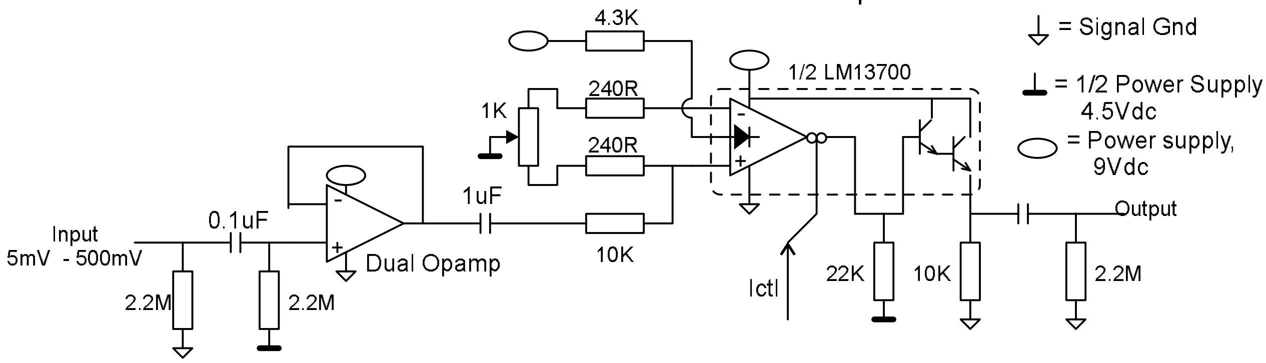
Applications of an OTA Current Controlled Amplifier

A Practical OTA Current Controlled Amplifier

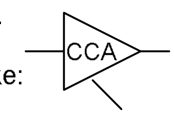


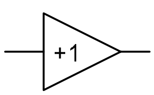
The schematic above shows a practical Current Controlled Amplifier (CCA) for musical effects use. It's made from half a dual opamp of garden variety as an input buffer, and half of an LM13700 or NJM13700 dual Operational Transconductance Amplifier (OTA). The circuit has been designed to fit within the normal constraints of musical effects - single 9V battery power supply, and an expected max input of something like 100mV to 500mV.

The signal is buffered by the opamp front end and then gain controlled by the OTA. The OTA circuit as shown has a gain of about +3db (2 times) at a control current (Ictl) of 1ma down to about -80db from that, or 1/10,000th of the input signal, almost full muting.

The 1K trimmer pot is important to the operation of the circuit. It balances the differential input so that changes in Ictl do not feed through into the output signal as badly as they otherwise might. This is important whenever the control current changes quickly and the changes might be heard as a click or thump in the output if the balance is not done.

For the purposes of the rest of this article, I will show that whole circuit above as a single block, illustrated like:





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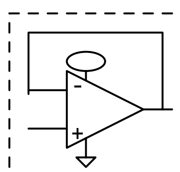
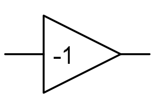


a non-inverting opamp circuit



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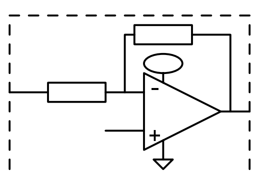

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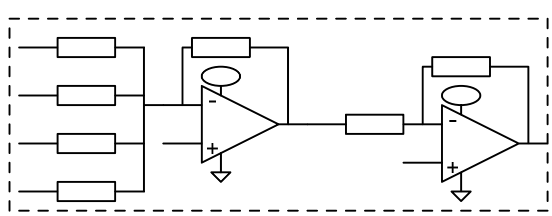
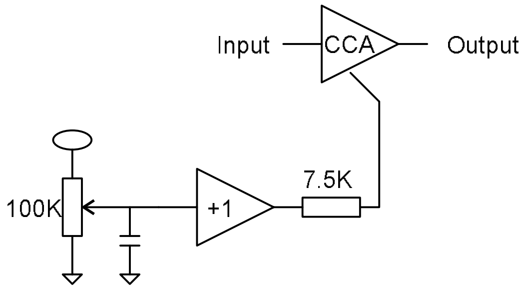


a non-inverting linear mixer circuit

The biasing details of the circuits above do matter, but the details will be clear from the context of the circuit diagram, and will be included in any completed schematics.

