DIY CD Player

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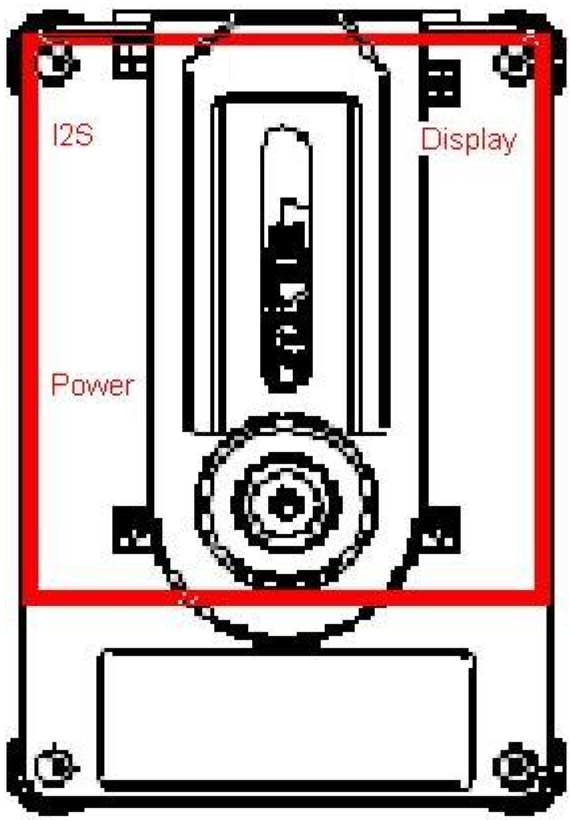
The transport I worked with is the CD-Pro2M. Another commonly available transport, which has a good pedigree as well, is the CDM12.1 by Philips. The CDM12.1 can be purchased with its own bitstream converter, power supply, display and control circuit through Steinmusic in Germany for 189 Euros (~$200). Thus the transport is basically ready to go for you without the fuss. Of course, there are plenty of places to tweak. While this guide focuses on building based on the CD-Pro2M, many of the same ideas in the transport section can be applied to the CDM12.1 transport.

Part 1: The CD-Pro2M Transport

The heart of any CD player is not exactly a mechanism that can be designed by hand, unless we're being paid a yearly salary to do so. Most modern CD players use some iteration of a Philips or VRDS transport, each with different laser designs, clock units, and onboard DAC. Some players have begun using DVD-capable transports, though these aren't always used for their DVD audio capabilities.

The most readily available and thoroughly documented transports are the Philips CD-Pro2M and CDM12.1. The Pro2M is the professional upgrade for the 12.1 (and the original CD-Pro2), though its specific sonic benefits (shortcomings?) haven't been concretely determined. For my own transport, I used the CD-Pro2M because ready-built display and control sections have been designed previously. The most extensive site focusing on the CD-Pro2M, and selling its components, is Nico Thevissen's Homeoptics. His site guides the user through design considerations and has transports and display boards ready to sell. Much of the credit for my effort on the transport section has to go to Nico himself.



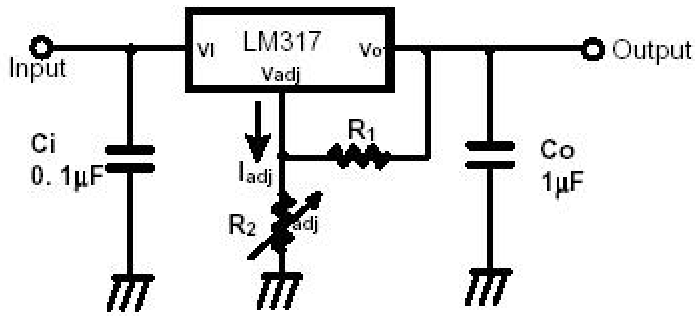
The circuit board underneath is represented by the red rectangle in the above picture. The CD-Pro2M transport requires the following: a +5V regulated power supply, a +9V regulated motor/actuator power supply, transformers, and display/control boards (plus its associated power supplies). These will be discussed in the next sections.

