Part Lists and Suggestions

While reading through these parts lists, you may find it handy to have a copy of the schematic to refer to. (PDF, 4 KB)

Required Parts

These are the parts required to build just the amplifier circuit. Enclosures, optional components, and enhancement components are in the next section.

I've been happiest with the parts from Digi-Key and Newark. Mouser sells cheap parts, in both senses of the word, so you do have to be careful when buying from them. Radio Shack's part quality varies all over the map, but the worst thing is that their overhead inflates their prices dramatically relative to the distributors. If you do get some of your parts from Radio Shack, beware that the part numbers I give below are the highest quality ones they offer of each type; I recommend you don't pick cheaper parts, as the cheaper ones *always* perform worse.

For those not in the US, I've added RS Components, who will ship almost anywhere in the world. All the parts numbers are simply a result of me searching through their online catalog. Many times I was able to find the same parts I recommend from the other distributors, but occasionally I had to just guess at a replacement, hoping that it is suitable.

Of the US distributors, Digi-Key is probably the best for people outside the US to use. Other distributors those outside the US might investigate are Farnell and Conrad. Farnell is actually part of the same company as Newark, but their part numbers aren't unified, and they don't carry all the same parts.

You'll probably end up getting the op-amps from Digi-Key or RS Components. If you didn't want to order from these distributors but wanted to put together a complete amp with parts from just one source, you'll probably have to choose an op-amp other than the ones I recommend below. I don't recommend that a beginner use anything but the OPA13x series op-amps, because they're simply the most forgiving op-amps that also sound good.

The best path will require ordering from multiple sources. Unless you want to build an amp in a day including the time to get the parts, there's little reason to get Radio Shack parts; the big mail-order houses have everything Radio Shack has and more, for cheaper, with better quality. I highly suggest you mail order everything you can, if you can stand waiting a week for the parts to arrive. The one exception is the protoboard: most of the mail-order houses only carry the expensive stuff designed to handle repeated soldering and desoldering. Since you'll be building the amp once and probably then leaving it alone, you might as well use the cheap protoboard from Radio Shack or RS Components.

Some components are marked “Alt.” These are alternatives for the immediately preceding component.

For superior resistors that are easily distinguished from the generics, see the Precision Resistors section, below.

Description	Qty	ID	RadioShack	Digi-Key	Newark	Mouser	RS C
220 µF/35 V electrolytic capacitor, radial leads	2	C1	272-1029	P5552	18C4706	647-UVR1V221MPA	315-07
Alt. 220 µF/25 V electrolytic cap	2	C1	–	P5541	18C4672	75-517D25V220-E3	365-41
Alt. 220 µF/16 V electrolytic cap	2	C1	–	P5530	18C4617	–	365-40
0.1 µF polypropylene film cap (large!)*	2	C2	–	P3104	89F3466	75-715P200V0.1	240-53
Alt. 0.1 µF metallized polyester cap (smallish)	2	C2	272-1069	E1104	–	75-MKT1813410014	–
Alt. 0.1 µF metallized polyester cap (really small)	2	C2	–	3013PH	46F3685	505-MKS2.1/63/10	179-98
10 kΩ 1/4 W metal film resistor	1	RLED	–	10.0KXBK	84N1687	271-10K-RC	148-73
4.7 kΩ 1/4 W metal film resistor	2	R1	–	4.75KXBK	50N2120	271-4.7K-RC	148-66
100 kΩ 1/4 W metal film resistor	2	R2	–	100KXBK	84N1685	271-100K-RC	148-97
1 kΩ 1/4 W metal film resistor, gain 11	2	R3	–	1.00KXBK	84N1712	271-1K-RC	148-50
Alt. gain resistor, 2.0 kΩ, gain 6	2	R3	–	2.00KXBK	84N1736	271-2K-RC	148-57
Alt. gain resistor, ~2.5 kΩ, gain 5	2	R3	–	2.49KXBK	92B9453	271-2.55K-RC	148-59
Alt. gain resistor, 3.3 kΩ, gain 4	2	R3	–	3.32KXBK	84N1757	271-3.3K-RC	148-62