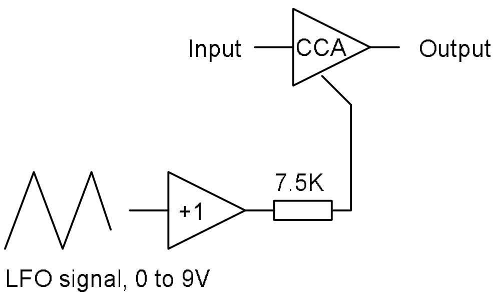
Application 1: A Volume Pedal



We can manually set the control current Ictl in the CCA. The simple way to do this is with a foot operated rocker salvaged from a wah pedal, a buffering opamp to provide the current needed to drive the CCA, and a series resistor to convert the control *voltage* at the opamp output to a control *current* as expected by the CCA. The LM13700 current input looks like two diodes in series to ground from the outside, so it will never get more than about 1.4V above ground. That means that if our opamp can provide 0-9V of control voltage, the current that will be pushed into the CCA will be a maximum of(9V-1.4V)/7.5K, or about 1ma.

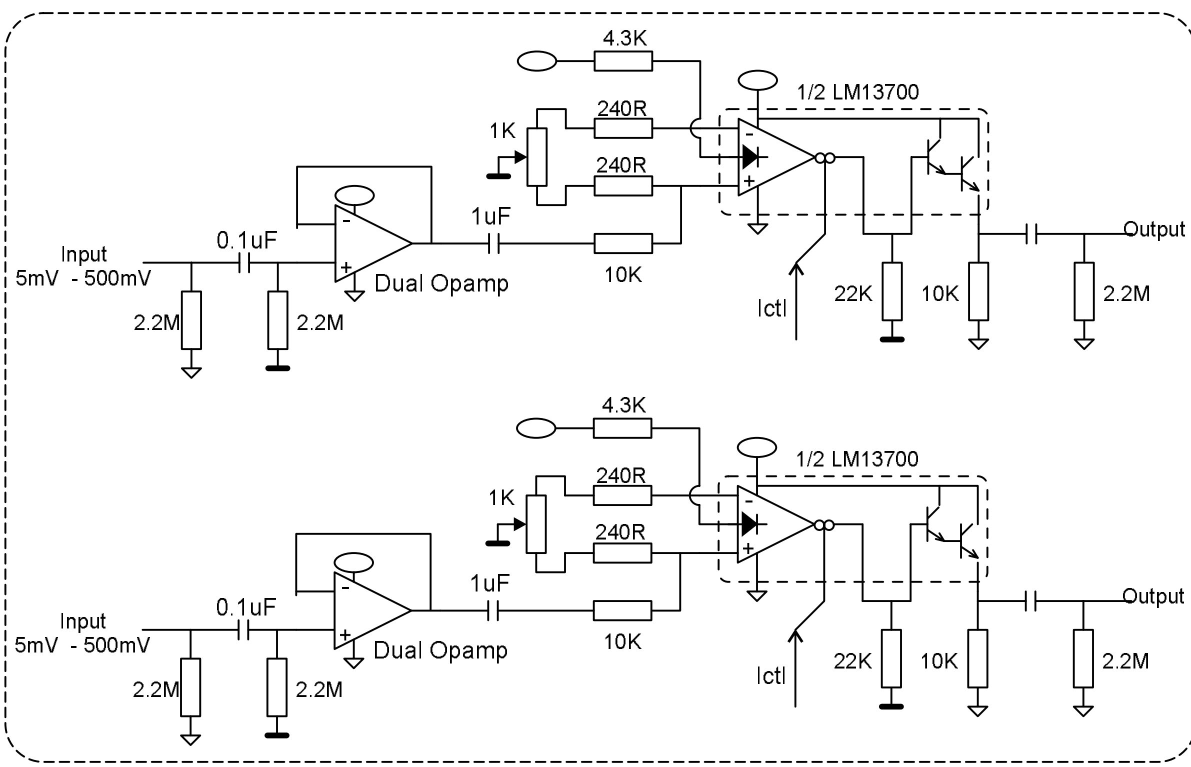
The LM13700 can actually live with Ictl up to 2ma, but many other OTAs

Application 2: A Tremolo Pedal



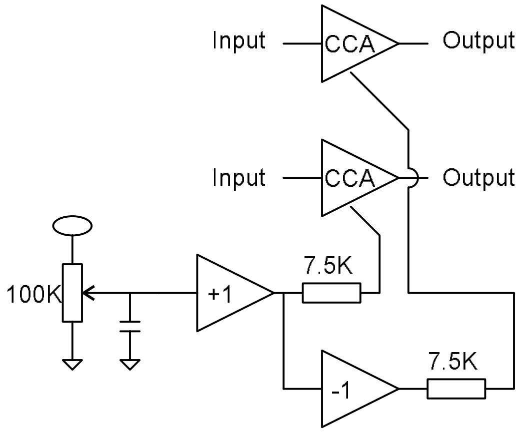
Of course, once we've gone to the trouble of making the CCA have a clean voltage controlled input of 0-9V corresponding to gains of essentially zero up to a gain of about two, we can go ahead and supply any control voltage we like, as in the output from an LFO. If the control voltage is zero to +9V, the gain is whaled from full on to full off. If we use a square wave control, the sound is chopped instantly on and off.

