Nostalgic tube sound from an IC

By Ton Giesberts (Elektor Labs)

Even now, the real audio 'connoisseurs' can't agree on one basic thing (which incidentally says enough about the 'connoisseurs'...): Which is 'better', an amplifier using vacuum tubes, or one using transistors? One will shout that the 'warm' nostalgic sound coming from tubes is 'the best', while the other points out the benefits of unnoticeable distortion coming from a well designed transistor amplifier. Happy to stay out of this discussion, we are still proud to present this experimental *digital* amplifier, which produces a sound which one could interpret as 'tube-like'.

A digital amplifier? The guys at the Elektor Labs must have had a drink too much, since **amplifiers** are clearly analogue circuits. Well, although this is usually the case, it isn't strictly necessary, since if an amplifier is treated as a '*black box*' which amplifies any given input signal, it doesn't really matter what kind of electronics are inside.

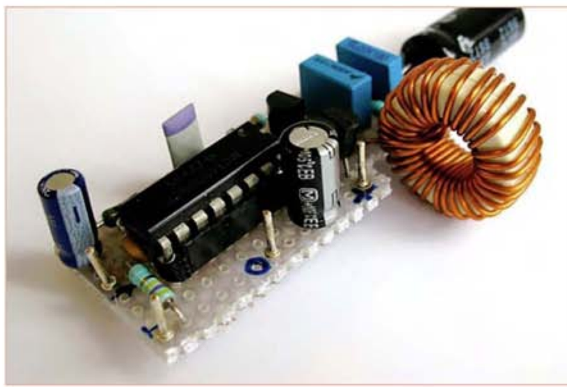
Strictly speaking, we've made an amplifier which no other self-respecting engineer would have made: our amplifier oscillates like a madman! This oscillation is caused by a self-oscillating pulsewidth modulator. Quite an impressive name for something as simple as an oscillator which merely produces square pulses with a width dependent on the input signal. The higher the voltage on the input, the wider the pulses will be on the output.

To summarise, our 'digital' amplifier works as follows: The low frequency input signal modulates an oscillator circuit in such a way that the *width* of the produced pulses vary in the rhythm of the input signal. This results in a pulse-density modulated (PDM) signal which controls a few transistors which can supply enough current. A low-pass filter on the output restores the information with a low frequency which is then fed to the loudspeaker. The big advantage of this approach is the low power consumption. Only the final transistors need to switch between a fully conducting and a fully insulating state, so only a little bit of power is lost.

The details

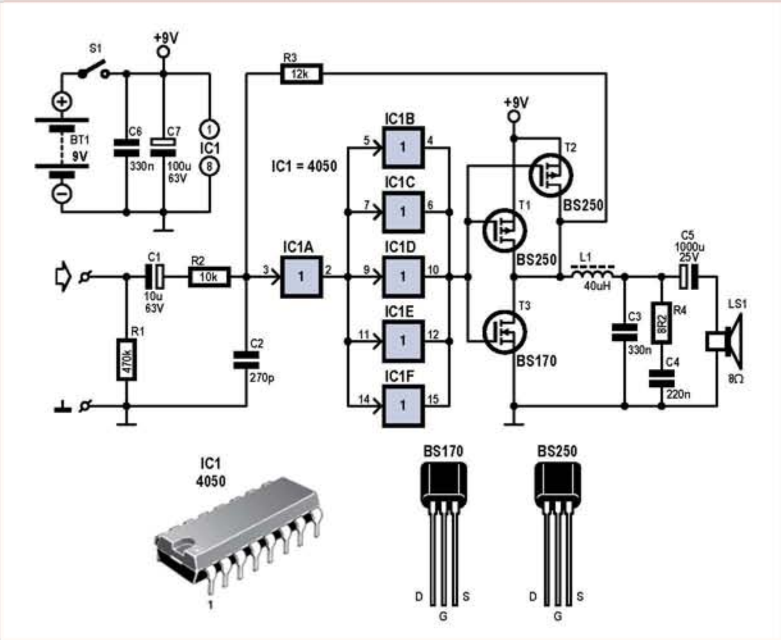
The final amplification of the signal is taken care of by three small MOSFET's (T1, T2, T3) which can supply 0.5 A each. Because the types shown in the diagram have a high on-state resistance, which is 5 Ω for the BS170 and 14 Ω for the BS250 when using a 10 V power supply, we need to use two BS250s in parallel to be able to supply the loudspeaker with a symmetrical signal. Because of the two transistors in parallel, the on-state resistance is effectively halved to 7 Ω.

The circuit is powered by an asymmetrical 9 V power supply; in our case a simple 9 V battery. This calls for decoupling capacitors (C1 and C5) at the input and output. To correctly drive the transistors, a few buffers from the '4000' CMOS logic series are used. Although these are extremely slow in comparison to the high-speed 74HC



series, the 4xxx series isn't as picky as regards supply voltage, happily working at supply voltages ranging from 3 to 18 V. And this application doesn't require the buffers to switch rapidly anyway. Of the six available buffers in IC1 (a 4050), two are placed in series to furnish adequate levels of amplification. The remaining four buffers are connected in parallel to the second buffer, which improves the way the transistors are driven.

Components L1, C3, C4 and R4 form a low-pass filter, which only allows frequencies humans can hear to reach the speaker. A standard choke can be used for L1, as long as it can handle *at least* 0.5 A. The amplification of the circuit as a whole is determined by the ratio of R2 and R3 and the impedance of the signal's source. If the impedance is way lower than the resistance of R2 (10 kΩ), the amplification will be around unity (1×).



Construction and specs

This circuit is quite straightforward to build. There aren't any components which need to be fitted at a critical location, nor any other serious design measures to be taken, as long as it's built compactly on a piece of prototyping board. It's also best to insert IC1 in a DIL socket. Keep in mind that pins 13 and 16 of the IC **should not** be connected. Also, a metal casing should be used to prevent the high switching frequency of this circuit (approx. 900 kHz at 9 V) from interfering with other appliances.

Running off a 9 V source, the amplifier can supply about 650 mW to an 8 Ω loudspeaker, which can cause a whole lot of noise! The distortion is about 5%. When the circuit supplies just 1 mW, the distortion decreases to about 0.15%. Capacitor C5 determines the bandwidth. With C5 at 1000 µF, the bandwidth is approximately 25 Hz to 22 kHz.

Admittedly this little amplifier is a far cry from its high-end or hi-fi brethren. On the other hand, it is very useful to get some experience with the principles of PDM. And, of course, it's great fun to watch what's happening at various points in the circuit with an oscilloscope.

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