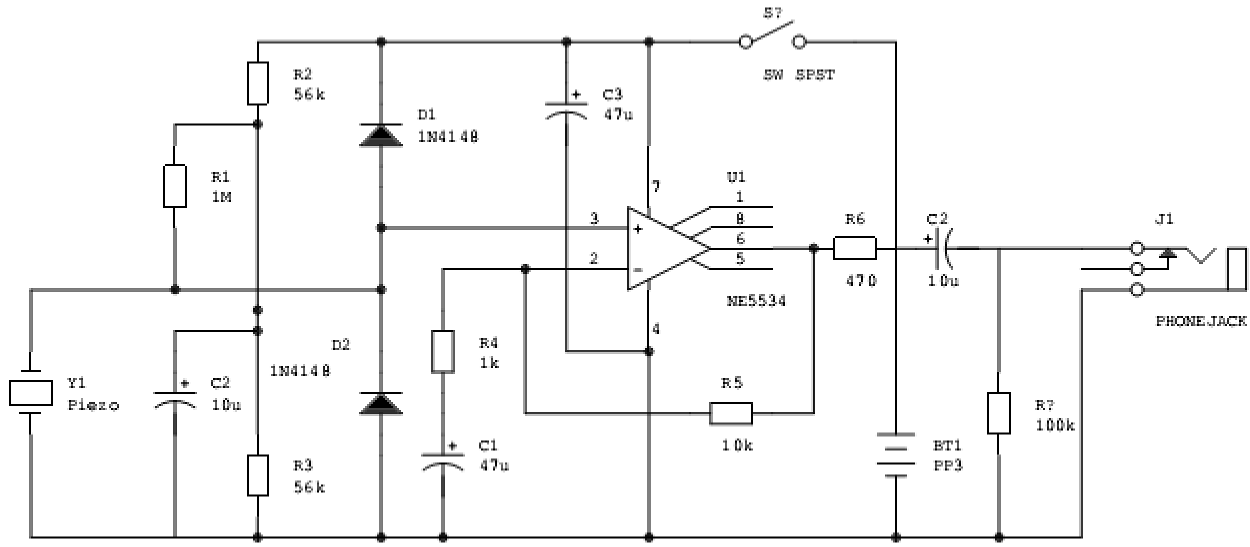
# Piezo contact mic amplifier (original article)

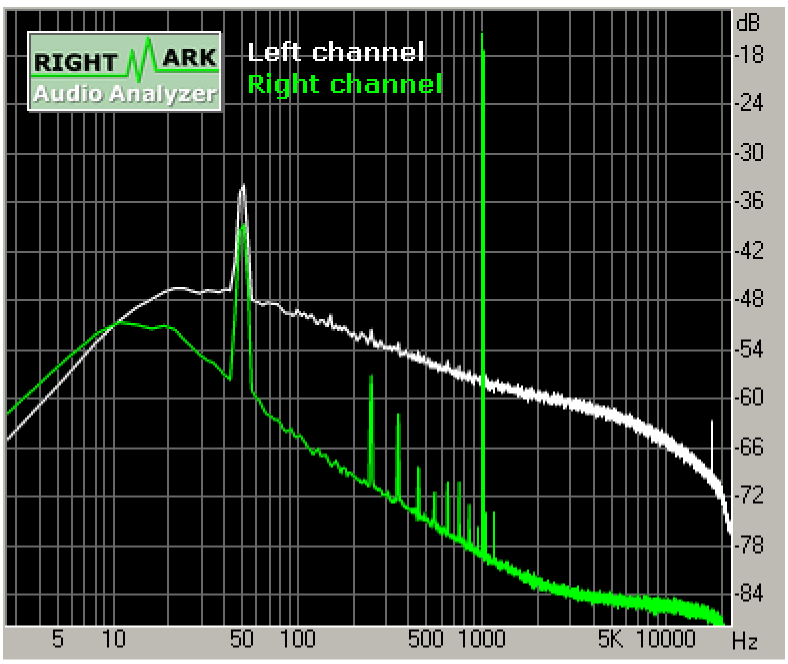
This is the purist approach solution to the tinny contact mic sound problem if you want the lowest electrical noise, or the lowest distortion at higher levels. Piezo mics aren't usually considered hi-fi, so distortion isn't usually a problem of the amplifier - at high levels the mic will not be particularly linear. However, they are remarkably low noise. Although they are high impedance, they don't need an outrageously high load impedance - not like an electret mic, where you need gigaohms to avoid losing bass. The calculation in the introduction showed a load of 330k was enough, so 1meg is plenty for a contact mic. The first thing that sprang to mind was a TL071 - the overall schematic is shown below.