If we bias the +1 buffer feeding the CCA at half the power supply voltage, 4.5V and feed no LFO voltage in, the gain of the CCA is about unity, no gain or loss. We can then AC couple in an LFO signal from a "depth" pot which feeds in a variable amount of the LFO, for a full featured tremolo circuit.



As a practical matter, we will often use both halves of the two chips involved in one CCA circuit to make a dual CCA, as shown above. The inputs, outputs and Ictl inputs can be interconnected in many interesting and useful ways.

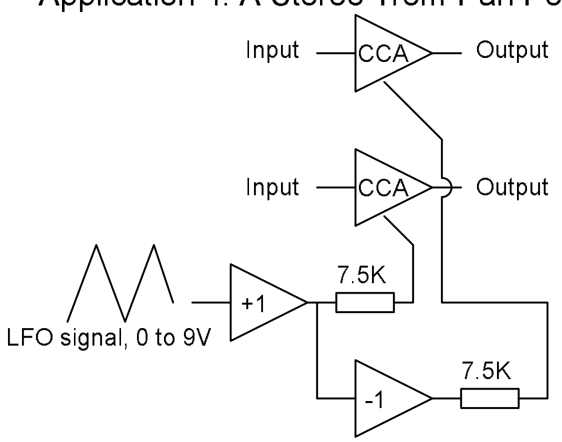
Application 3: A Pan Pedal



The two-CCA extension of the manual volume pedal is the pan pedal. Taking the same circuit as Application 1 and adding to it one more CCA and a DC coupled inverting amplifier to invert the control signal, we get a pan setup. With the rocker pedal centered (that is, the input control voltage at 4.5V) the gain of both CCAs is about unity. Rocking the pedal away from this center point rainses the gain on the higher channel to about 2 and lowers the gain on the lower channel to almost off.

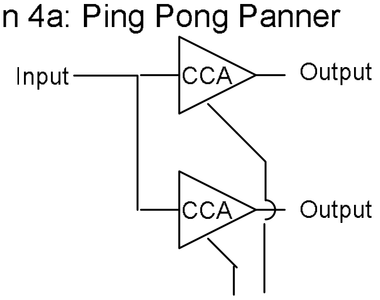
Purists will note that we're using a linear control voltage, not an exponential one. There is a simple modification to the drive circuit for the CCA that gives exponential response, but in the case of an effects pan pedal or crossfade pedal, the linear response is usually more useful.

Application 4: A Stereo Trem-Pan Pedal



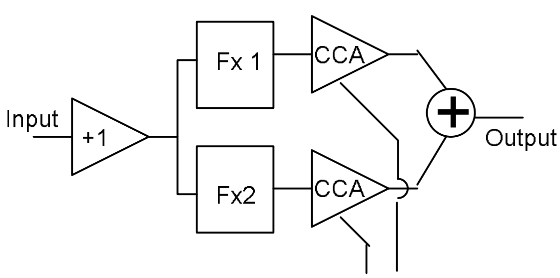
Just like with the single channel tremolo pedal, we can hook up an LFO to the two channel CCA setup and have two sides that alternately fade between one another depending on the LFO voltage. This is similar to the action of the commercial Boss PN1 Trem-Pan pedal and the old Ibanez Flying Pan pedal.

Application 4a: Ping Pong Panner



This is the stock hookup for the two channel Trem-Pan operation. The same input is routed to both CCA's and each CCA's output goes to a different place. This lets you pan a single guitar signal to two amps or do ping-pong jumps depending on the control signal you send them.