Alt. gain resistor, ~4.7 kΩ, gain 3	2	R3	–	4.75KXBK	50N2120	271-4.7K-RC	148-6
Alt. gain resistor, 10 kΩ, gain 2	2	R3	–	10.0KXBK	84N1687	271-10K-RC	148-7
10 kΩ 1/4 W metal film resistor	2	R4	–	10.0KXBK	84N1687	271-10K-RC	148-7
Alt. 1/4 W metal film resistor assortment	1	R1-R5	271-0309	–	–	–	–
Dual op-amp OPA2132PA	1	OPA	–	OPA2132PA	–	595-OPA2132PA	218-8
Alt. dual op-amp OPA2132P	1	OPA	–	OPA2132P	35C1844	595-OPA2132PA	–
Alt. dual op-amp: OPA2134PA	1	OPA	–	OPA2134PA	–	595-OPA2134PA	285-8
Power indicator LED, red diffused, 3mm	1	D1	276-026	160-1708	90F5862	859-LTL-1CHE	588-3
Alt. power LED, amber/yellow	1	D1	–	160-1709	96F2333	859-LTL-1CHY	588-3
Alt. power LED, green	1	D1	–	160-1710	87F393	859-LTL-1CHG	589-0
Stereo mini jack (3.5mm)	2	IN/OUT	274-0246	CP1-3513	96F9608	502-35RAPC4BH3	476-3
Alt. input jacks (RCA; black, white and red)	2	IN	274-0346 – –	CP-1412 CP-1414 CP-1413	84N1165 – –	161-2003 161-1004 161-2002	476-5 – 476-5
Alt. output jack (1/4" stereo)	1	OUT	274-0312	SC1125	84N1155	16PJ509	449-3
Protoboard (recommended type)	1	BOARD	276-0150	–	–	–	–
Alt. protoboard (simple "stripboard"**)	1	BOARD	–	–	–	–	206-5

* These caps are much bigger than the ones in the photos on subsequent pages, and so aren't great choices for amps in mint tins and other compact enclosures. In exchange for the bulk, you get better sound. The farther down the list of alternatives you go, the worse the sound gets, with the last ones still being okay, but recommended only when space is at a premium. The barrel-shaped axial lead caps in the pictures are the Vishay MKT1813s on the second row, from Mouser.

** If you must use stripboard (such as because you can't get the recommended perfboard style), you will need to have some way to break the copper strips at strategic points. RS Components sells a stripboard cutter (543-535) for this purpose. Alternately, you could simply use an X-acto knife, which will not produce breaks as definitive as the stripboard cutter, but should suffice.

Optional Parts

Here are some parts that you may need, or that are "preference" things: I can't call them required, since some may disagree.

Description	Qty	RadioShack	Digi-Key	Newark	Mouser	RS Components
DIP-8 IC sockets, gold contacts	1	–	ED90032	04M0550	575-11043308	813-115
Power switch (mini SPDT* toggle)	1	275-0625	360-1788	61F1245	–	330-840
Alt. power switch (mini SPST toggle)	1	–	–	13F3970	–	–
Alt. power switch (micro** SPST toggle)	1	275-0624	–	–	10TA805	–
5.5/2.5mm DC power jack (standard)	PWR	274-1576	–	–	163-4024	–
Alt. DC power jack (closed circuit)	PWR	–	–	–	163-4305-E	–
Volume knob (plastic, single bar indicator)	1	274-0403	8568K	57F2374	450-2070-GRX	259-6941
Alt. volume knob (aluminum; black and silver)	1	– 274-424	226-1041 226-2041	92N4099 92N4096	450-7031 45KN031	196-5829 196-5813
Alt. volume knob (aluminum, black and silver)	1	–	226-1033 226-2033	92N4093 92N4095	450-7015 450-6015	498-845 498-918
R5, 47 Ω 1/4 W metal film resistor	2	–	47.5XBK	84N1767	271-47-RC	148-174
Alt. R5, 100 Ω 1/4 W metal film resistor	2	–	100XBK	84N1686	271-100-RC	148-269
9 V battery clip (not needed for Serpac H-65)	1	270-0324***	2238K	16N942	534-2240	–

