with an input signal

COMPONENT LIST
Power supply board



Resistors
R1,R2 = 100kΩ
R3,R4 = 1kΩ

Capacitors
C1,C5,C6,C11,C12 = 100nF ceramic, lead pitch 5mm (0.2”)
C2 = 100pF, lead pitch 5mm (0.2”)
C3,C4,C9,C10 = 10µF 63V radial electrolytic, lead pitch 2.5mm (0.1”)
C7,C8 = 4.7µF 63V radial electrolytic, lead pitch 5mm (0.2”)

Inductors
L1 = 10µH axial (vertical mounting)
L2 = 1mH axial (vertical mounting)

Semiconductors
IC1 = TLC555 (DIP-8)
IC2,IC3 = ICL7662CPA+ (DIP-8) (Maxim IC)

Miscellaneous

of 0.5 V is less than 0.005 % (1 kHz, 22 kHz bandwidth, volume control to maximum, tone controls to neutral). The current consumption of the entire circuit is 56 mA at 9 V, 12 mA up on the PWM amplifier by itself. With an 8 Ω loudspeaker and the amplifier overdriven slightly, the current consumption peaks at about 162 mA. This really is too much for a 9 V battery. With multiple channels we therefore recommend that you use an AC power adapter.

During the tests we didn't actually use potentiometers for the tone controls, but instead went for rotary switches and resistors. This is because the interest is mainly in the performance at the neutral positions and at the upper and lower limits. So, each potentiometer is reduced to two resistors and a rotary switch. The tolerance of pots is usually quite large; ±20 % is typical, and inevitably has an effect on the frequency ranges and maximum and minimum gains. With multiple channels the individual deviations can result in audible differences. If you have the opportunity to check whether the individual channels of stereo potentiometers are matched then it is certainly recommended that you do this. With more than two channels, the use of rotary switches with multiple poles may be considered, but this is an expensive solution.

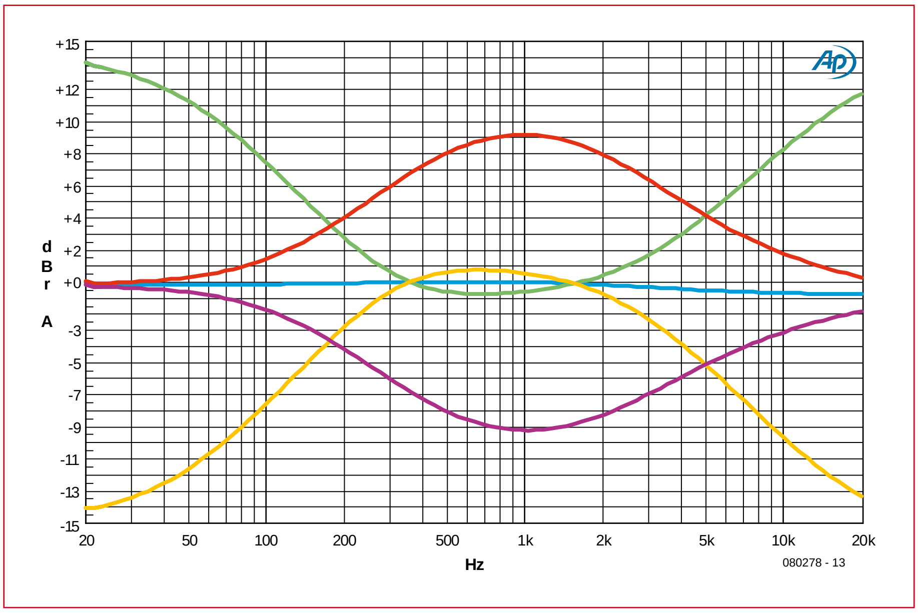


Figure 3. The curves show the effects of the different maximum settings of the tone control.

Construction of the three boards

The connections for the three boards have been placed in the same positions as much as possible. The output of the preamplifier is in the same corner as the input to the power amplifier. The power supply connections of the preamplifier are in the same place as the power supply outputs of the power supply board. The 9-V input of the power supply board is looped directly to the two connections for the power amplifier. The position of these corresponds to the power supply connections of the power amplifier. On the power amplifier, next to the power supply connections, there are also the connections for the power supply switch (S1). This is only for the power amplifier. It is better to insert a switch in series with the input to the power supply board. You can then short out the connections for S1.

Mounting holes were deliberately not included on all three of the boards so that everything is as compact as possible. For a reliable mounting option you could consider a couple of plastic supports with slots. The boards can then be mounted one above the other. The best order is the power supply board at the bottom, the tone control above that and the power amplifier at the top.

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Kit set

As indicated in the parts list, you can order the bare printed circuit boards for this project from www.thepcbshop.com. However, a complete kit set is also offered in the Elektor web shop, which comprises the printed circuit boards and all necessary parts, see www.elektor.com/080278.