Diodes D1,D2 stop you destroying the opamp with large signals from the piezo device if you drop it. You can leave C1 and R4 out if you need less gain, though there is much to be said for the cheap version (http://www.megalithia.com/sounds/tech/piezo/fetamp.html) if you have lots of signal.

The results were good. a 7mV rms 1kHz signal was fed into a 10k:12ohm attenuator, and then coupled via a 15nF capacitor to approximate the piezo source, generating 8uV. A satisfying drop in noise was obtained. However, substituting the TL071 for the usual audio workhorse opamp, the bipolar NE5534 brought the lowest noise of all.

Noise comparison of 2n3819 single fet with opamp version using a NE5534 (left and right channels respectively)
freshwater hydrophone recording using this with an air cell piezo disk hydrophone
At the start of the recording you can faintly hear woodpigeons calling above the surface propagating through the water, and aircraft noise, before the chomping sound.



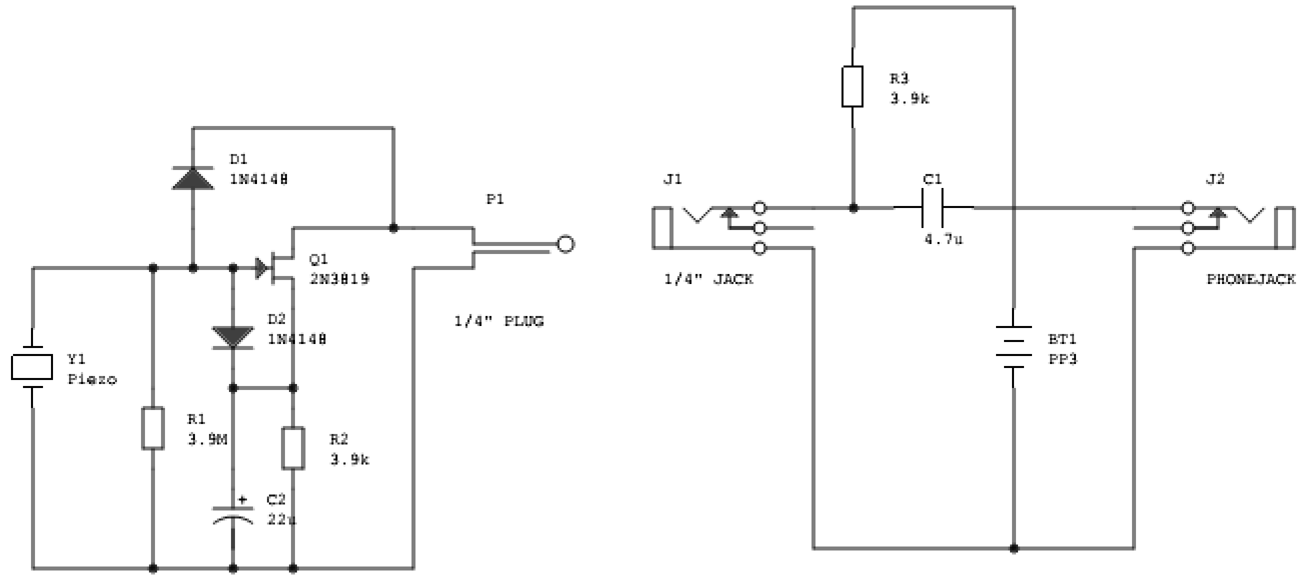
Matching levels of the 1kHz test tone to correct for the slight difference in gain shows the NE5534 offers a noise floor 10-20dB lower than the 2N3819, in return for extra complexity. At the back of my mind was the wonder whether a piezo mic would not have more self-noise anyway, so I removed the test tone and put in the mic. This is a reasonably quiet location. The hum is because this circuit is on a breadboard with the mic laid on the shelf, and some of the hum is mechanical, from the transformer of the power supply powering the unit, which is on the same shelf unit. About 3/4 of the way in some piece of machinery is started by my neighbours - I did not hear this at the time but it was conducted through the house into the shelf with the mic. You wouldn't normally have to put up with this level of hum - building the circuit into a metal box and using screened cable to the piezo device would fix that. However, the piezo mic has not raised the noise level significantly.

