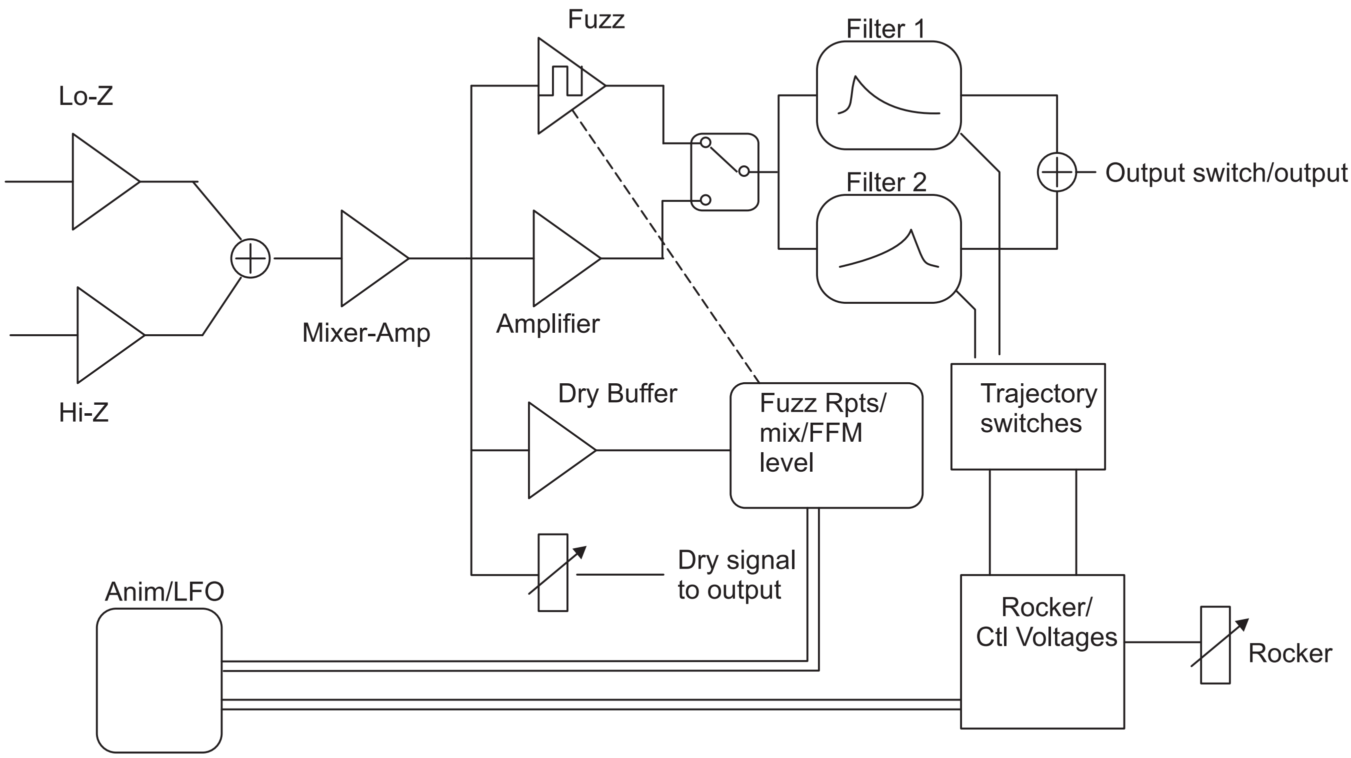
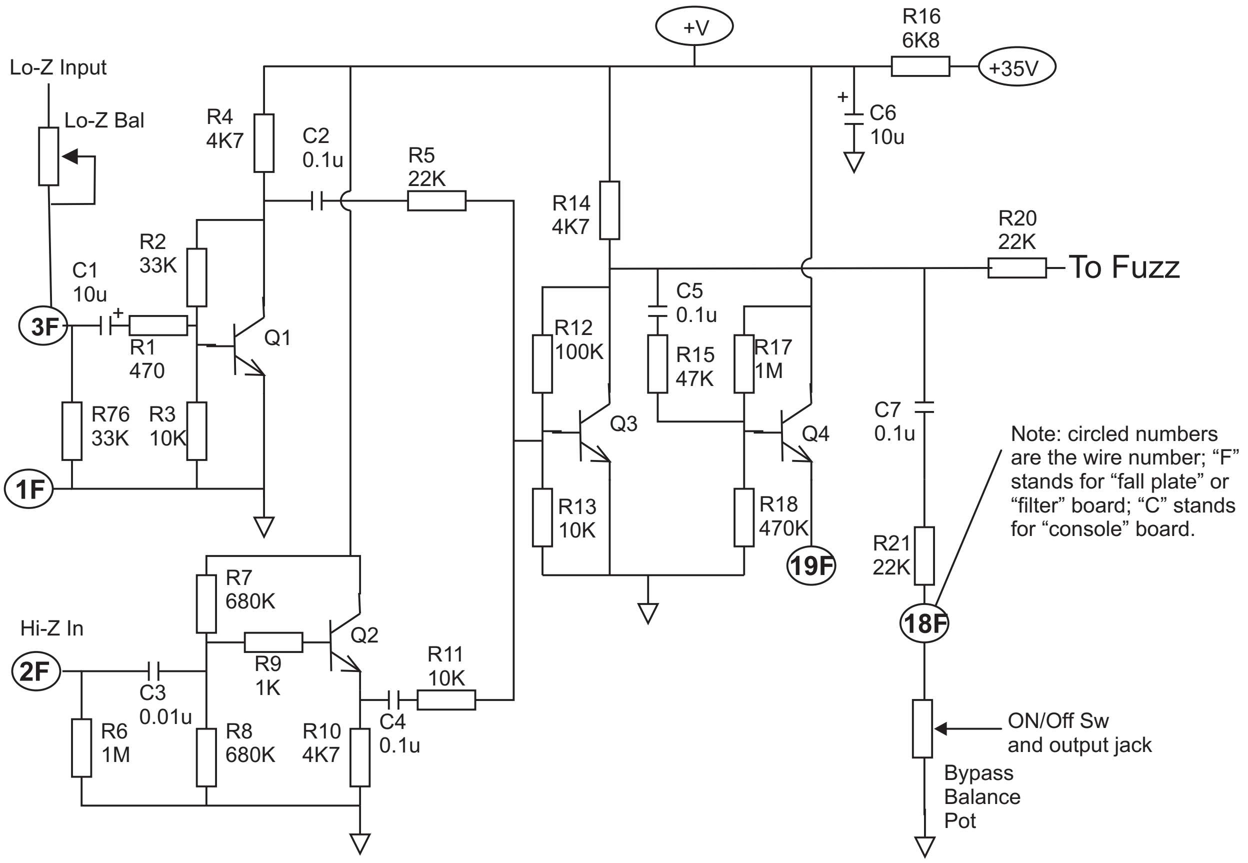
Ludwig Phase II "Synthesizer"
Tech Overview



