Diamond Church Street Chorus

PT2399 Tri-Chorus

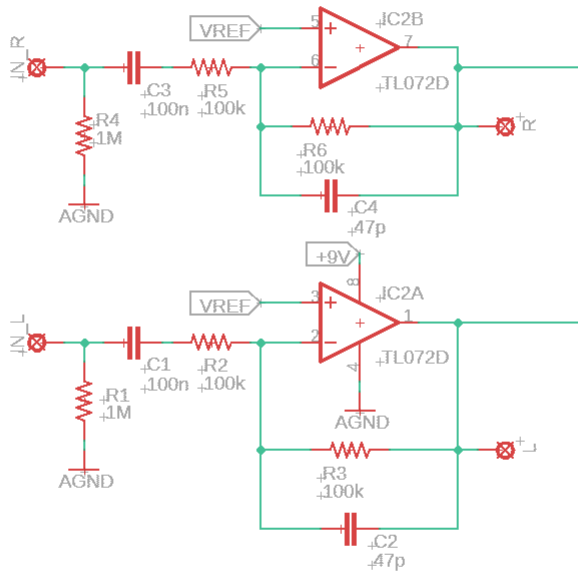
Overview

Tri-Chorus is one of those classic studio rack effects. It's a stereo effect that utilizes three delay lines (duh) that are modulated to produce three distinct chorus voices. The voices are all modulated 120 degrees out of phase with each other, which creates a big, lush stereo field on the resultant signal. The 120 degrees out-of-phase thing is what makes the tri-chorus such a difficult effect in the DIY world. If we use opamps to create phase differences, any phase difference besides 180 degrees is going to make for a frequency dependent filter. The Diamond Church Street Chorus (named after a great song by one of my all time favorite bands) uses modern technology and low cost delay chips to create a tri-chorus that, while certainly not up to a high end rack unit, still gives a good attempt at the sound in a project that is doable for most DIY'ers. Perhaps the largest limitation is the fact that it is subject to the minimum PT2399 delay time of about 30 ms, which gives it a little bit of a sense of "space" with three of them in parallel. This design also allows for mono in/mono out, mono in, stereo out, and stereo in/stereo out configurations.

How it Works

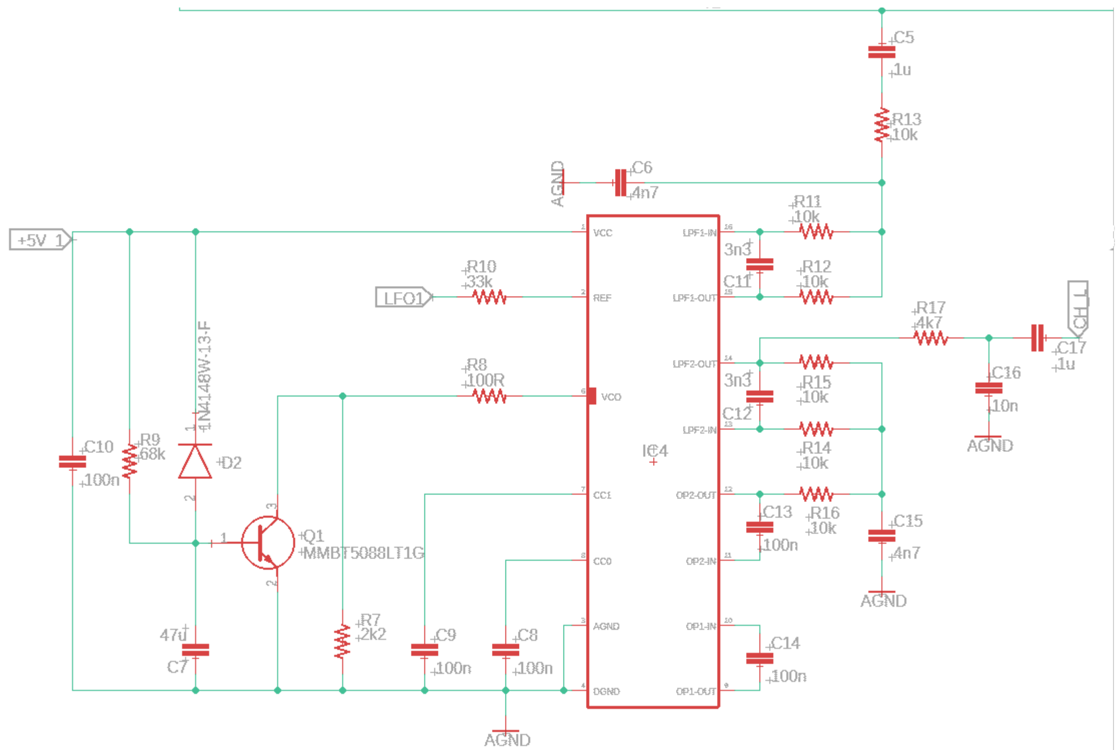
The Diamond Church Street Chorus (DCSC) is a pretty simple concept. Each chorus is a modified Little Angel chorus while the LFO is being produced by a microcontroller. With the microcontroller, the LFO's can be kept at a constant phase relationship regardless of speed. All of this is capped off with input and output buffers for the splitting and mixing.

