REAL WORLD INTERFACES

TR-909 sound mods - BD, SD, HH Tuning and HCP with external signal inputs for SD Snappy and HCP

Robin Whittle 10 October 2018 http://www.firstpr.com.au/rwi/tr-909/

These modifications affect the BD, SD, HCP and HH circuits:

1 - Three pots (potentiometers, which have knobs) which affect the BD circuit. Some other changes to the circuit which do not require new controls. These mods are based on Colin Fraser's work of 2004:
http://www.colinfraser.com/tr909/909mods/909mods.htm .
A copy of this is appended to the printed version of this manual.

2 - Some changes to the noise component (Snappy) of the SD circuit, based on mods I developed in August 1985. No new controls are required for this. To summarise these mods, they produce a better exponential decay to the main part of the Snappy sound with a potentially louder signal and more lower mid-range noise. There is an external input for the signal, which is normally the internal noise generator, which is used to create the two Snappy components of the sound.

3 - Extending the lower range of the Tune pot for the SD. This enables the tuning to go so low that there is no tone generated for most of the SD note. The frequency of the two oscillators depends on this setting plus a short pulse of voltage which occurs at the start of the note, so this pulse always causes the oscillators to run briefly at the start of the note, with a peak frequency which depends on the Tune pot setting, and is not affected by the accent level of the note.

3 - Two pots, a toggle switch and a 3.5mm socket for modifications to the HCP circuit, along the lines of my TR-808 mods.

4 - One pot which controls the tuning of the HH signal. This is based on Colin Fraser's notes on the abovementioned page.

The new controls:

- 6 pots,
- 1 toggle switch,
- 2 3.5mm sockets for the SD Snappy and HCP External Signal Inputs.

are all mounted at the right end of the rear panel, and are clearly labelled. **This takes the place of the Cartridge socket, which is removed as part of these modifications.**

The SD circuit is altered in ways which do not enable it to produce all the original sounds, so please read on and listen to the sound samples before deciding to proceed with these modifications.

The descriptions which follow, and those provided by Colin Fraser, make reference to particular elements of the circuit, since this is the only way to explain the modifications and how they affect the sound produced by the circuits. The final pages of this manual contain parts of the TR-909 schematics for the BD, SD, HCP and HH circuits. These are from the TR-909 service manual at a remarkable repository of service manuals, NoDevice.com:

https://www.nodevice.com/service-manuals/musical-instrument/roland/tr-909/399945

These schematics show the original circuitry, not the modified versions. Colin Fraser describes the changed components in his modifications, and my descriptions below note where my modifications differ from his, which is only in a few component values.

In the SD and HCP descriptions, I list all the components changed or added, but without the PCB details which Colin provides. Neither set of descriptions includes the altered schematics. It would take a week or two to create fresh, easily readable, versions of the original schematics in KiCad or some other EDA software, which would be needed as the basis for modified schematics which could be clearly read by anyone.

With the document you are reading now and Colin Fraser's page, all the details of these mods are specified. So with care, other technicians can apply them to TR-909s and TR-909 clones. This is not recommended for inexperienced people. The TR-909 has dangerous mains voltages on exposed terminals in the power supply section. If you don't already know how to prevent static electricity damage to electronics, I suggest you hire a technician who does, rather than find out the hard way how not to do it with your TR-909. The pots are Taiwan Alpha from Jaycar, though some values are not available so I use a dual of a lower value to achieve the same result.

The TR-909 is difficult to debug and fault-find since the PCBs are connected by wires which make it difficult or impossible to access both sides of the boards while they are connected. I made some extender cables which allow the main voicing board to be well detached from the chassis, while everything is connected and running.

Thanks to Colin Fraser for publishing his modifications and to Sam Antonio for his patience while I devised these additional mods for his TR-909.

Bass Drum modifications

The electronic details of these changes are similar to those described in Colin Fraser's web page.

The first two mods do not involve any new controls:

1 - The maximum decay time is extended to about 4 times the usual.

2 - The TR-909's Tune control does not control the overall frequency of the Bass Drum oscillator (see the new Pitch pot below, which does). It controls the decay time of an envelope which causes the oscillator frequency to be higher than normal (starting high and sweeping to normal) at the start of the note. This mod retains the existing minimum time and extends the range of the Tune pot to about 4 times the normal decay time.