Enclosure, Serpac H-65-9V (black and bone)	1	– –	SRH65-9VB SRH65-9VA	– –	635-H-659V-B 635-H-659V-A	–
Volume control, Panasonic EVJ-C20 10 kΩ	1	–	P2U4103	–	–	–
Alt. volume control, Alps 10 kΩ (RK097)****	1	–	–	–	–	249-9159
Alt. volume control, Radio Shack 100 kΩ*****	1	271-1732	–	–	–	–

* Although you only need an SPST for power, SPDTs are more common, probably because it's just as easy to make them as SPSTs and you can use them like an SPST by just leaving the second pole disconnected. Since they're more widely useful than SPSTs, some manufacturers only make SPDT toggles. (Or at least, distributors don't often carry the SPST variants if the manufacturer does make them.)

** These "micro" switches are the smallest type of toggles you can easily find. Micro toggles tend to be rather delicate, especially the bushing area. I've broken two of the Radio Shack micro toggles when tightening the mounting nut. I haven't broken one of the Mouser micro toggles yet, but I don't know if it's because I'm wary now or that they are better built. If you can afford the space, I recommend that you use standard mini toggles instead. They're much tougher, and they often look better, too.

*** This part number is for Radio Shack's heavy-duty battery clips. Radio Shack also sells a cheaper set of clips (RS 270-0323) which suck, badly. Avoid, avoid, avoid.

**** I sell a similar pot to this one in my parts shop, with one difference: mine has a built-in SPST switch. This switch is intended for power: when you turn the volume all the way down, the switch opens, turning off the amp. This saves a bit of money and keeps your panels neater. Of the pots in the table above, only the Radio Shack 10 kΩ unit also has a built-in switch. For all others, you need a separate power switch for the amp.

***** Beware, this pot's body is too big to fit into a mint tin. (Actually, it can be done, but you have to notch the lid to get it to close around the mounting nut.)

Precision Resistors

All resistors spec'd above are generic 1% metal film resistors. Generic resistors work fine, but many people swear by premium resistors because of their higher inherent accuracy and higher thermal stability. (The latter means that as the resistor heats up due to the power it's dissipating, it changes value less than generic resistors. All resistors change value as they change temperture; premium resistors simply change value to a lesser degree.)

The most popular brand for this is Vishay-Dale's CMF (a.k.a. RN) series. Specifically, the RN55x-F (1%) type. (For full details on how to interpret these CMF values, see the CMF data sheet.) Vishay-Dale CMF resistors are more expensive than generics, but in the quantities needed for this amp, the additional cost is negligible.

The Vishay CMF line also has 0.1% resistors, but you do not need that level of precision for

this amp. If you do anything to get more accuracy, it should be to use a good multimeter to hand-match your resistors to higher tolerances. That may provide some audible improvement to some ears, but realize that this is *relative* matching. The point of buying 0.1% resistors is that their *absolute* values are within 0.1% of nominal. There are very few places in audio where absolute value accuracy is important.

If you can't get Vishays but still want to try premium resistors, RS Components offers the RC series from Welwyn. I've never heard a report about whether these are an improvement over generics, but the specs suggest they're on par with Vishay-Dale's CMF series. They're physically a bit bigger since RS only offers the 1/4 W resistors, but the price is similar to 1/8 W 1% Vishays.

Herewith, part numbers for Vishay-Dale RN55C/D resistors in all the values given above:

Description	Newark 1%	Newark 0.1%	Mouser 1%	Mouser 0.1%
47 Ω	03F7910	50B2558	71-RN55D-F-47.5	71-RN55C-B-47
100 Ω	83F1209	83F1208	71-RN55D-F-100	–
1 kΩ	83F1211	83F1210	71-RN55D-F-1.0K	71-RN55C-B-1K
2 kΩ	83F1230	83F1229	71-RN55D-F-2.0K	71-RN55C-B-2K
2.5 kΩ	–	–	71-RN55D-F-2.55K	–
3.3 kΩ	83F1256	–	71-RN55D-F-3.32K	–
4.7 kΩ	83F1272	–	71-RN55D-F-4.75K	–
10 kΩ	03F9465	83F1213	71-RN55D-F-10K	71-RN55C-B-10K
100 kΩ	83F1502	83F1214	71-RN55D-F-100K	71-RN55C-B-100K

Are 1/8 W Resistors Sufficient?