The input consists of two identical input buffers. The right input buffer is only used when the circuit is wired for stereo input mode, otherwise it is unused. This is a simple unity-gain, inverting buffer. The solder points shown in the figure are connection points for a jumper on the board that determines the 3rd voice's input source.



DCSC Input Buffer

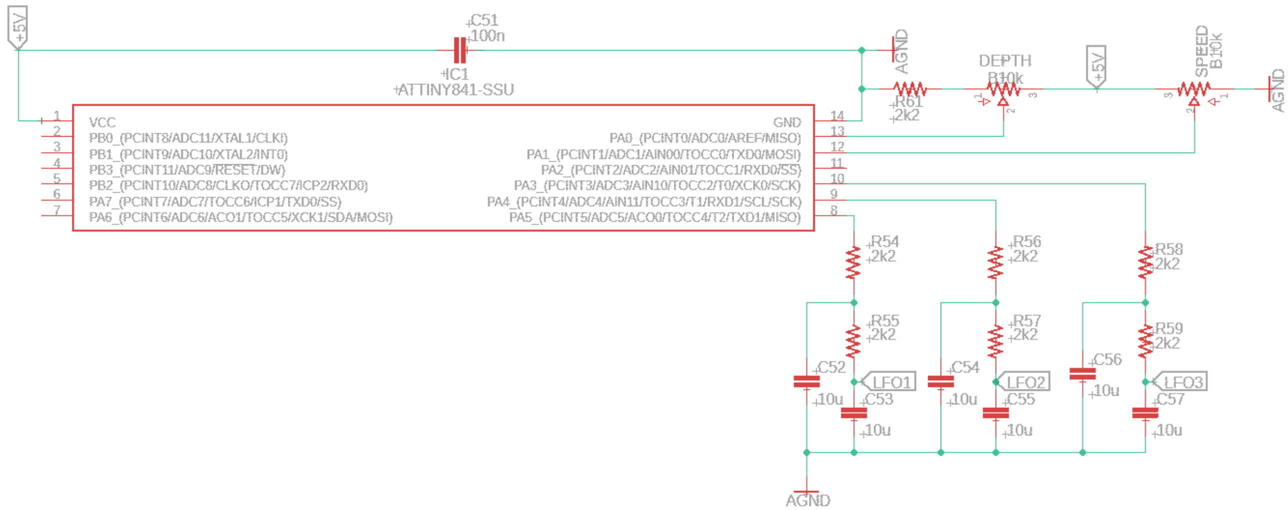
As mentioned previously, this is based on the Little Angel chorus by Rick Holt (a.k.a. frequencycentral). The topology is all the same, including the soft start for the PT2399 to prevent chip lock up. As far as a PT2399 stage goes, it's rather simple as there is less shaping and no feedback or time control compared to the standard delay stage. This is because we want minimum delay time and no feedback for the chorus effect.