The other three mods for the BD circuit involve three new knobs:

3 - **Drive**. The BD oscillator produces a triangle wave, which is rounded somewhat to make it more like a sine wave, by two back-to-back diodes, which turn on around 0.5 to 0.6 volts above and below ground. This pot enables a range of drive levels to these diodes, from about 0.9 of the normal level to about 10 times the drive, which is achieved with the pot turned fully clockwise. This results in a somewhat larger signal, with clipping resulting in a signal closer to that of a square wave than a sine wave.

4 - **Tune Depth**. Normally the internal CV which controls the frequency of the BD's oscillator starts at a higher frequency than normal (see the description of the Tune pot above), and sweeps down to the normal frequency. This new pot enables us to control the degree to which this happens, from no effect on the oscillator frequency to about twice the normal amount of sweep. Colin's mods' maximum range is set by replacing R28 (150k) with a 300k. I don't have 300ks handy, so I use a 330k and the maximum amount of sweep is therefore 2.2 times the normal amount.

5 - **Pitch**. This controls the pitch of the BD oscillator. The lowest frequency is about 0.43 of the usual frequency, and the highest about 4.7 of the usual frequency.

Snare modifications

The most significant of the two parts of the Snappy signal is changed in that it is has more mid-range, and so is louder and gutsier, its envelope is potentially shorter and potentially longer (both ends of the range of the Tone pot are extended), the decay of this portion of the sound is closer to exponential, and there is no longer a 24 ms flat part to this envelope, before the decay starts.

The lower range of the Tune pot is extended so that for the main part of the SD sound, if this control is between ACW (about 7 o'clock) to about 10 o'clock, the two SD oscillators do not run for most of the note. There is still a pulse to the final frequency CV at the start of the note which causes the two oscillators to run briefly then. This pulse is the same for all SD notes, and is not related to the accent level. This brief period of the oscillators running produces a short "bump" sound, the pitch of which depends on how far ACW the Tune pot is turned.

The SD signal is composed of four elements:

1 - A VCO1, which has its own VCA (these are very crude, single transistor, Voltage Controlled Amplifiers) Q50 driven by a decaying envelope (C70) which starts its decay with a pulse at the start of the note which is in proportion to the accent level for the SD. So for higher levels of accent, the capacitor starts off at a higher voltage and takes longer to fall, with a natural exponential decay, to a voltage which no longer causes signal to flow through the VCA.

VCO1 creates a triangle wave (at the left of R283) and this is rounded to a rough approximation of a sine wave by back-to-back diodes D65 and D66. The frequency of VCO1 is determined by how positive a voltage is on pin 14 (positive supply) of some inverters, driven by the op-amp driving R250. A mirror negative version of this voltage drives pin 7 (negative supply) of the inverters. This pitch voltage also drives VCO2 in the same way. It is set by the sum of a voltage from the Tune pot and a short rising and falling pulse (ENV1, on C56) which occurs at the start of the note, and is the same for all notes without regard to the accent level.

2 - A VCO2, tuned somewhat higher, with its own VCA Q51 driven by a different envelope (C79) in the same manner as above.

3 - Some filtered noise, with its own VCA (Q41), driven by a short envelope ENV5 which is the same irrespective of the accent level. The output of this circuit, which is quiet and very brief on its own, and which I think is inaudible in the presence of the next signal, is added to that signal and sent to the Snappy pot, which is a volume control for these two noise components of the SD sound.

4 - Some noise, via a different filter, which goes through its own VCA (Q48) and likewise to the Snappy pot. However, the envelope ENV4 driving this VCA has its starting voltage set by the accent voltage, via D60. More on this circuit below.

The first modification is a **Snappy External Signal Input** by which an audio signal can be used in place of the internally generated noise signal for the creation of the two components of the Snappy signal. The noise generator is a digital system using two 18 stage shift registers (see the top of the HCP schematic below), which produces a recurring sequence of pseudo-random ones and zeros, as high and low voltages. (The TR-808 uses a noisy transistor, so its noise source is genuinely random and non-repeating, with a spikier characteristic to its waveform.)