NE5534 at same gain as test circuit but with the contact mic replacing the 1k tone.

This goes to show that the piezo contact mic, for all its uneven frequency response faults, is capable of an excellent noise performance when used correctly. A more practical stereo version of this was constructed in a box, measurements and test results (http://www.megalithia.com/sounds/tech/piezo/opampm.html) are available.

# Piezo contact mic amplifier (cheap version)

This is the solution to the tinny contact mic sound problem - at least the electrical matching issue. A FET amplifier will sort out the mismatch, and give a useful amount of gain for a contact mic.




By using a separate box for the battery and load resistor the circuit is automatically powered when you plug in the piezo device. By keeping the FET close to the piezo disk you maximize signal levels and reduce the extent of the high impedance part of the circuit, which has a tendency to pick up hum. You also raise the signal level on the interconnectng cable run, which also helps to improve the system signal to noise ratio.

Diodes D1,D2 stop you destroying the FET with large signals from the piezo device if you drop it. You can leave C2 out if you need less gain in your application. Musical instruments and anything where you bash the sounding structure with an object fall into the leave C2 out territory

The FET can be the typical 2N3819 or a BF245A/B. You may be able to get away with RF FETs like the J309 but you may find that the input noise starts to rise at audio frequencies.

My original version of this (no diodes, C2 and slightly different source resistor) I glue the contact mic using epoxy resin to the back of the actuator magnet of an old hard disk. This is a nice strong magnet, and since many resonant structures are steel you get an instant easy good contact with the object.

The bad news, however, is that the manufacturers of FETs don't control their parameters well, and have somehow conned us into living with the problem. The gate-source voltage needed to bias the transistor into the linear region can vary between 0.25V and 8V, which leaves a good 7.75V down to a hopeless 0.4V for the transistor and load if used with a typical NiCad 8.4V PP3

You'll have to get more FETs than you need and throw out the dogs. It's easy enough to test, and this parameter is a given for a particular device - it doesn't age of change greatly with temperature.

Design manuals get all sniffy about that sort of thing because selecting FETs obviously adds to the cost if you are mass producing something. That's not the case here, and there's just no way to cope with a manufacturing tolerance which can throw more than 90% of the battery voltage away in variations in manufacture without screening the bad 'uns. Ideally you'd run the FET from a higher power supply voltgae, like two batteries in series and perhaps double the values of R2 and R3, but it would be a shame to have to use two batteres just because the manufacturers couldn't be bothered to grade by Vgs.

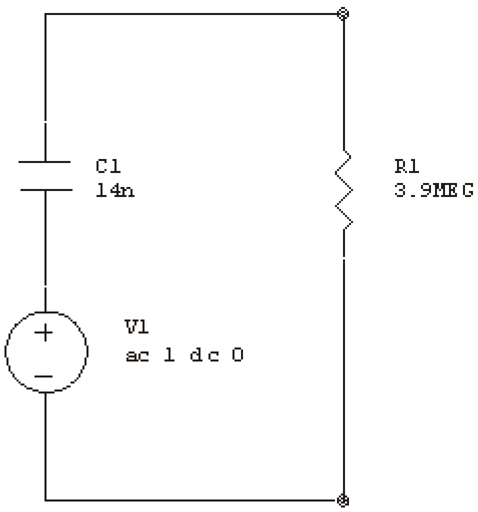
You can tell if you have a good 'un by measuring the voltage at the drain and source of the FET in circuit. Ideally you would like Vs to be about 2.5V and Vd to be about 6V (assuming a 8.4V Nicad PP3)
In practice you can live with Vs at 1 to 3.5V which will correspond to a Vd of 7.4 to 4.9. This will run the FET at 0.25mA to 0.9mA