1.1: The +9V Power Supply

This supply is not required to be the most robust in the world. Generally, the +9V transport can stray from this target voltage by +/-10% (8.1V to 9.9V), and may in fact work slightly better at some voltage other than exactly +9V. During startup, when the CD initially starts spinning, there is a 750mA peak. During playback, current draw is approximately 200mA. Thus, the voltage regulator and associated transformer should be able to supply at least 1A to avoid overheating and possible vibration on startup.

The design and expense of the power supply depend on just how clean the builder wants the power supply to be. The +9V supply is not as important as the +5V, so a simple linear LM317-based design would probably be adequate here. The LM317T (note the T here, which is the TO-220 package) is rated for up to 1.5A of current, though heatsinking is required to higher currents. I'll explain the design of a higher quality power supply later in the +5V section.

The LM317T is a variable output voltage control with the following as its standard configuration (from its datasheet):



$$V_O = 1.25V\,(1 + R_2/R_1) + I_{adj} R_2$$

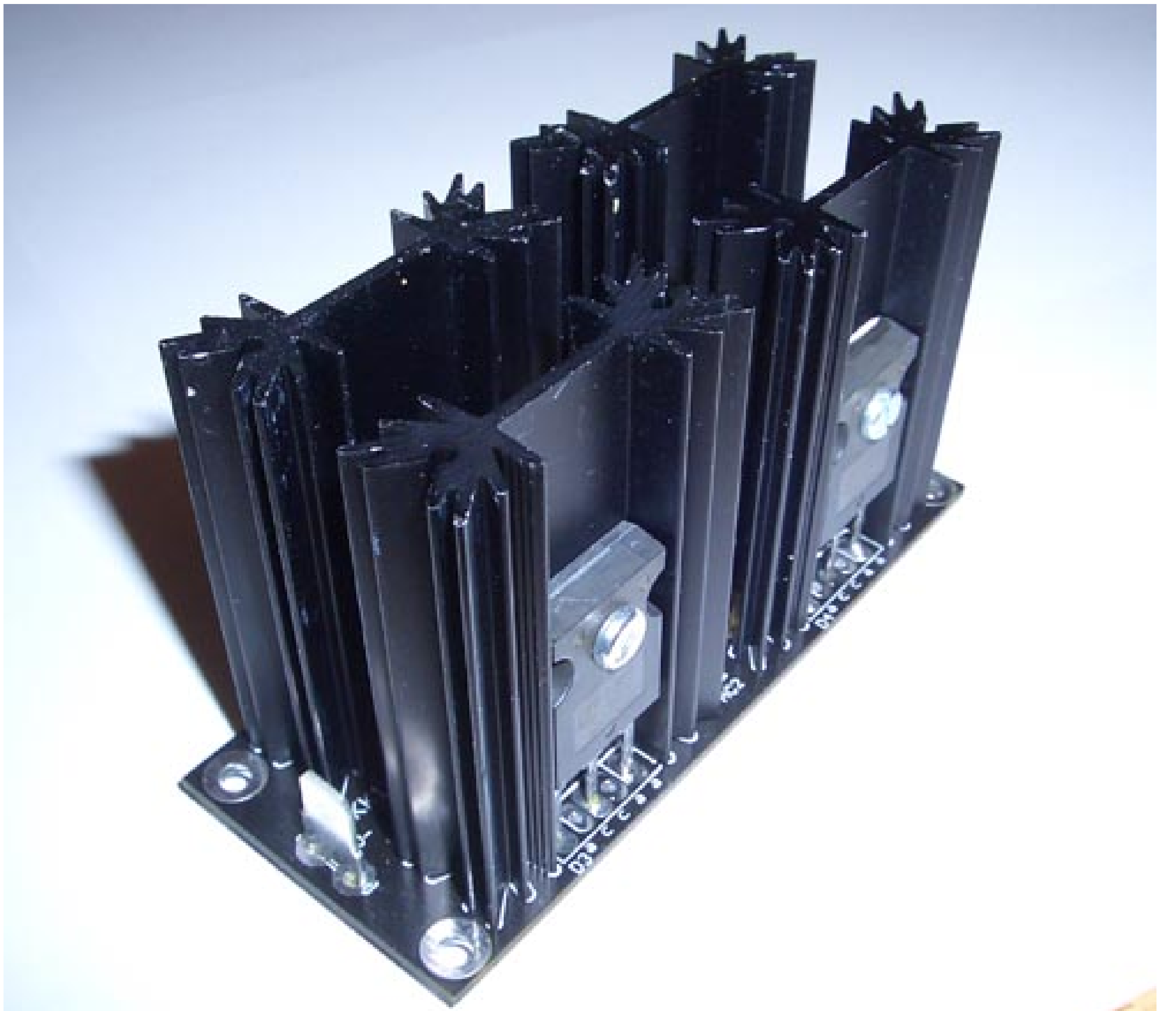
The potentiometer, R2, controls the output voltage. A 5kohm pot here would probably work, with R1 at ~220ohms. Co improves the 317's transient response (ie. the time at which the current would be increasing from 200mA to 750mA) -- experimenting with more capacitance at the output, in the range of 1uF to 1000uF, can further improve transient response. Before the regulator, I chose to use approximately 10000uF of filtering (two 4700uF electrolytic caps, specifically) to flatten the DC output from the bridge rectifier.

