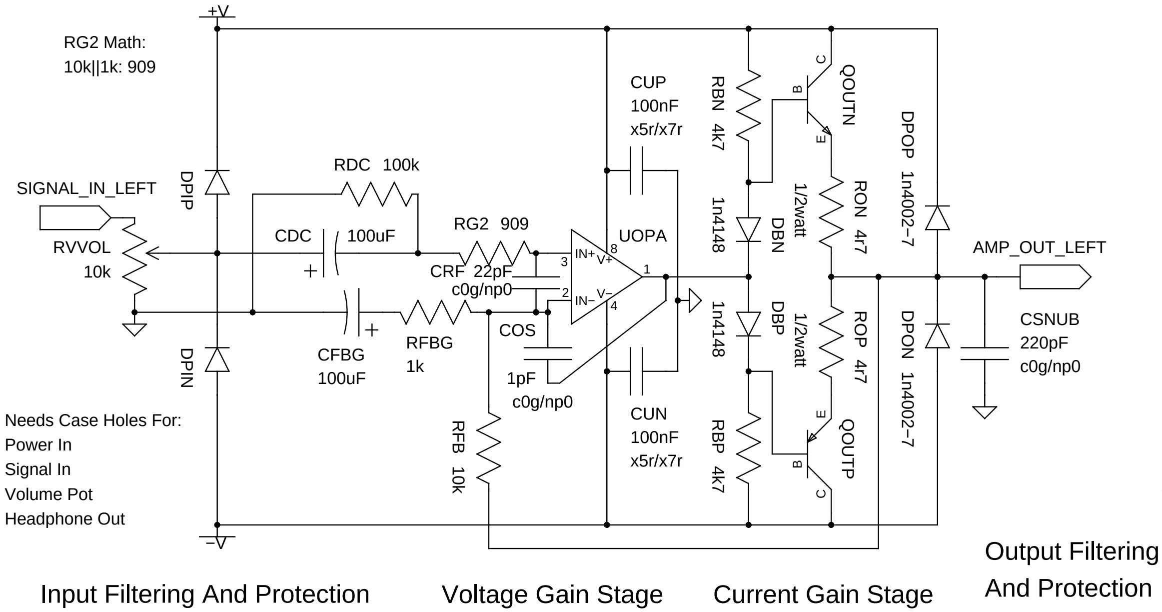
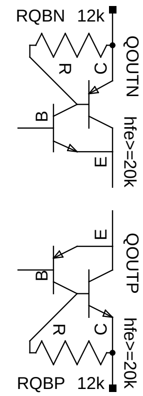
Boosted CMOY Headphone Amplifier

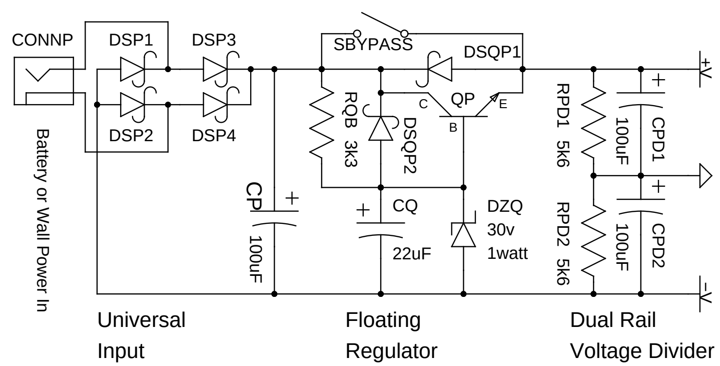
2014−04−10

(Very stripped down, lower power, and small portable version.
Duplicate boosted op−amp circuit for the desired number of channels.)



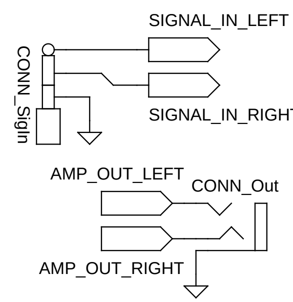


Optional Sziklai Output Transistors.
Replace the regular single output transistors with these for improved sound handling.



Note: Use 1/4 watt resistors, 35v rated capacitors, and 40+v transistors and diodes.
* Do not exceed 30v power input or the op−amp will be damaged.
* This is designed to use two 9−12v batteries in series for 14−28v.
* Use Schottky diodes for the bridge and battery loss will be minimal when plugging in through the external power connecter.
* Use the stripped down floating regulator if powered from wall.
* SBYPASS on floating regulator should be closed when on battery.
* Each ground triangle should go back to power ground as a star.