Block Diagram

Inputs, mixer, and buffers



The Ludwig Phase II (Ludwig) has two inputs, a low impedance (Lo-Z) and a high impedance (Hi-Z). The two are intended for different sources. The Lo-Z would likely load guitar down too much by modern standards, causing treble loss. The Hi-Z is more likely to be used for guitar today.

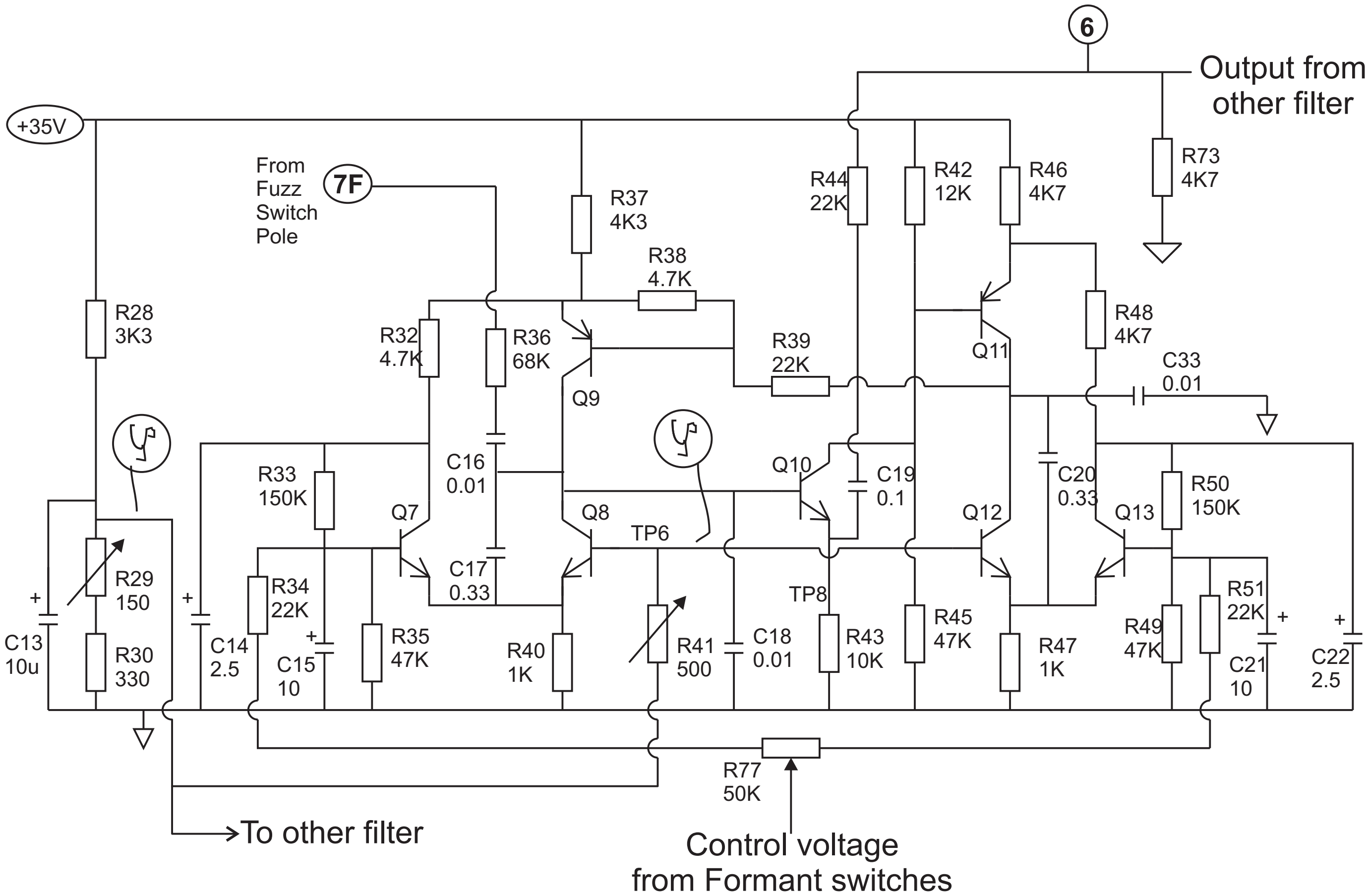
Oddly, the Hi-Z input has no gain. A mod to insert a resistor into the Q2 collector circuit and take its output from the collector instead of the emitter would likely give more signal level to a guitar. It’s a good place to start for tinkering.

The Lo-Z and Hi-Z signals are mixed by R5 and R11 into Q3, where they are amplified and sent to both fuzz and a follower output. The follower output is the emitter of Q4, on pin 19F (wire number 19 on the filter/fall plate circuit section). R20 limits current from Q3 collector into the fuzz circuit input.