The transformer: The motor supply doesn't power any audio-related machinery, thus the transformer here is of the builder's preference. I use the same dual bobbin transformer for the +9V supply as the +5V supply, but some might prefer a separate one.

1.2: The +5V Power Supply

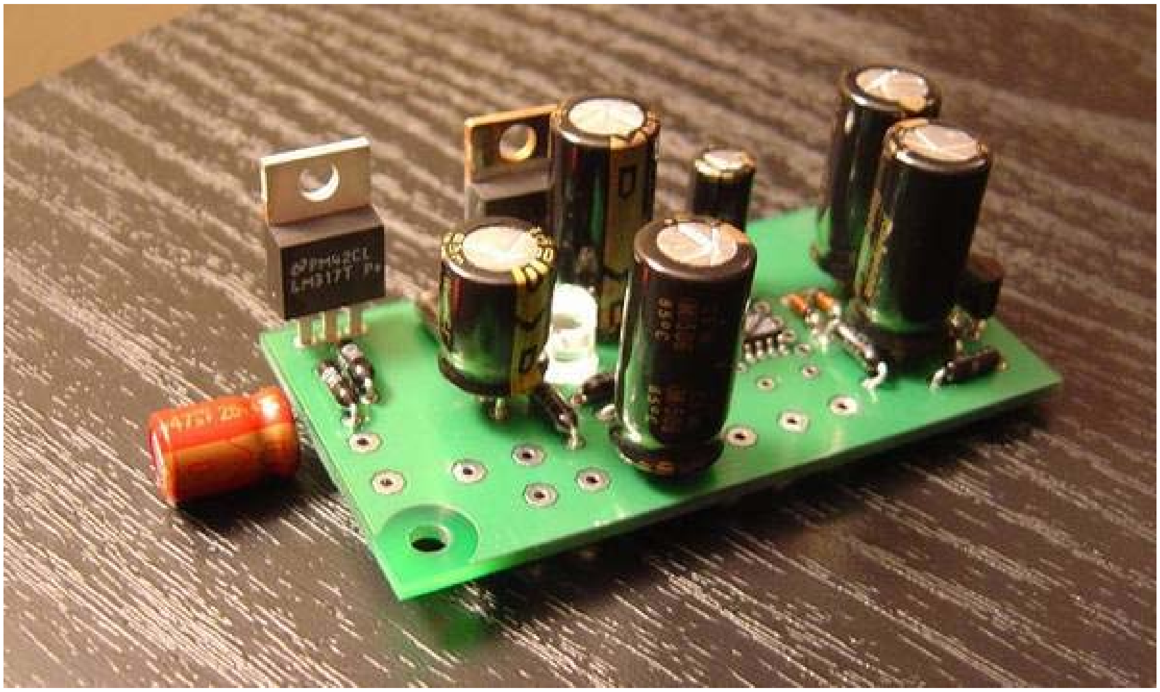
This power supply has a very important purpose: powering the onboard servo decoder, clock, and digital to analog converter. Thus the power supply for this section must be quite clean, and preferably designed with low ESR parts to keep noise from finding its way into the supply.