I prototyped this and tested it out with all the spare FETs I had in my junkbox, on a supply voltage of 8.5V

| device | Vs | Vd | usable |
|---|---|---|---|
| 2N3819 #1 | 2.07 | 6.3 | **OK** |
| 2N3819 #2 | 2.03 | 6.2 | **OK** |
| 2N3819 #3 | 1.4 | 6.8 | **OK** |
| J309 #1 | 2.1 | 6.1 | **OK** |
| J309 #2 | 2.27 | 5.98 | **OK** |
| BF244B | 2.39 | 5.86 | **OK** |
| BF244 | 4 | 4.2 | **BAD** |

# Using piezo contact mics right

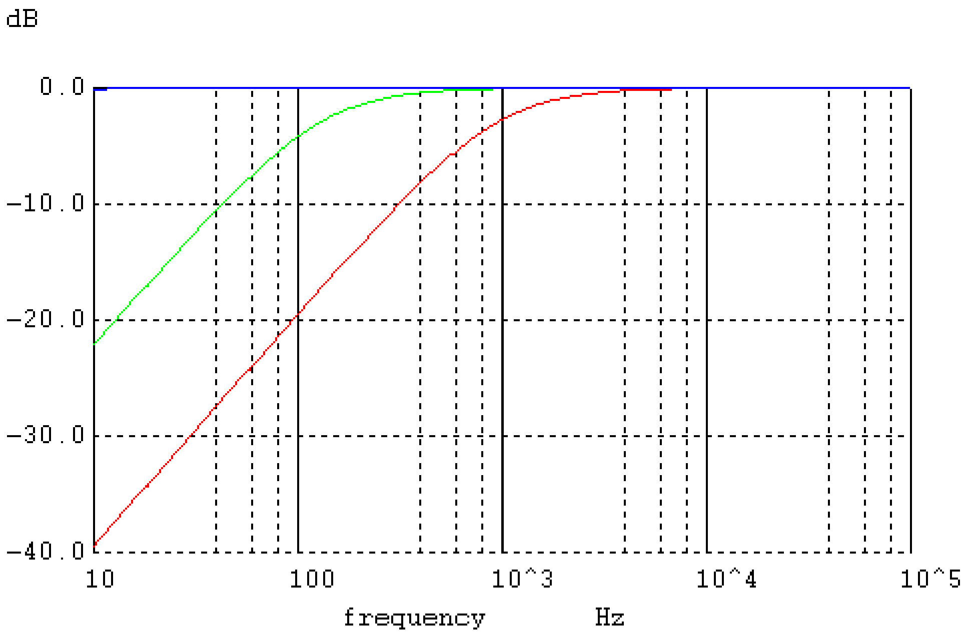
Cheap, innocent looking piezo elements do okay as greetings cards sounders. They seem to cause grief when used as contact mics. They seem to promise a lot but easily sound rough as commonly applied. Two solutions are proposed - the cheap and cheerful FET buffer which probably meets all the requirements of 80% of users who are using the devices on outside structures, and the high performance version for those who want higher performance and lower noise. First of all though, why do these things sound rotten the way they are most commonly used.
The sound to voltage conversion isn't noted for its high quality - most piezo contact mics are tuned speaker elements used in reverse.
The brass disc on which the element is glued is designed to resonate at the design frequency of 2-4kHz so that a large audio ouptut is achieved with a small power input. This will tend to lead to a peakiness at mid-frequencies, which is why I glue these to a magnet to try and spread this peak and make the coupling to the source better.
However, the main reason these have gotten a bad rap is that many people couple them into a standard audio load, which loses low frequencies.



A piezo element can be thought of as a sound-dependent voltage source in series with a large capacitance of about 15nF.

Here the trouble starts. You need to put this into a load which is higher than the impedance of the series capacitor at the lowest frequency of interest. If that is 20Hz, since the impedance of the capacitor is 1/2*pi*freq*C then you want that to be > 320k. I've terminated mine in 3.9M because that's what I had to hand.