The output of Q3 is also the signal sent to the output jack when the effect is not engaged. It goes to the bypass balance pot and then to the “effect on/off” switch and the output jack. The Ludwig is a buffered-bypass pedal in the sense that there is no bypassing, only an unaffected signal when the effect is not engaged.

Q4 buffers the output of Q3 and sets a DC level of about 1/3 of the power supply for signal to the Fuzz Mix section; this output appears at pin 19F.

Filter and Trimmers



There are two filters, identical except for minor differences in frequency range. One is shown. They take in the signal from the fuzz select switch, either amplified normal signal or fuzz signal, and then output to R73, which mixes the two outputs. The filters are bandpass filters, and their frequency range corresponds to the first and second formant frequencies of the human voice. Each filter by itself sounds much like a wah pedal, but with different frequency ranges.

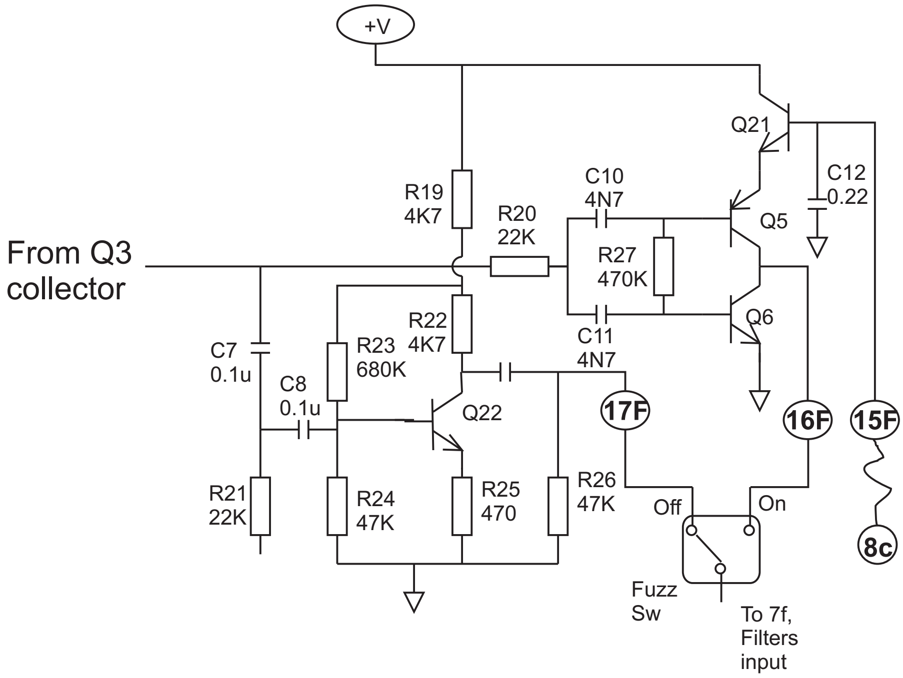
It is not clear to me exactly how the filter itself works in detail. But they do work, both in breadboards and in simulation.

Each filter's center frequency is controlled by a control voltage fed to it through the formant switches and into the wiper of a trimmer that sets some kind of balance between the two halves of each filter. For the filter shown, this is R77, for the other one it is R55. Both filters are fed a control voltage created by R28-R29-R30. This control voltage is critical in setting the filters up, as they only work in a narrow range of about 1.8-2.2V of this control voltage. R41 and its counterpart R62 in the other filter set some kind of internal sensitivity to the master control voltage. Someday I'll figure out more about this.