The bridge rectifier: A rectifier has a simple purpose -- to take an AC signal and convert it to a DC signal. A standard diode bridge rectifier here probably would be sufficient, but a high speed diode bridge would be better. This is likely overkill, but recall that the diode bridge does eventually supply a multiple MHz clock on the CD-Pro2M itself. Ultrafast diodes can be purchased from most online retailers in TO-220 or TO-247 packages. The rectifier shown below has heat sinks, but for the current requirements in this project they aren't required.



The regulator: The choice here is a Jung super regulator circuit, available from Head-Fi's own [b]aos[/b], or DIYAudio's [b]ALW[/b] or [b]peranders[/b], among others. The ones I purchased were from ALW.

For the main discussion about the design of the Jung regulator and its incarnations, I defer to ALW's extensive webpage. The basic idea behind the regulator is to use an error amplifier circuit, which features a standard Analog Devices opamp, to greatly reduce the ripple on the output of a LM317-based pre-regulator. The super regulator is both much more advanced and certainly more expensive than any standard LM317-based power supply. The +5V supply is worth the cost. The overall drop across the super regulator, including an LM317 pre-regulator circuit, is a minimum of 5V. ALW's pre-regulator drops a constant 2.5V, thus the regulator portion will drop at least 2.5V as well.



Most of the components on the regulator board are standard issue items -- the variables are the type of resistors and capacitors used. For resistors, the bare minimum is standard metal film, with Vishay-Dales as the next step up. It's important to buy the correct size resistors for the board you purchase -- ALW's boards require small RC55 resistors rather than the more common RC60 package. Thus it is also important to consider the power rating of the resistors -- from what I could find, expensive IRC resistors are rated at 1/4W in the RC55 size. They aren't cheap -- about a buck a pop. ALW recommends Beyschlag resistors. These may be the same as the 0.4W BC Components resistors available from Newark.

Capacitors are always a touchy subject when it comes to most DIY designers. Some swear by Rubycon Black Gates, some say Panasonics are more than acceptable, etc. For this application, perhaps the best choice may be Sanyo OSCON capacitors, which are reputed to be very low noise. This is highly desirable for digital applications. An interesting test can be found at DIYParadise, which shows the OSCONs to be lower noise than any other cap tested. They're somewhat hard to find, but Parts Connexion has a limited stock of values. These can be placed in parallel or series to get desired values outside what's available. DIYParadise offers a limited selection for sale as well. ALW recommends Rubycon ZA capacitors, which are a cheaper alternative to Rubycon's Black Gates while still giving good performance.

The transformer: The preference when powering digital electronics is to use split or dual bobbin transformers, thus a simple Hammond transformer available at Mouser would do the trick. For the super regulator, we will have an output of 5V at ~200mA constant current. Since the super regulator drops a minimum of 5V during standard operation, the minimum voltage rating on the transformer should be 8V at a minimum of .5A, thus giving a voltage output after rectification of about 11.3V depending on the transformer and load. More headroom than this is probably desirable, so at least 10V at 1A (thus a 10VA power rating) would be preferable. Remember though, the more voltage you give the reg, the more voltage it has to dissipate. Heat sink accordingly.

It is preferable to have separate transformers for the +9V and +5V supplies, but this is dependent on the space available. If building a transport on its own, separate transformers for the +9V, +5V, and display boards are preferred.

1.3: The Display and Control Board

For this section I recommend exploring Nico's webpage for the design and power requirements of his CD-Pro2M display and control board. I have chosen for my particular player to ignore the display power supplies and simply use the control circuit. Thus, my CD player will function more like a turntable -- you don't know the particular track or time.

Why did I choose to do this? Two reasons: simplicity, and noise. The display unit requires two additional voltages, and I simply felt it would be easier to leave this part out. I seldom find myself looking at the track or time anyways. As for the latter reason, the display itself, when operational, adds some undesirable noise to the system. If the builder would like to propagate these supplies, it is recommended that the display be either shielded or housed in a separate case along with the transformers. I will discuss this later on.

The control unit, without the display, requires only a +5V supply. Generally, it is preferable to use a separate +5V supply than the one used for the servo. In my particular case, I've decided to use the same one (again, for simplicity's sake).

1.4: Putting It All Together

The CD-Pro2M has some unique characteristics that require the different supplies to activate in a specific order. The +5V for the servo and display should come up first, followed by the +9V supply. The easiest solution for this requirement is to use more capacitor filtration on the +9V supply than the +5V. The idea here is that the capacitors on the +9V supply will take slightly longer to charge than those on the +5V supply, thus allowing the +5V to come in sooner.