Connectors In and Out



Preferred Parts

Resistors should be metal film.

RVVOL should be a small dual type for stereo.

Electrolytic capacitors should be low impedance or high ripple rated.

Op−Amps: (DIP8 in a socket)
OPA2134 (very stable)
OPA1642 (stable, needs SMT adapter)
LM4562 (needs COS)
LME49720 (needs COS)
LT1364 (needs COS)

Transistors: (Toshiba, Preferred)
2sc2705o+2sa1145o (50mA, 200MHz, high Z only)
2sc4793+2sa1837 (1A, 100/70MHz, preferred)
2sc5171+2sa1930 (2A, 200MHz, alternate)

Transistors: (Generic, Not Always Ideal)
bc546b+bc556b (50mA, 300/150MHz, tolerable)
ksc1815y+ksa1015y (150mA, 80MHz, good)
ksc815y+ksa539y (200mA, 200MHz, ok)
2n3904t+2n3906t (200mA, 300/250MHz, ok)
2n6517ta+2n6520ta (500mA, 200MHz, ok)
2n4401t+2n4403t (600mA, 250/200MHz, good)
ksc1008y+ksa708y (700mA, 50MHz, good)
bc337−25+bc327−25 (800mA, 100MHz, good)
pn2222a+pn2907a (800mA, 300/200MHz, ok)
bc639+bc640 (1A, 100MHz, good)
bd139−10+bd140−10 (1.5A, ok)

Boosted CMOY Headphone Amplifier

This is a current boosted version of the CMOY type headphone amplifier. It is a stripped down version designed to be mounted in a small enclosure like a mint tin. This design should generally be used with other portable sources. Since portable sources often have poor sonic qualities, the stripped down design probably won't matter much. This design is also a good start for beginners in electronics and is relatively cheap.

Op-amps by themselves (like used in the original CMOY design) have very poor output and are not designed to drive high capacitance or high inductive lines. Small speakers in headphones are moving inductors (complicating things a bit). While some op-amps may “tolerate” this, they do not perform well.

By adding a current boosting stage to the op-amp output, the op-amp gets isolated from high capacitance and high inductance and becomes a signal driving device again (which is what it was designed to be in the first place). This gives a significant performance boost.

As an observation, op-amps tend to sound “least stressed” when operating in a near voltage only mode (hardly any current coming out of the op-amp output stage). This is typically defined as less than 0.1mA. To produce this, the output transistors need a high beta, to be in a darlington configuration, or a sziklai configuration (shown on schematic). Once the op-amp is in near voltage only mode, most tend to start sounding similar to each other.

With that being said, the output transistors start dominating the color of the sound. While any generic transistor could be used, high quality ones tend to sound the best. Generic transistors will still dominate over most “commercial consumer” headphone amps, though. Most transistors have NPN and PNP matched pairs (check the data sheet). Use these for balanced sound. In a sziklai or darlington configuration, the driver transistor (small one on the left side as shown in the schematic) is usually a faster MHz rating with a lower current than the right one. The right one is the main power output transistor and should be 500mA or higher.

The original CMOY amp design uses input DC blocking capacitors smaller than 1uF. While mathematically this may work for a stand alone schematic, when capacitors are put in series (often the case when the source has output DC blocking capacitors), the value will be reduced according to paralleled math. This then changes the RC value and will often destroy low frequency bass response (freq = 1/(2*PI*R*C)). The -3db corner frequency should be set for less than 1Hz in most cases to avoid unnecessary roll off and capacitor phasing issues with the signal. A 100-220uF capacitor will meet the need nicely in most cases (100uF shown).

Note that the DC blocking capacitors (CDC, CFBG) should not be omitted when using portable devices. They often have very poor DC characteristics and this amplifier is capable of “cooking” headphones if there is a DC offset.

The COS capacitor is used to stabilize high speed op-amps. 1pF will usually be enough. It can go as high as 4.7pF if needed. The idea is to keep the capacitor size as small as possible to keep it outside the audio band. The COS capacitor should be directly at the “OUT” to “-IN” pins with hardly any extra space at all between them (needed to handle the HF responses).

The power supply starts with a full diode bridge using low voltage drop Schottky diodes. This will allow a connector of any polarity and AC or DC input. Rectified power should not exceed 28 volts. There is little need to go over 28 volts as this will just waste energy and over heat the parts. Optimum power ranges are 10-20 volts, 15v preferred. Lower voltage may be used if the headphones are low impedance and don't need the extra voltage overhead (check this carefully for distortion in the output signal peaks). If batteries are plugged in the power connector, the Schottky diodes will have minimal voltage loss while providing reverse voltage protection. While the entire regulator section can be removed for battery only power, at least one protection diode is recommended to avoid blowing the circuit.