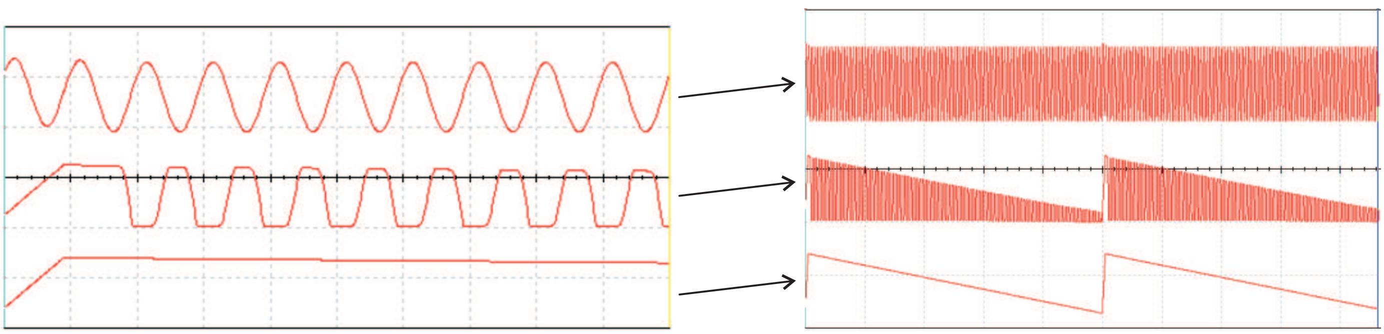
The fundamental action of the Ludwig is to set up control voltages to these two filters, sweeping both center frequencies in "trajectories" selected by the formant trajector switches, so that they do one of (1) sweeping up and down in frequency together, (2) one sweeping up while the other sweeps down, and (3) a "vocal" sweep, with the center frequencies moving in some approximation of what the F1 and F2 formants of human voice do in speech. If this last is set up well, a sweep of two or more distinctly vowel sounds results.

Exactly how the voltages are swept is controlled selectively by the rocker pedal and an "animation" feature which repeatedly creates a slow speed sweep.