DCSC Delay Stage

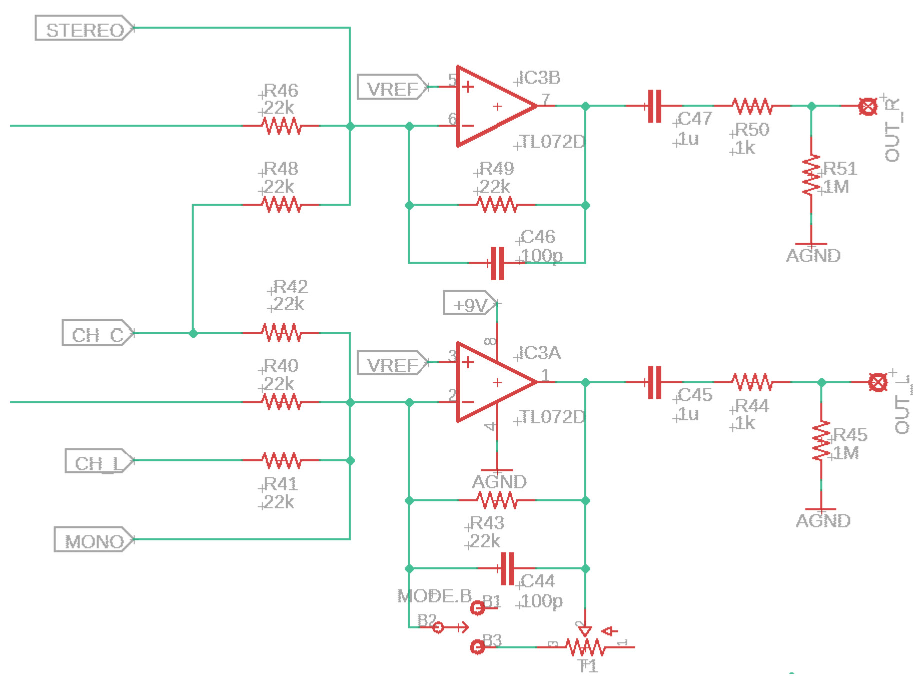
Now that we have delay, we need to create our modulation. As mentioned earlier, the LFO's are all spaced 120 degrees in phase from each other. With analog LFO's, this is extremely problematic, as phase shift of an analog filter is highly frequency dependent, so you would have to change the phase shifting filters any time you change the LFO speed. By using a microcontroller with 3 PWM outputs, we can create 3 LFO's that are perfectly synchronized at all times. For this task I used the ATTiny841, which has 4 PWM outputs. This chip was also employed in the EchoWreck for the delay time synchronization. Unlike the EchoWreck, this LFO implementation uses analog inputs to determine time and depth. These are simple voltage dividers that are sampled by the onboard ADC's othe ATTiny. All of the conversion for speed, depth, and pot taper as well as LFO waveform are defined in the code and can be changed to suit the user's desired min/max speed, min/max depth, pot taper, and LFO shape. In fact, switches could be used to change any of those parameters, but that is left as an activity for the reader.

The LFO output is a PWM signal at a pretty high rate, but there are still audible effects of the square output. Several filtering topologies were experimented with to reduce the high frequency noise in this particular circuit, including use of CMOS switches, Sallen-Key and Multi-feedback active topologies, and passive filtering. In the end, cascaded RC low pass filters were found to reduce the noise to an acceptably low level while minimizing complexity, part count, and maximizing end effect performance.



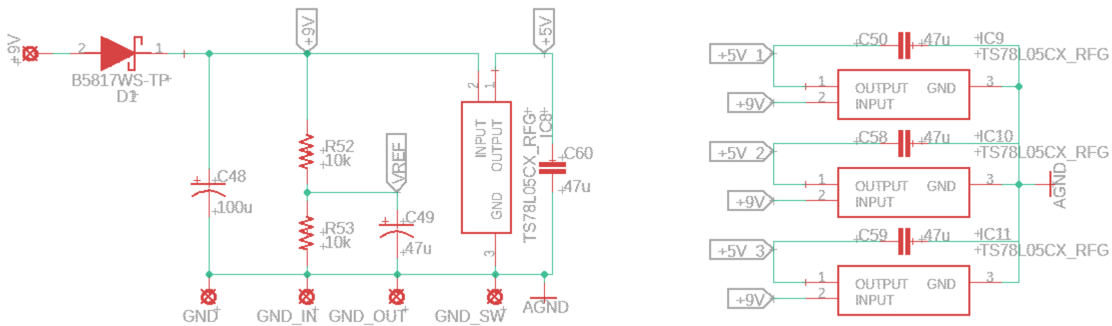
DCSC LFO

The remainder of the signal path is the summing of dry and wet signals. There are two output buffers, one for each side. The “center” chorus signal is sent to both sides, while the other two chorus signals are sent to either left or right. There is a switch for sending the “right” side chorus signal to the left side for mono out operation. When in mono out operation, there is also a trim pot put in place in the feedback loop of the left summing amplifier. This is to control the overall signal level rise inherent in summing more signals. I have found in most cases that 100k is an acceptable resistance value to even things out.