This input is a 3.5mm socket, and if you plug a lead into it, and send it a line-level signal (anything up to +/- 15V is fine), then your signal will be high pass filtered and sent to the VCAs mentioned in points 3 and 4 above. These VCAs distort the signal to some degree, and you should experiment with different signal levels, and all sorts of sounds, such as brash chords, reverbed distorted signals of any kind or whatever you like. For instance, if you modulate some white noise via an external VCA, with an oscillator at 100Hz or so, then these pulses of noise will be used for the Snappy component of the SD sound.

In the modified circuit, the raw 0 to 15V digital noise signal passes through R286 (10k, in the left centre of the SD schematic) and this is applied to the NC (Normally Closed) contact of the 3.5mm socket. When nothing is plugged into the socket, this signal goes to the main contact, and on to the rest of the circuit. (If you gently insert the plug, it will touch the main contact without opening the main contact's connection with the NC contact, so your lead will have the internal noise generator signal imposed on it.)

In the original circuit, R286 drove R285 (3.3k) to reduce the signal level to 1/4 of the 15 volt digital signal. The result passes through C85 as the first stage of some high pass filters. In the modified circuit, R286 is 10k, so the signal driving C85 is theoretically twice as high.

The main contact of the Snappy External Signal Input socket drives this junction of the new R285 and the C85. So the input impedance your signal faces is about 10k ohms. Any line-level signal in your studio can be used to drive this – not a signal straight out of a microphone or electric guitar. Generally you will need a high signal level.

The rest of the SD modifications involve no new controls, and all relate to signal 4 (in the list above), which is the most prominent component of the two noise components which pass through the Snappy pot to the output of the SD circuit. (The two oscillators' VCA outputs are always mixed fully into the SD circuit's output. The Tuning pot affects both their frequencies, and has no effect on the Snappy circuits.)

I have boosted the mix level of the output of the Snappy pot, by placing a 22k resistor in parallel with R294 (47k). So this is 13.4k instead of 47k, leading to 3.5 times the signal level, which is about 10dB. However, see below for the new value of R279 which reduces the signal level. The usual maximum level of Snappy signal can be selected by setting the Snappy pot less then fully CW, to compensate for this extra gain and for the doubling of the noise level due to the new value of R285.

The rest of the changes to the SD circuit mean that it is not capable of producing the sounds it produced before the modifications. (It is also possible that the change to R285 changes the nature of noise signal in some way other than level, in which case discerning ears *might* detect sound quality differences due to that mod alone.) These mods are for people who want something different from their SD circuit. These are my ideas, based on my tastes, and I hope some other people will share them.

The envelope of circuit 4 (above) does not resemble any ordinary physical process, for four reasons, each of which I regard as a problem to be solved.

1 - It stays at its maximum level for about 24 ms (milliseconds) before the decay begins.

2 - Its decay is faster than the normal, natural, exponential decay due to the discharge path (VR7 500k – the Tone pot – in series with R254, 100k) being to a negative voltage, rather than to zero. (A charged capacitor with a resistor to ground will decay exponentially, halving in voltage after a certain time, halving that again after the same period has elapsed again, forever approaching zero, but never quite getting there. This exponential decay is also found in the natural decay of sound in a reverberant space, or in many but not all, plucked string instruments.)

Even if it was a natural exponential decay, with no such problems, this would not result in an exponential change of volume in this part of the snappy signal, due to two further problems.

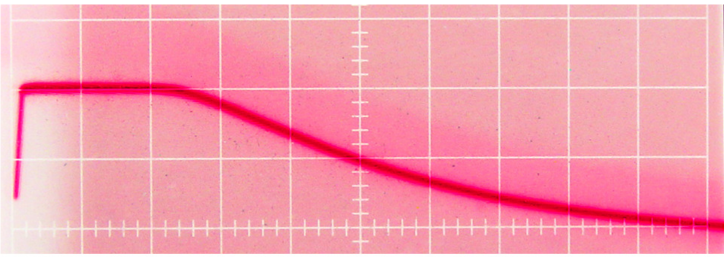
3 - In about the top half of the voltage range, such as above 8 volts, I think there is little change in VCA output, due to the transistor Q48 being very much turned on. Perhaps this depends on the beta (gain) of individual transistors, and so might be different from one TR-909 to the next. Therefore the volume envelope doesn't drop as quickly as it should in the first part of the decay.