Fuzz/non-fuzz signal to filters

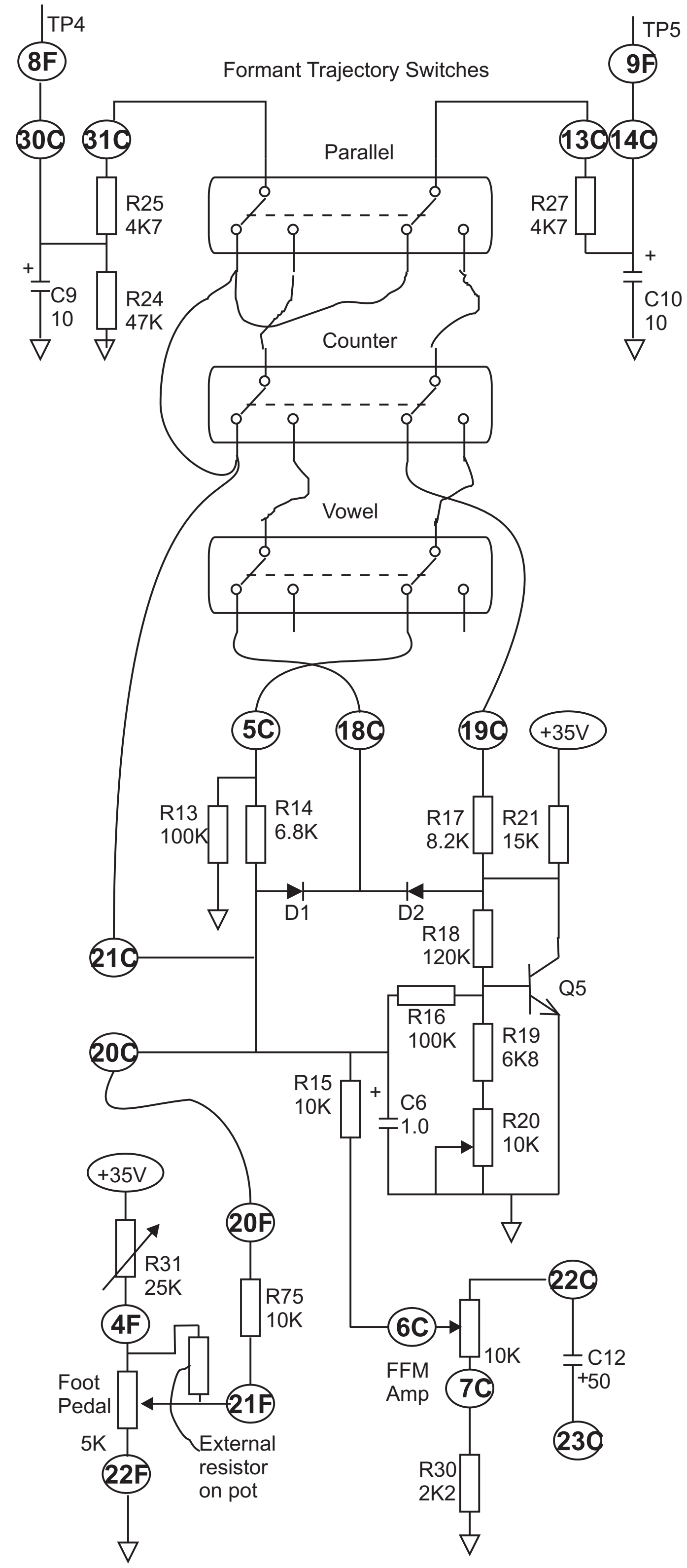


The fuzz/non-fuzz section provides the signal to the filters. Non-fuzz just amplifies up the normal signal. The fuzz circuit Q5-Q6 amplifies the normal signal up to a square wave. The size of the square wave is determined by the voltage on Q21 emitter. This is in turn set by the signal on pin 15F. This comes from the fuzz repeats section of the unit, and causes the fuzz signal to be amplitude modulated. A signal from about 1.8V to 7V here raises the fuzz output signal on pin 16F from zero through about 7V, the peak voltage following the level of Q21 emitter. This is used for a percussive repeat effect. Pin 17F is the non-fuzz signal amplified up to a consistent level. The fuzz switch selects which signal is submitted to the filters.



The signal at pins 8C/15F 8 is from the fuzz animation circuit. It is a slowly swept DC level, and causes the fuzz level to increase as it increases. The pictures are captured traces from simulating the circuit. The top trace is a sine wave input signal; the bottom trace is the modulating signal at 15F, and the middle trace is the resulting output at 16F.

Formant Trajectory



The formant frequency control voltages at 8F and 9F come from the formant trajectory switches. These are scaled to size by R25, R24, and R27, and smoothed by C9 and C10. The trajectory switches pick whether both filters get the same control voltage (parallel) or opposite (counter) going voltages, or the special vowel combination.

The control voltages are generated by the action of Q5, which is set up as an amplifying inverter. A varying DC voltage is fed to Q5 base through R15 and R75. The voltage at pin 19C rises when the input voltage falls, and vice versa. The voltage at pin 5C rises and falls with the input, and the voltage at pin 18C rises with the higher of either the input voltage or the collector voltage of Q5; so it starts high, falls, then rises again whether the input voltage rises from minimum or decreases from maximum. This reversal in direction corresponds somewhat to the frequencies of the human vocal formants, and is responsible for the vowel sounds the Ludwig can do.

If the “parallel” switch is set, the filters both rise and fall with the input voltage to the Q5 circuit.