Why does the +9V supply need to come in later? Giving +9V without the +5V there already can cause the lens to pop up in the CD-Pro2, the predecessor to the CD-Pro2M. In my own experience, bringing the +9V and +5V simultaneously causes the lens to oscillate up and down slightly, enough so that the lens moves above the plane of the transport's upper surface. Thus if anything is close to it, there is the possibility that the lens will get scratched.

Another question is how to orient and place the transformers. We'd have a minimum of one dual bobbin transformer and a max of four that we would have to deal with -- a lone transformer if we use the same one for the +9V, +5V, and +5V supplies, and four if we have entirely separate transformers for those three, plus the display.

If we have only one or two transformers, they can be placed in the same case as the transport. To minimize the power of the fields around a pair of dual bobbins, the two should be oriented perpendicular to one another. Using a split or dual bobbin reduces the need for an electrostatic shield, which is why they're preferred in applications where noise performance is important. At the same time, the output from the power supplies should be as close to the power input of the transport as possible.

To maximize the noise performance of the transport, I'd generally recommend organizing it into a two box system:

bottom box: all transformers, display/control board and associated +5V (control)
top box: transport itself and associated power supplies (eg. +5V and +9V regs)

The boxes would be connected by two cables -- one that transfers the AC power from the bottom box to the top for the regulators, and one that would communicate between the display board and the transport itself. If looking for a one-box transport solutions, organize all the transformers so they are as far away from the transport and any audio outputs as possible.

Part 2: The Digital-to-Analog Converter

Now that we have the transport ready, it would be nice and simple to just use the onboard DAC of the CD-Pro2M and be done with it. To be fair, the onboard DAC isn't too bad, and can be used if funds are an issue. But this is DIY, and if we can make something better without spending an excessive amount, we may as well give it a shot.

The DAC that I chose is a non-oversampling design based on the Philips TDA1541A chip. Similar Philips chips have been used in non-oversampling configuration in the

Scott Nixon DAC Kit (TDA1543), ack! Dack (TDA1545), etc. So why did I choose a non-oversampling DAC?

2.1: Oversampling vs. Non-Oversampling

There's plenty of debate as to the merits of oversampling vs. non-oversampling DACs. The question isn't whether one is inherently better than the other. It's simply a matter of preference and implementation.

So what the heck is oversampling? First we should understand a little something about the audio frequency range. Humans can basically hear sound between 20Hz and 20kHz, a range of ~20kHz. To sample a musical signal so that it will reproduce these frequencies, we need a sampling frequency at least twice the range of the music we can hear. Thus, we want a sampling rate of at least 2*20k = 40k. This is called the Nyquist frequency, which should be familiar to any signal processing geeks out there. I'm not going to get too much farther into theory, but suffice to say that the standard sampling frequency for CDs is 44.1kHz.

So why oversample? Basically, oversampling a signal reduces the amount of noise that is inadvertently added into the signal as it's processed. So, 8x oversampling converts the sampling frequency from 44.1kHz to 352.8kHz, and proportionally decreases the amount of noise found in the output signal. This is *not* the same as upsampling, which increases the number of bits in the signal. For instance, many DACs upsample from 16 bits to 24 bits. This is useful because it reduces the probability of roundoff errors during processing. Unfortunately, many upsamplers are actually designed to change the signal, which is why they can be undesirable.

So what I've just written about oversampling would seemingly indicate that doing so should be a sure thing. But as I've said before, it's all about implementation and preference. A poorly designed oversampling DAC is going to sound cold and harsh. But can you afford to buy a Mark Levinson DAC? Meanwhile, it's not as if there's an upper limit to the sound of non-oversampling DACs. Audio Note uses the AD1865 chip in all their high end DACs (and I'm talking tens of thousands of dollars here) in non-oversampling configuration.

In my personal experience, a moderately priced TDA1543 non-oversampling DAC can outdo a higher priced oversampling model like the AD1853-based Benchmark DAC1. But this is only my specific preference. The DAC I built is a non-oversampling board based on the TDA1541A, and was designed by Pedja Rogic. A full explanation of his design and a previous revision can be found at his webpage.