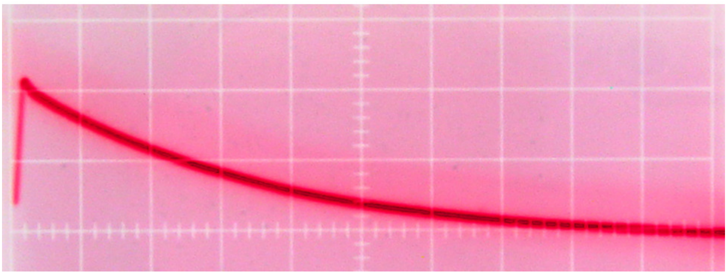
4 - These single transistor VCAs are rather crude, and when their input voltage, via R297 in this case, is below about 0.4 volts, they do not let any signal through. This will vary somewhat with temperature, with the threshold voltage dropping slightly at higher temperatures.

    So even with a natural exponential decay, the volume will drop off rather suddenly as the envelope voltage drops below about 0.4 volts, with no appreciable sound after that.

Four changes solve these four problems, resulting in a much more natural decay to this, the major component of the Snappy signal.

1 - C68 is removed, which eliminates the 24 ms flat start to the envelope. The inverse colour scope traces below show the original envelope at the top and the new one at the bottom. This is 10 ms and 0.5V per division. As noted below, anything below about 0.4 volts will produce little audio signal.





The original waveform made a longer noise blast like a steam valve opening and shutting. This might have been the fashion for *fat* snares in the 1980s, but I choose to make it a more natural audio-style decay now, with options described below for shortening or lengthening it.

2 - This fixes both problems 2 and 4. R254 (10k) is disconnected. Instead, the wiper and CW end of the Tone pot VR7 is driven by a voltage divider which produces about 0.263 volts. This is produced by a 10k resistor to ground and an 820k (560k in the first TR-909 I worked on) to +15V. This is far enough below the approximately 0.4 volt threshold of the VCA control input (Q48 base) that there is no significant continual background noise when the SD is not triggered. It is high enough to make a much more natural sounding decay to the actual sound level of this part of the Snappy signal. This end is not, of course, exponential in the true sense. For that to be the case, the bias voltage would need to be about 0.4 volts, and ideally produced by a transistor circuit so it reduces at higher temperatures to match the behaviour of Q48. While not perfect, it is a good sounding exponential decay to my ears.

(Some other drum circuits in the TR-909, involve decays of exponential envelopes which do result in good exponential volume changes, due to the fact that a capacitor is discharged through a resistor into the base of the transistor, with this being the only discharge path. Therefore, the current is naturally exponential, whatever the critical voltage of the transistor. I didn't want an exactly exponential decay to the Snappy signal, since this would tend to produce low levels of noise which are still clearly audible some time after the main pulse.)

This also changes the minimum decay time (with the Tone pot fully ACW) to be much shorter, since the fastest decay is now via the resistor divider, which is slightly less than 10k to 0.263 volts, whereas previously it was via R254 (100k) to a slightly negative voltage.

3 - This problem is caused by the current from R297 (220k) into the base of Q48, at about 0.4 to 0.6 volts, being too high. So I change it to 470k. This reduces the overall signal level produced by Q48, but other changes mentioned above boost the level of this part of the Snappy signal more than this approximately factor of 2 loss.

So now this envelope voltage closely resembles a natural exponential decay (to a 0.31V endpoint, rather than ground, and rather than the negative endpoint of the original circuit), starting immediately after the start of the SD trigger. The VCA (Q48) more faithfully creates an exponential decay to the noise signal from this envelope.

The final change for the first TR-909 is to add a 0.1uF capacitor across the 0.022uF C80 capacitor, which forms a high-pass filter for the noise signal which is sent to this pathway 4, via the Q48 VCA. So the cutoff frequency is significantly lower and there is more mid-range noise, giving an overall louder and gutsier quality to this aspect of the SD sound.