I spec 1/4 W resistors for the generics above simply because they're the most readily available sort, not because the CMoy amp really dissipates 1/4 W anywhere in the circuit. The resistors in a CMoy amp that see the highest load are the power supply splitter resistors. With the highest supply voltage you're likely to use — 30 V — these resistors only dissipate about 50 mW. Therefore, even 1/8 W resistors are adequate for all aspects of the CMoy design.

The Radio Shack Metal Film Resistor Assortment

Radio Shack's part number 271-0309 is a package containing 50 1/4 W assorted metal film resistors, including all values necessary to complete this project. One package is sufficient for two CMoy amps, with the exception of the 10 kΩ resistor: it only has five of these, and you need three for each amp.

Since this assortment is the only way to get metal film resistors at Radio Shack, you will have to get a bit creative to avoid buying two packs of resistors if you want to make two amps. One way is to also get a 5-pack of 10 kΩ carbon film resistors (RS 271-1335) and use these for RLED. (The power LED's current-limiter.) Metal film resistors are nicer than carbon ones, but for the LED resistor, their virtues don't matter. Another way you can go is to use a different value for this resistor than the CMoy schematic calls for. See the section on tweaking the LED resistor for details.

Circuit Board Alternatives

This tutorial is centered on the Radio Shack 276-0150 patterned perfboard. The Radio Shack brand is US-only, but those in other parts of the world do still have options here.

In Canada, there's a store called The Source by Circuit City that is basically the Canadian version of Radio Shack, even using the same part numbers as Radio Shack. The page for the board is here currently, though beware that URLs of this sort often break. Search for 276-0150 via the previous link if it's broken when you read this.

In the UK, Radio Shack used to operate under their Tandy brand until several years ago. Since then, a new company called T2 has emerged to sell much of what Tandy used to, including the patterned perfboard we use in this tutorial. They will ship to many other countries in the world.

In Australia, Dick Smith Electronics used to carry this same board as part number 21-113, but it no longer appears on their web site. Your local store may still have one in stock. The New Zealand site does list the part, however. I don't know if this means that the NZ stores always still carry it, or if it's some web site management problem.

In Japan and probably other areas of Southeast Asia, you can find part number ICB-86 by the Sunhayato company, which again is all but identical to the Radio Shack board we use here. There is an alternate version of the board, part number ICB-86G, which uses a higher-quality epoxy-fiberglass board, rather than the cheaper phenolic paper substrate.

If none of those options work for you, the best alternative I can give you is the D-4 prototyping board, designed by DH Labs and sold by the people who publish audioXpress Magazine. It's a fiberglass board, not phenolic paper as with the Radio Shack board, so it's more durable. It has 3-pad pairs down the edge, instead of 2-pad pairs like the Radio Shack board, so you can replace the M-jumpers with a simple jumper connecting the outer pads on the R4 and R5 rows. The dimensions are different, too. It should fit the width of a standard mint tin, but just barely.

Failing all that, you might look at part number 1172142 from Farnell. This is a much bigger board than the Radio Shack board, so it'll have to be cut down. The pattern is even more different from the recommended one than the DH Labs board, but close enough that

adapting my layout to fit it should be straightforward. It looks like you just need to substitute a few bus strip cuts for the M jumpers I use on the RS board.

If you must use a much different type of protoboard, I recommend against trying to use the same parts layout I came up with for the Radio Shack board. Instead, create a new layout tuned to that pattern. If your board has a very generic pattern, such as stripboard or pad-per-hole board, I'd probably just go with a point-to-point layout: all the connections are made direct from one part lead to another on the bottom side of the board, instead of going through copper foils on the board itself.

You can read more about different types of prototyping boards here.