2.2: I2S vs. SPDIF

There are a number of possible ways for a DAC chip to get its data. The most common, as used between distinct transports and DACs, is SPDIF. Most transports have an SPDIF (or EBU) output, which is a format that's a little more friendly about moving over long distances than I2S. The SPDIF data is then sent through a receiver chip such as the CS8412, which in turn converts the data back to a format the DAC chip can read.

Obviously, if we can avoid this extra processing, we should. The CD-Pro2M transport has a direct I2S output, and I2S is the default input for the TDA1541A chip. I'm not going to go into what I2S actually is, because you don't want to have to hear about digital logic. Just trust me on this one.

So eliminating the use of SPDIF also means that we don't need to worry about the CS8412 or its power supplies. The TDA1541A will take the I2S directly, so the key is to simply minimize the distance between the DAC and the transport. I'll get into this a little later.

To anyone out there building their own DAC, make sure to explore all your options before building. Listen to multiple design types in similar price ranges and see what suits your fancy. Furthermore, if propagating a DAC board seems like a daunting task, there are ready-made DAC boards just waiting for power supplies. This could make things much easier.

Part 3: DAC plus transport builds

Say you want to stop at step two, ie. keeping it relatively simple and only including the transport and DAC within the same case. There are a few things we need to consider:

1) distance between the transport I2S output and the DAC inputs
2) location of the transformers
3) mounting the DAC and transport adjacent to one another

3.1: One box build

For a one box system, we have to make some compromises. For one, the DAC board I chose (even without the CS8412) requires five AC voltages – on the TDA1541A, one supply for the +5V, one for the -5V, and one for the -15V, and for the output stage, +/- supplies for +/-12V. This requires either one big honking, custom-made transformer, or several smaller ones. I decided for my build to use separate ones. The +/-5 on the DAC is mostly used for the digital information, so I use a dial bobbin there. For the -15V and +/-12V, I used one toroid each. Thus there is one dual bobbin for the CD player, one dual bobbin and two toroids for the DAC, thus four transformers total.

It is hypothetically possible to put all these transformers in the same box as the DAC and trasport, but it would be very difficult to keep noise out of the system if they're on the same level. This would basically require that the transport and DAC be pushed off to one side of the transport, with the transformers on the other side. All the same, this is a non-ideal solution because the interior will still be cramped, and noise would undoubtedly get into the audio line. Plus, there would need to be room for the transport power supplies, and there certainly wouldn't be room to place anything else besides the DAC and transport (imagine trying to fit a headphone amp or preamp into this afterwards). A different solution is desirable.

I've come to the decision over time that a two box solution is in fact ideal for this application, but it is still conceivable to put it all in one large box, as I did with my first build. The problem here is that 60Hz noise [b]will[/b] leak into the audio output. But for cheaper builds, one box might be more economical.

The enclosure I used was from Lansing Enclosures, who sell elegant but relatively expensive aluminum cases. In my mind, it is worth the expense simply because they look more professional than any Hammond or Par Metal cases. The cases themselves come in three rackmount-standard heights, standard rackmount width, and a variety of depths.

The particular box I used was a triple-height box (a bit over 5" tall) and 14" deep. In addition, I bought a extra bottom panel for the design.

The idea I came up with was to put the transformers on the lowest plane of the box, below and separated from the audio electronics. The extra bottom panel is suspended using standoffs about two inches above the lowest plane, and has the DAC and transport power supplies attached to it. The transport itself would be mounted to the top of the player, thus mounted rigidly rather than using its spring suspension. The transport is placed almost directly above the DAC so that the I2S had a minimal distance to travel.

Using this method, the transformers are a decent distance from the DAC and transport and have a metal plane between them to keep possible noise out of the system. With this sort of setup, there still is -88dB of 60Hz noise on the audio output when no signal is present. This is acceptable for a DIY design, but could certainly be better. This leads to the two box version.

3.2: Two box build

The next idea is to separate the transformers and power supplies/audio electronics. Again, the DAC is somewhat of a limiting factor here – it has onboard power supplies that take AC power directly. This is desirable because it keeps the rectified, regulated DC power as close to where it's actually used as possible. Likewise, it is desirable to have the power supply for the transport in the same box as the transport itself.