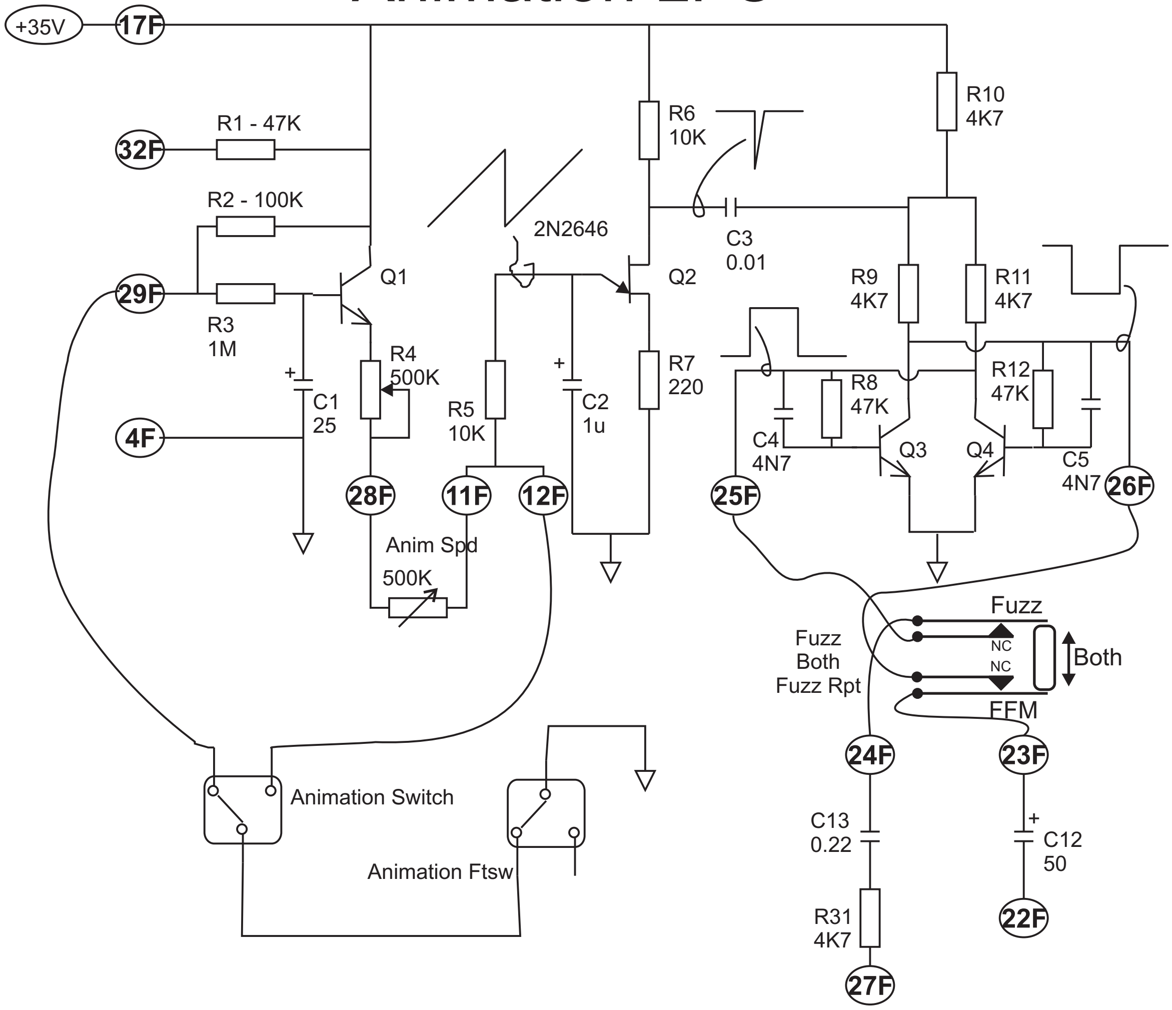
If the parallel switch is off, the control voltages can come through the “counter” switch. The counter switch selects either the opposite-going voltages from the input voltage at pin 21C and pin 19C, or the output of the “vowel” switch. The opposite-going voltages make the filter frequencies move in opposite directions in frequency.

If the vowel switch is on, the control voltages come from pins 5C and 18C. This allows the emulation of vowels in the filters. To hear vowel simulation, “parallel” must be off, “counter” must be off, and “vowel”must be on. Counter pre-empts vowel, and parallel pre-empts counter.