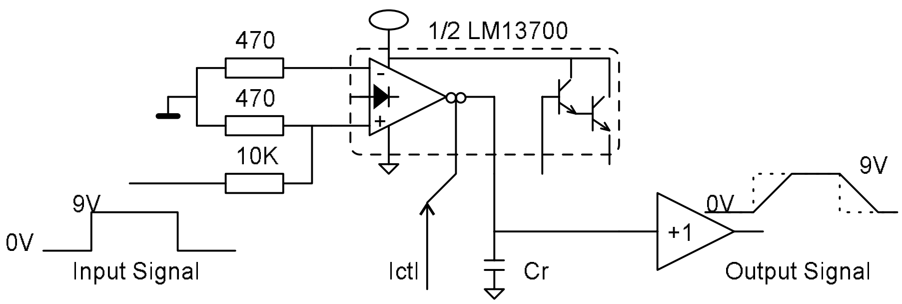
Application 4B: Fadeover Morpher



But you can also fade two separate inputsto one output if you put a mixer on the output of the CCA's. In this case, two different effects or effects chains are set up after a buffer. The CCA control fades or switches between them. If the LFO control circuit is a digital signal (that is, full on or off) and one of the Fx loops is no effect at all, just the dry signal, this circuit reduces to the Ibanez "bypass" system, where the bypass signal merely selects the dry or effected signal.

But it's capable of much more. A slow fadeover LFO signal produces a condinuous changing mixture of sounds.

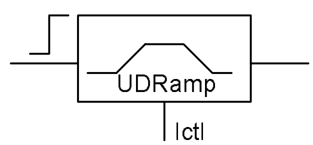
Circuit 2: A ramping control voltage generator



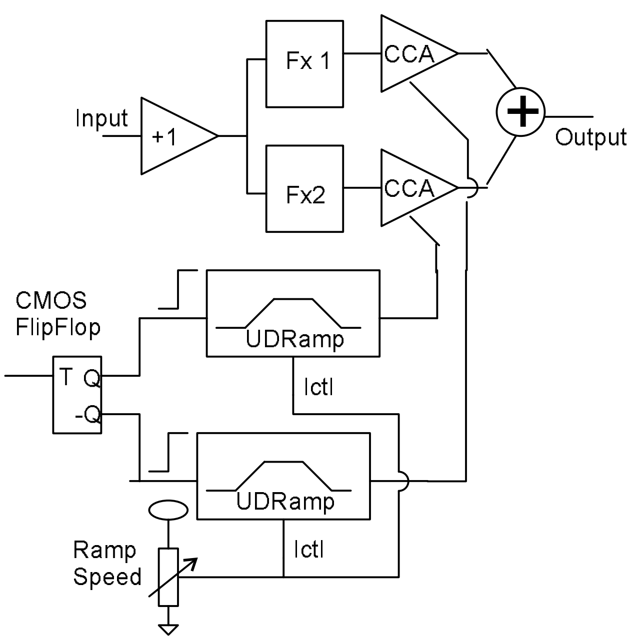
It's very useful to be able to generate a ramp up or down signal to control CCA's, as we've seen. One easy way to do this is with another OTA. The OTA converts a differential voltage at its input to a current at the output.

The maximum current out or into the output of the OTA is equal to the Ictl at any moment. If we load the output of the OTA with a capacitor, and bang the input fully to one side or the other, the capacitor fills with voltage at a rate of dV/dt=Ictl/C. By changing Ictl, we can get any slope we want from 0 (no Ictl, so C's voltage never changes) to 1ma/C. If C is 1uF and Ictl is 1ma, then the change in capacitor voltage with time is 1000V/second, or more usefully, 1V/mS, so we go from 0 to 9V or vice-versa in 9ms. If Ictl is 1uA, the ramp

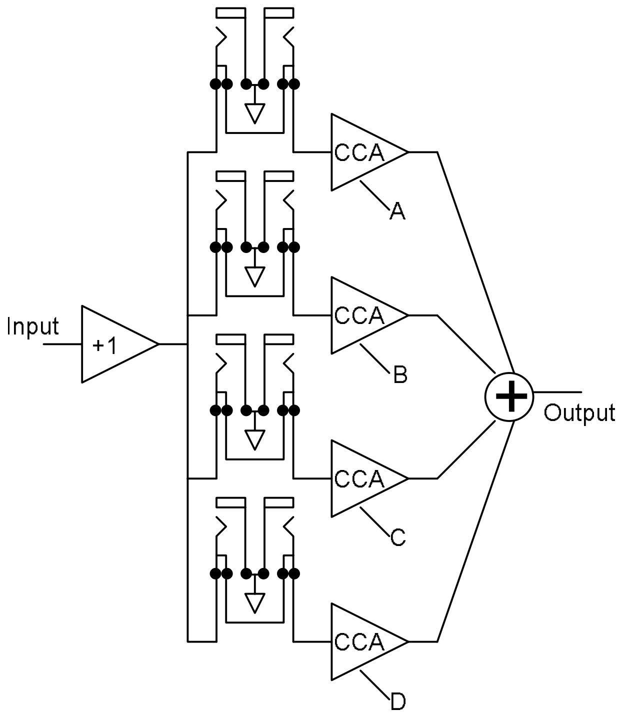
It turns out that this little module is going to be useful to us later, so let's make a shorthand symbol for the thing so we don't have to keep redrawing it. I call this an Up/Down Ramp (UDR) circuit.