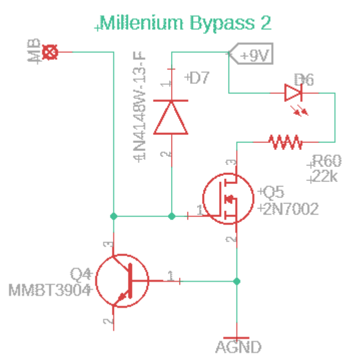
DCSC Output Buffer

The power section is relatively straightforward. The only thing that I found I needed to do to make things more predictable at power up was to have individual voltage regulators for each PT2399. I don't know if this is a function of the chips I had on hand or if it is always necessary, but this is how I implemented it so that all the chips start up correctly. Even with these safeguards in place, there is the occasional power up where there is no chorus output. This just requires unplugging power and plugging back in and it usually works. A bit of a pain if you are gigging, for sure, but this is only a power up, not a bypass toggle issue, so once it's working right, you can toggle the effect on/off without issue. Again, it is likely due to the mix of PT2399 and CD2399 chips that I have on hand, I just didn't have enough on hand to experiment a lot.



DCSC Power Section

The final part of the circuit is the built in Millennium Bypass 2 circuit from R.G. Keen. Because this circuit allows for stereo in/out, a Millennium Bypass is necessary to true bypass two inputs and two outputs and still have an LED bypass indicator. If you are going to use mono in/stereo out, you can either use a 4PDT switch with normal bypass LED wiring, or a 3PDT switch with the Millennium Bypass, which is what I did.



DCSC Millennium Bypass

BOM

The BOM below is the list of parts I used for mine along with quantities. The project is all SMD due to the space constraints of a 125B and because the ATTiny841 is only available SMD. All passives are 0805 sized.

Part	Qty.	Notes
100R Resistor	3	
1k Resistor	2	
2k2 Resistor	10	
4k7 Resistor	3	
10k Resistor	20	
22k Resistor	9	
33k Resistor	1	
68k Resistor	3	
100k Resistor	4	
1M Resistor	4	
47pF Capacitor	2	
100pF Capacitor	2	
3.3nF Capacitor	6	
4.7nF Capacitor	6	
10nF Capacitor	3	
100nF Capacitor	18	
1uF Ceramic/Film Capacitor	8	
10uF Ceramic Capacitor	6	
47uF Ceramic Capacitor	7	
47uF Electrolytic Capacitor	1	
100uF Electrolytic Capacitor	1	
B10k Potentiometer	2	9mm PCB Mount
100k Trimmer	1	3362P style
1N4148	4	Soft startup
1N5817	1	Voltage polarity protection
MMBT5088	3	Soft startup
MMBT3904	1	Millennium Bypass
2N7002	1	Millennium Bypass

LED	1	
TS78L05	4	SOT-23 package
TL072	2	
PT2399	3	
ATTiny841	1	
DPDT On/On Toggle Switch	1	
Enclosure	1	
1/4” input jack	2	
DC power jack	1	
Footswitch	1	DPDT/3PDT/4PDT depending on configuration (see build notes)

Schematic

The schematic for this project is much too big to be legible on a single sheet, so it is included as a separate PDF in the project documentation folder.

Build Notes

Here are some things I noted from building the DCSC that might be helpful to you. Please read this section to make sure you don't go through excessive frustration.

Enclosure Size/Drilling

The DCSC fits nicely into a 125B. The board is a little too wide to fit a 1590B. There is plenty of room for the placement of the footswitch and top mount jacks due to the use of 9mm potentiometers.

Jacks

The jacks will be going over the top of the board/potentiometers. Lower profile jacks like box jacks or Lumberg jacks will work best, though you may be able to get away with open frame jacks if you are careful.

Input/Output Configuration

As mentioned, the DCSC can be wired up for mono in/mono out, mono in/stereo out, and stereo in/stereo out. If using mono in/mono out, the SRC jumper needs to be set or hard wired to the L solder pad and the switch can be omitted. The switch pads will need to be jumpered such that the two center terminals are each soldered to the pad directly beneath them, as if the toggle switch was permanently set in the “up” position as viewed from the front of the pedal. IN_R and OUT_R solder pads will be unused. Toggle switch can be either DPDT or 3PDT depending on LED configuration.