The “Floating Regulator” will allow noisy wall power to be used and filtered to something acceptable. This regulator is a capacitance multiplier type filter and will preform very well, even if stripped down for size. QP should have a high hfe (beta) for optimal performance (the filter math depends on it). QP should also be rated around 500mA and 50 volts (or higher). Beyond that, QP's selection isn't overly critical. DZQ will act as a surge suppressor if the input power rail gets too high. Do not use it as a fixed voltage regulator. SBYPASS can be used to go around the floating regulator to avoid the voltage drop if powering off batteries. SBYPASS will usually be a 2 pin jumper. The floating regulator section can be totally removed if only powering from batteries.

The “Dual Rail Voltage Divider” section will split the input power to provide the necessary power rails for the op-amps and transistor output current boosters. Under some strange conditions, the floating ground can cause DC offset issues at the output. This is solved by the CFBG capacitor in the feedback loop. With both CDC and CFBG, there should be no significant DC offset at the amplifier output.

The virtual ground created by the voltage divider should not be connected to the case. With some connectors, there's a risk shorting it to the negative terminal or real ground. This would cause a massive power drain and likely damage or destroy something.

The DP* diodes protect against signal levels that go above or below the power rails and will keep the circuit from damage. DPIP and DPIN can be 1n4148's if the signal source isn't high current.

The CRF capacitor prevents the signal leads from acting like an antenna and turning the circuit into an unwanted AM radio. CRF could go directly on the input connector, but that may interfere too much with portable devices that use the headphone cable as an FM antenna. CRF should go directly at the “-IN” and “+IN” op-amp pins. CRF should not exceed 47pF.

CSNUB is used to sink high frequency junk that the output cable may pick up. Under certain circumstances this junk could cause amplifier instability. Some may note that snubbers usually have a resistor in series (1-10ohms). One can be added if desired, but it often doesn't do very much in these configurations. Valid values are 47-470pF. Anything higher will start sinking too much in the audio high frequencies.

If building a multichannel amplifier (stereo or surround sound), match the resistors and capacitors as closely as possible between each channel for optimum sound balance. NPN and PNP transistor betas should also be matched (many volt meters include an hfe function).

Some may note that the headphone amplifier topology is one of a generic amplifier. This is quite true. Variations of this amplifier can handle things that a stand alone op-amp cannot. Unchanged, this amp can be an unbalanced line driver suitable for long cable runs (usually 1/4” mono connectors). Add an inverted input amplifier in parallel and a balanced line is created (usually XLR connectors). As a trick for long cable runs, run the signal voltages hot (over 4v) and use a pot or L-pad at the destination to drop the voltages back down. This can noticeably reduce picked up noise. Use 1-2amp output transistors and a small speaker set (such as a stand alone set for portable media players or computers) can be powered (anything larger will require an increased power supply and current gain stage design). Variations can be used as mic and speaker amps for the long runs in an intercom system.

By now, more experienced builders will note that there are many upgrades that could be done to this amplifier. That is quite true and I've done them in my HA-XS-T2 design. Keep in mind that this design is supposed to be simple, easy for beginners, tiny for portability, and cheap. It will still outperform most of the junk that is on the commercial market.

Potential upgrades:

- Parallel the electrolytic capacitors in the signal chain with polypropylene ones.
- Parallel CUP and CUN with electrolytic reservoir capacitors and add a 1-10 ohm resistor for a simple RC filter.
- Add 100uF or larger reservoir capacitors to the transistor buffers for better current

loops and bass response. Parallel these with 100nF to 1uF ceramics for better high frequency response.

- Add a Jung multi-loop feedback.
- Add a 10 ohm resistor to the op-amp outputs to help isolate it from any residual stray capacitance.
- Add polypropylene capacitors between the transistor bases to speed up response.
- Change the output transistors to sziklai's for significantly higher beta and sound improvement.
- Add a small resistor before CP to form an RC filter.
- Add a second RC filter to the floating regulator's transistor base for a second order filter.
- Change out the floating regulator's transistor with a sziklai for much better performance. A darlington could be used, but with a larger voltage drop.
- Beef up the voltage divider with larger reservoir capacitors and parallel them with 100nF ceramics.
- Modify the voltage divider to have active ground tracking to remove some of the ground bounce.
- Better wiring for signal, power, and ground loops.
- ...and so on...