R20 sets the bias on Q5 to get good inversion range and DC bias for Q5.

The input to Q5 is the sum through R15 and R75 of the rocker pedal voltage and the voltage from the animation oscillator through C12. R31 sets the maximum voltage across the rocker pedal, and hence the voltage range from the rocker pot. The rocker pot has a “tapering resistor” soldered across its lugs as shown. The FFM control pot selects a portion of the signal from the animation LFO output at pin 23C through C12. The signal from the animation LFO is a low frequency square wave; C12 prevents this from changing the DC bias of Q5, but allows through a repetitive low frequency changing voltage. This wobbles the input voltage around the DC position set up by R20 trimmer and the foot pedal rocker.

Animation LFO



The Animation section creates a pair of opposite-phase square waves at pins 25C and 26C. These signals come from the collectors of Q4 and Q3 respectively, which are set up as a digital flip-flop. One collector is always high, and the other is always low. High is about 16V and low is nearly zero. The fuzz/FFM repeats switch selects whether you get animation on the frequencies in the filters, fuzz repeats or both. Both outputs are AC coupled to prevent the square waves from the flipflop from affecting the DC conditions on the circuits they feed, but the capacitors (C13 and C12) are large enough to couple the resulting AC signals into the corresponding circuits.

The flipflop inverts at a rate determined by negative-going pulses through C3. The value of C3 may need to be adjusted so that the size and sharpness of the pulse from Q2 causes reliable triggering. 0.01uF, 0.1uF, or 1uF may be used/needed.

Q2 is a standard unijunction transistor (UJT) oscillator. This produces large negative pulses at B2 (connection of R6 and C3, and smaller positive pulses at B1 (top of R7). The timing is set by the voltage on C2. At power-on, the voltage at C2 rises from zero. When it reaches a critical voltage set by the nature of Q2, Q2 suddenly conducts from the terminal connected to C2 very heavily, and continues to conduct until C2 is almost drained. Q2 then turns off, and C2 begins charging again. The sudden conduction is what causes the negative-going pulse on C3, and also the change in state of the flipflop.

C2 voltage rises at a rate determined by the voltage fed to it through a series resistance. In this case, the resistance is the sum of R4, R5, and the animation speed pot. Larger resistance makes C2 charge more slowly, so the time between flipflop inversions is longer. Smaller resistance makes this faster. Changing the animation speed pot changes the resistance, as does trimmer R4, which sets how small the total resistance can be, and hence how fast the animation can get. At some low setting of total resistance, Q2 will lock up and not oscillate. The setting of R4 can prevent this; it's probably why it's there.

The voltage fed to the series timing resistance comes from the emitter of Q1. Q1 is an emitter follower, fed a DC voltage through R2+R3. If the animation switch and animation footswitch are open, this is connected to the power supply voltage, and Q5's emitter sits at nearly 35V. If the animation switches ground pin 29C, then the base is pulled to ground and oscillation of Q2 stops, as does the output changes of the flipflop. C1 and R set how fast the voltage Q1 emitter can change, and therefore how fast the animation turns on and off. This can produce a ramping up/down of animation speed.

Percussion Repeats

At right is the fuzz repeats/animation circuit. The level of output from the fuzz circuit depends on the voltage on the base of Q21, from pin 15F. In one position of the fuzz switch, the buffered signal from Q4F at a DC level of about half the 35V power supply is connected to the fuzz mix control. In the other position, a fixed 47K to +35V is connected. This lets the fuzz mix control vary between about half the power supply and nearly ground in the Q4F position, and about 8-9V in the R1 position. This DC level sets the DC for the base of Q21, and hence the fuzz level.

The LFO can be added into this through the percussion repeats pot, which lets in a portion of the square wave LFO output, and makes the fuzz jump up and down in level as the LFO cycles. The amount of jump is controlled by the setting of the percussion repeat pot. The diode prevents the LFO from actively pulling down on the level, so it jumps up and decays back down, like a percussive signal.