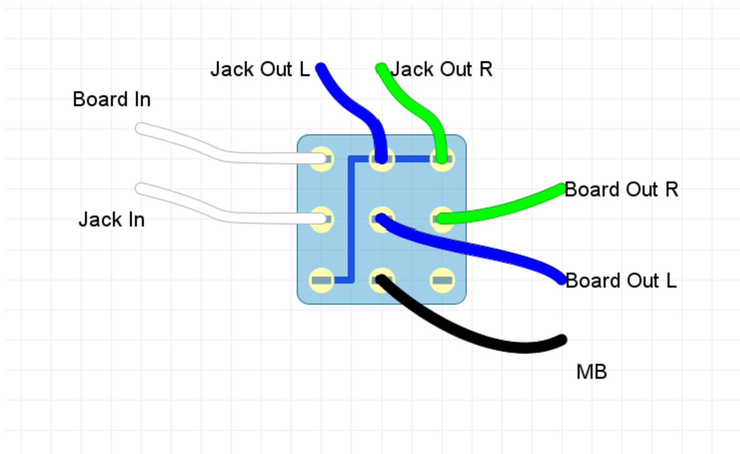
For mono in/stereo out position, the SRC jumper needs to be set or hard wired to the L solder pad. The switch can be kept to allow for stereo or mono output, or it can be jumpered such that the two center terminals are each soldered to the pad directly above them, as if the toggle switch were permanently set in the “down” position as viewed from the front of the pedal. IN_R solder pad will be unused. Toggle switch can be either 3PDT or 4PDT depending on LED configuration.

For stereo in/stereo out, the SRC jumper needs to be set or hard wired to the R solder pad. The switch can be kept, but is not recommended. Instead, it is recommended to jumper the switch pads as described in mono in/stereo out. The IN_R and OUT_R pads will both be used and a 4PDT toggle **must** be used.

LED Configuration

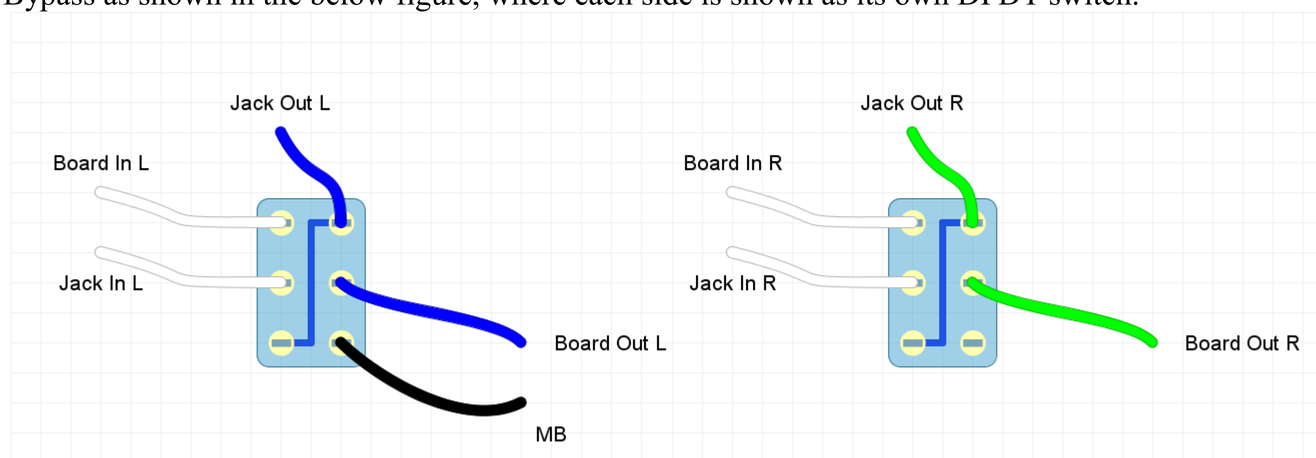
For mono input configurations, the bypass indicator LED can be wired either in the standard way to the toggle switch, or using the Millennium Bypass. If using Millennium Bypass, the toggle switch can have one fewer pole than in the standard way. The SW solder pad is a ground pad that can be used for standard LED wiring. The LED anode is soldered into the corresponding LED solder pad, while the cathode of the LED needs to be wired to the foot switch in the normal way.

For Millennium bypass wiring, the LED is soldered to the LED pads as indicated and the MB pad is wired to the toggle switch as indicated in the figure below, which shows mono in/stereo out on a 3PDT switch. For mono in/mono out with a DPDT switch, simply eliminate the third pole (right hand side) of the switch.



Mono Input Millennium Bypass Wiring

For stereo in/stereo out, a 4PDT switch **must** be used. The wiring for the switch utilizes the Millennium Bypass as shown in the below figure, where each side is shown as its own DPDT switch.



Stereo Input Millennium Bypass Wiring

In Closing

The DCSC creates a great, lush chorus sound, despite the limitations of the PT2399 chip used for the delay. Better results could no doubt be achieved with a different delay chip, but I wanted to make something that was at least a little more accessible to the DIY community. It's a fun build and the controls are deceptively simple for what lurks beneath, but it's certainly worth a build.