So what to people do? They go and stick this into the line input of their recorder, typical impedance 50k, or the mic input of their minidisc, typical impedance about 7k, and they start to grouch that this damn thing sounds tinny. Which is does - from the frequency response you can see that the mic input starts losing low frequencies below 1kHz (red line) and the line starts to go below 200Hz (blue line).




We don't really like that very much. This tends to be compounded with the problem that these things aren't really designed as mics and resonate at 2-4kHz anyway unless you stick them down so you get a harsh ugly result. What you need is a high impedance input (http://www.megalithia.com/sounds/tech/piezo/fetamp.html), which gets you the blue line in the plot above.

You could try and equalise in post production. The trouble with that approach is you need the specs of the mic and amplifier input to know where to start your 6dB/octave LF boost, so you will probably have to tune that by ear if you don't know these. Plus you will boost all the noise and hum at low frequencies. With the mic input you are looking at puuting in a 25dB boost by the time you get to 50Hz which is just asking for hum problems, and even the 8dB boost on the line input version is more than doubling any hum you may have.

These things are very much like the crystal mics people used to use with valve open reel recorders. Valves do high impedance really well, and inputs were often in the area of 1 megohm input impedance.

The move to transistor circuitry meant consumer audio inputs tended to end up around 50k which is reasonably easy to do. Crystal mics also used the piezoelectric principle, and were valued for their low cost and high output voltage which overcame the preamplifier noise better. Transistorising audio gear killed off the crystal mic as they sounded tinny and harsh with the lower input impedances for the same reason.

<u>**Piezo contact mic amplifier**</u>

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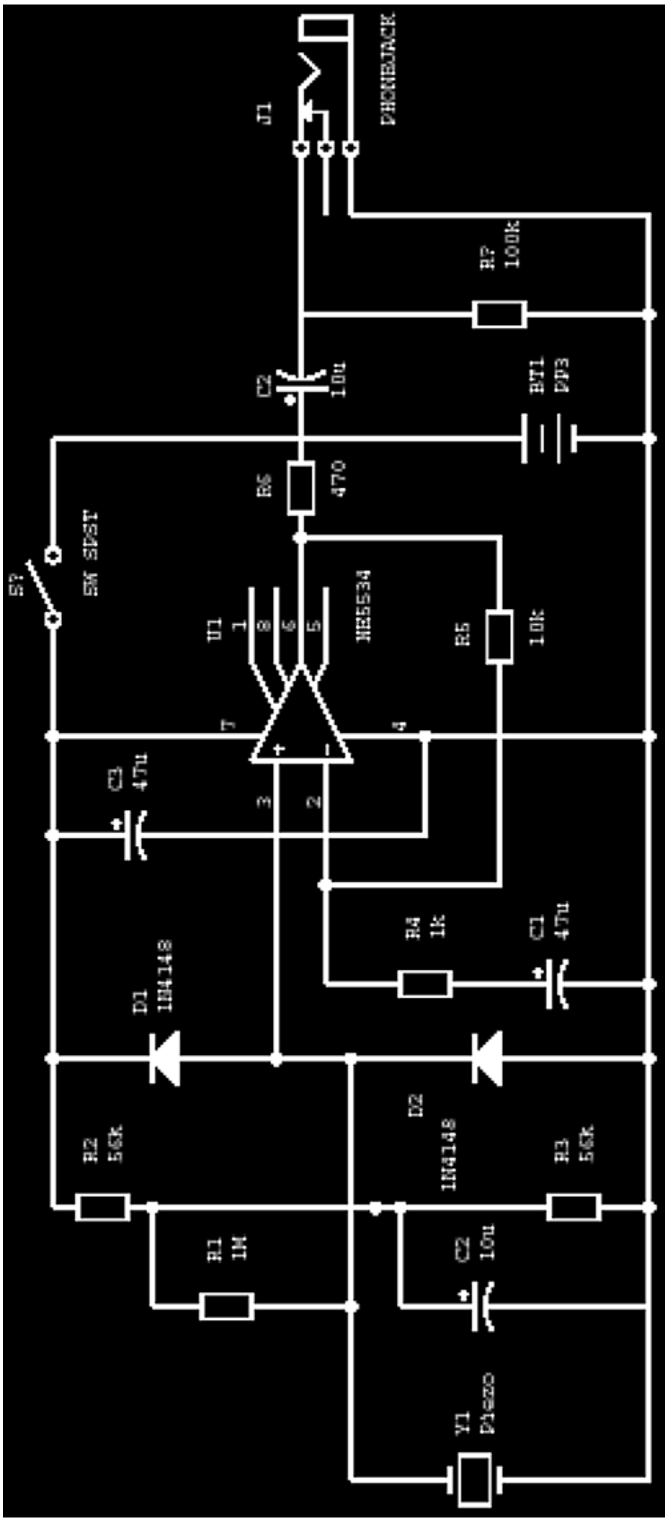