So the two box unit would be as follows:

bottom box: all transformers, display board and its power supplies
top box: transport, DAC, transport power supply

There are advantages and disadvantages to this. The advantage is that the transformers are now in a separate box entirely and have two sheets of aluminum between themselves and the audio electronics. Aluminum is well suited for rejecting low frequency (ie. 60Hz) noise, which makes it ideal for these situations. The drawback is that putting the transformers in a separate box with the power supplies in another requires that AC power be sent out of one box and into the other. This is dangerous, and will require special considerations for the connector used.

An overall count of the number of wires needed to connect the bottom and top boxes is 20 -- 14 AC signals and 6 for the display board. If you don't plan on propagating the display on the display board itself and intend to only use the control section, then it can be placed in the same box as the transport. This saves six connections, leaving only AC power to send. We need at least one beefy connector. Also, given that the upper box is floating (no connection to earth ground), it is essential to ground the box in some manner.

Amphenol manufactures military-spec connectors in a variety of shapes and sizes. In particular, they have a connector set that has fourteen 20-gauge wire connectors and one

16-gauge wire connector. Perfect, fourteen for the AC and one for earth ground to the top chassis. These connectors are *expensive* -- a set of two jacks and two plugs runs nearly $100. And you'd have to buy the actual multi-conductor wire to even use the connectors in the first place. Thus, it might be desirable to get cheaper connectors, or perhaps some that have fewer connections per terminal (say, two with eight each). Either way, these are very nice connectors and absolutely ideal for the purpose.

The Amphenol connectors can connect the boxes, but we want to place this AC line so that it's as far away from the top box's audio outputs as possible. Thus, this connector should go all the way to one side of both boxes. On the power supply box, the power receptacle, fuse, and switch can go just inside of this. In the top box, the audio outputs can be put as far away on the opposite side of the case as desired depending on the ins/outs of associated equipment you'd use this CD player with.

Links

CD Transports & Information

Homeoptics http://www.daisy-laser.nl/homeoptics/
sells Philips CD-Pro2M and associated control/display boards
Steinmusic http://www.steinmusic.de/indexeng.htm
sells Philips CDM12.1 and equipment, along with completed CD players
Enco Systems http://www.enco-group.com/
sells Philips CD-Pro2, but with no associated equipment
Andrea Ciuffoli's CD Guide http://www.audiodesignguide.com/cdplayer/index.html
offers solid info on building a CD Player from scratch
DIYZone http://www.diyzone.net/
sells kits and boards for the CD-Pro2M

Power Supply Boards and Information

AOS Electronics http://aoselectronics.com
sells regulator boards, along with DACs and headamps
ALW Audio http://www.alw.audio.dsl.pipex.com/
the source for my super reg boards (e-mail him for availability) and contains extensive information on their theory
Per-Anders hifi pages http://home.swipnet.se/~w-50719/hifi/]
sells power regulators among many other projects
A.Galavotti's Builder's Guide http://www.geocities.com/agalavotti/cdpro.htm
offers power supply designs for building your own CDP

Transformers

Hammond Mfg. http://www.hammondmfg.com/
source for myriad transformers, and most are commonly available
Plitron http://www.plitron.com/
some of the best toroids out there at decent prices
Toroid of Maryland http://www.toroid.com/
contains a good selection of transformers
Avel-Lindberg http://avellindberg.com/
good quality but somewhat expensive toroids
Victoria Magnetics http://www.victoriamagnetics.com/
can make custom toroidal and EI transformers

General-availability Parts

Mouser http://www.mouser.com/

	my personal favorite online parts site, great selection
Digikey	http://www.digikey.com/
	the other of my "big two", look here for Analog Devices parts
Newark	http://www.newark.com/
	sells smaller-sized 0.4W resistors among myriad other items

Audiophile Parts

THL Audio	http://www.thlaudio.com/indexE.htm
	great selection of specialty caps, resistors, etc...due to overseas shipping, the more you order, the better
Percy Audio	http://www.percyaudio.com/
	plenty of audiophile parts from this "online mail-order" style site
Parts ConneXion	http://www.partsconnexion.com/home.php
	one of the few sources for Sanyo OSCONs
Reference Audio	http://www.referenceaudiomods.com/
	source for Rubycon ZA capacitors