Choosing an Op-Amp

The op-amp (operational amplifier) is the chip that does the actual amplification in the CMoy circuit. It has the single biggest effect on sound and power draw of any component, so it behooves you to pick this part carefully. It's also the part most likely to fail if your implementation is imperfect; a tolerant op-amp will reduce the chances of failure.

If you're a raw newbie, I recommend that you try one of the Burr-Brown OPA132/134 series op-amps first because they have low voltage requirements, they don't oscillate easily (see below), the lowest grade is adequate for this project and is quite reasonably priced, and they're very popular so a lot of your fellow DIYers are familiar with them and so can help you more easily. I won't say they're easy to find; you'll probably have to mail-order one. Take my word: these are very good chips for the price. Any replacement you try and source locally will likely not perform as well.

> *"Oscillation" is a condition where the chip develops periodic or constant noise due to problems in the surrounding circuit. If you keep at this hobby, you will eventually develop the necessary knowledge and experience to avoid oscillation in your circuits. Until then, stick with tolerant op-amps.*

The specific chip I recommend for beginners is the OPA2132PA. Under ideal conditions, the cheaper OPA2134PA performs just as well, but your first DIY headphone amp probably won't be flawless. I've had circuits where the OPA2134PA would distort or oscillate, but popping in a 2132PA or 2132P would fix the problem. As a beginner, you don't need problems like this. You'll have enough difficulties just assembling and testing the thing without the op-amp acting up as well! If you later want to build another amp, go ahead and try the 2134PA. If you run into problems, you can pull the 2132 out of your first amp temporarily and try that in the new amp to see if it fixes the problem.

As for the OPA2132P, it's about twice the price of the 2132PA, and I can't hear a difference relative to the 2132PA. This isn't surprising, since the only specs that are different between the two chips are the DC specs, and there is no DC in audio.

If you think you might want to try different op-amps in your headphone amp, it's all but mandatory that you use DIP sockets in your design so you don't have to desolder the chip to try a new one. Sockets are useful even if you never change the chip since they prevent damage to the sensitive op-amp chip during soldering. However, you should only use high-quality machined sockets. If you can only find cheap sockets, you're better off just soldering the op-amp to the board, because a cheap socket will result in weak connections, which is a serious risk factor for bad sound.

I review many other op-amps in the companion article, *Notes on Audio Op-Amps*.

Choosing an Enclosure

There are two main kinds of enclosures used for pocket amps: plastic enclosures designed to house electronics, and various types of boxes designed for other uses and converted to hold an amp. The latter includes the popular mint tins, plus other found objects.

For general portable use, I like the Serpac H series cases. The H-65 (1.0 × 2.75 × 4.95 in.) has plenty of space inside for a CMoy circuit, and its rounded corners and slim body give it a sleek look. The overall impression is of a pocket cigarillo case; it slips into a pocket very nicely. The H-65-9V variant has a nice 9 V battery compartment: it holds onto the battery snugly, and the contacts are fixed into place instead of using a 9 V battery strap. There is a taller version called the H-67. While the 9 V version of the H-67 only holds one battery, the "AC" version has a battery door without a battery compartment behind it; you can stuff two 9 V batteries in there. You'll have to add some padding and such to keep the batteries from rattling around inside the case if you go this route.

If you're thinking of going with a much larger case but still want to be able to run from batteries, I recommend adding a Bulgin dual-9 V battery drawer to one of the larger cases (Mouser part #122-BX0026).

Notes on Audio Jacks

All of the recommended jacks above will work, but there are differences among them. Here are some things I've noticed that aren't obvious from the information in the table above or the distributor's web site:

- The Mouser 161-* RCA jacks include insulators. The other RCA jacks mentioned don't. (This is useful if you're using a metal case that has some other voltage tied to it, such as with an external DC power supply, which will usually tie V- to the case.)
- The recommended Radio Shack 1/8" jack may be the same as the Switchcraft 1/8" jack from Newark. I say "may" because some stores carry a similar-looking jack that isn't as good as the Switchcraft. The Switchcraft jack has solid lugs, while the

cheaper Radio Shack one has small holes in the end of the lugs.

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