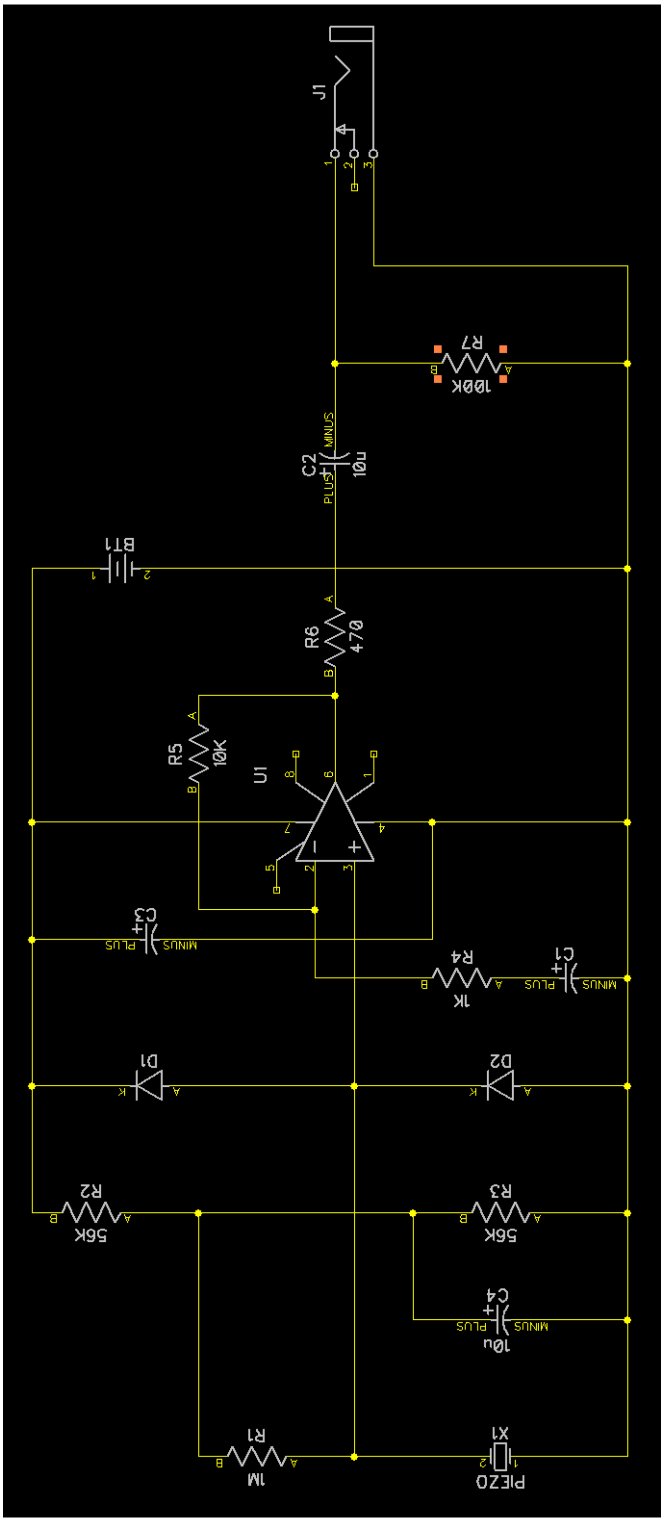


Result: Works great and the sound of the piezo has extrem power. I've changed the R1 resistor to a pot, so I can play with the impedance. This helps if I connect more than one piezos parallel, to find a good setup. Works good with a battery.