Application 4C: Stompable Fadeover Morpher



Application 5: Multichannel Fadeover Morpher



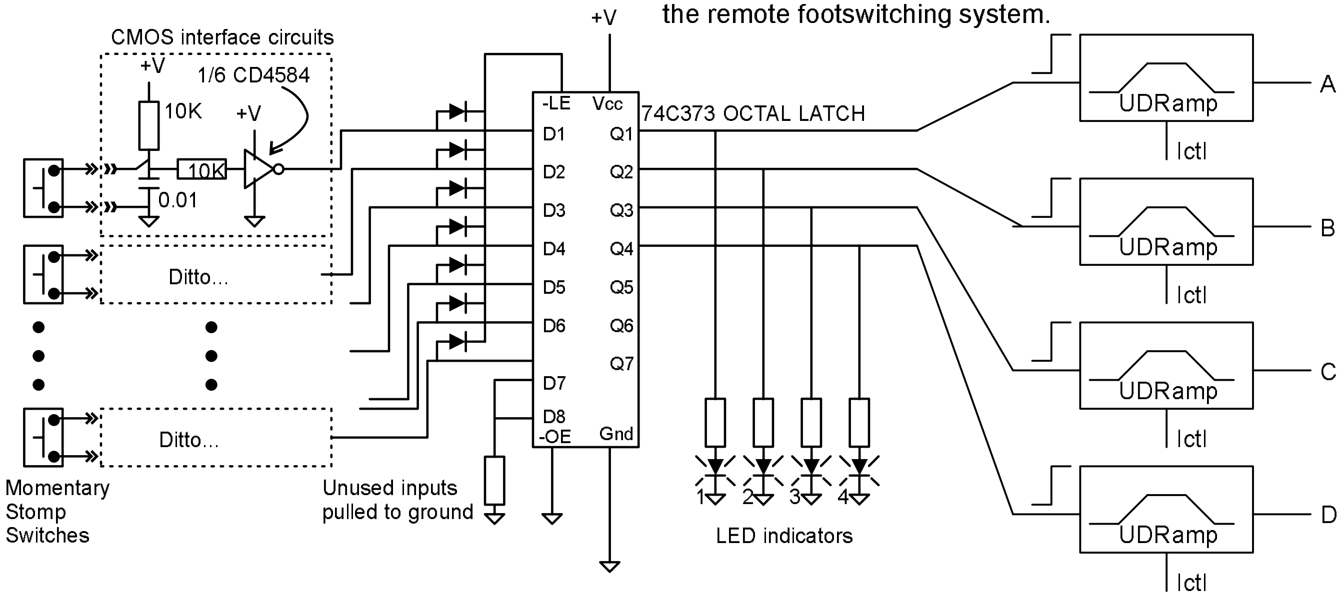
Now we're getting complicated - here's a four channel fadover circuit. The pairs of jacks in the middle of the mess are normalled insert jacks. The normally closed switch inside the jack connects the signal between the jacks when no plug is inserted, so if nothing is plugged in, all the channels are just direct passthrough. If you plug an effect or effect chain into the loop, the loop's sound is only heard when its control voltage (A, B, C, or D) is more than 0. The outputs are all mixed in the output mixer. If you control each channel manually, you have a voltage controllable mixer - not all that interesting.

It gets more fun when you use a bit of logic to make the thing switch from one channel to the other, and our UDR circuit to make that switchover happen in a variable time.

Here's one way to do the selection. A single CMOS octal latch can work with a momentary footswitch to select one and only one of up to eight output signal lines. Better, we can use the ones we want and ignore the extra ones. So a single CMOS chip does the selection of one channel of the Morpher.

Those of you who follow GEO will remember this from the remote footswitching system.

Footswitch Logic



Of course, by this time, the use of discrete logic gets a bit complicated, and you could just as easily use a $2.50 PIC microcontroller to do the selection, and also tuck into it a lot more fancy stuff, like circulating patterns, random channels, and so on.