For the second TR-909, I noticed a slight fizzly sound in the Snappy signal for a second or two after each note. This was due to C73 (470pF) discharging not to 0 volts, but to some low voltage such as 0.3 volts or so, where the BE current of Q47 was very low indeed. This charge would persist for a few seconds, causing an output signals at the very peaks of the filtered noise signal on the collector. So the final mod for this machine was to add an 8.2M (10M would be fine too) across C73. I am not sure to what extent this was a problem with the first machine. Perhaps it was only a problem when Q47 was a BC547, as mentioned next.

In October 2018, when I was working on the second TR-909 with these mods, there was a problem with excessive continual hissing when the Snappy pot was turned up. The problem was collector to base leakage in Q47, slightly turning the transistor on at all times, unless the current was shorted to ground experimentally. I replaced Q47 and Q48, both of which are controlling the level of noise for the SD Snappy circuit, since if one of this type (2SD1469-R) and batch is leaky, so might the another be in the future. I used ordinary small signal NPN transistors – BC547 – which have a different pinout. From rear to front, the pins of Q47 and Q48 are BCE. Some level of continual noise will be present in the Snappy circuit, due to the capacitance between collector and emitter of these transistors, but this leaky Q47 was causing excessive noise. I replaced it before applying the abovementioned 8.2M to C73. That might have been sufficient to quell the leakiness of this transistor, but there is always a chance of the leakage getting worse in the future.

Hand Clap controls and external signal input

The Hand Clap circuit is similar to that of the TR-808, which filtered noise is fed to the output in a series of short, decaying, pulses for the direct hand clap sound, and in a longer, softer, more slowly decaying signal for the pseudo-reverb sound.

In the TR-808 there is an analogue noise generator, which drives the SD, Toms, HCP and MA circuits, while in the TR-909, there is a digital noise source, using a shift-register and some logic, which drives the HCP and some other circuits.

The digital noise source is really a repeating random-looking waveform and is consistent for all machines, according to the frequency of its oscillator, which would vary a little between machines. That said, I can't hear the repeating nature of the signal, and without looking up the math of the shift register XOR pseudo-random bit generator, I can't easily tell what the repeat cycle time is. The analogue noise source in the TR-808 is a noisy transistor, amplified, with a trimpot to control the level and so cope with variations in noise level between one particular transistor and the next.

I think the quality of the noise is different, with the noisy transistor producing a more spiky and of course genuinely random and non-repeating signal.

In the TR-808 mods, I have a front panel pot which controls the level of the noise signal, which affects all the circuits which use it. So turning it up will drive stronger noise signals to the two components of the HCP sound – the clap pulses and the pseudo-reverb longer, softer, pulse.

In the TR-909 mods, the noise level remains constant. I leave the pseudo-reverb circuit the same (except for the external signal input described below) as the standard TR-909. I provide an **Intensity** pot which controls the amount of noise signal which is presented to the VCA (a BA662) for the generation of the clap pulses. This pot enables the signal to be turned off (in which case we still hear some clicks from the VCA, due to feed-through from the pulses of control current). Turned up somewhat, it enables the normal level of signal. Turned fully clockwise, it allows a greater signal level than normal – theoretically 10 times the normal level. The actual level boost is hard to measure, and is subjectively not that extreme.

This mod is achieved by replacing R201 (1k) with a 10k linear pot.

The VCA is driven with a series of short pulses, like a few cycles of a sawtooth wave, with the rising edge being louder and the sloping edge which follows leading the VCA output to be quieter. The overall level of these pulses, and the degree to which the drive the VCA continually, rather than constituting separate pulses, is controlled in the TR-909 by a trimpot (TM) which drives (via R494) one base of the dual PNP transistor Q38 (which functions along the lines of a log to linear converter, to make the sawtooth peaks very high indeed).

The **Density** pot is, like trimpot TM, is connected between GND and -15V. It drives this base of Q38, via a 150k resistor. I adjust TM to give a good range of pulse densities for the Density pot: ACW (anticlockwise) there are almost no pulses and CW (clockwise) the pulses join to be one long pulse.

The **Reverb** toggle switch, when in the down position, disables the pseudo-reverb section by shorting out C61.

The **External Signal Input** socket normally passes the noise signal on to the filtering section, whose two outputs drive the claps section and the pseudo-reverb section, via R208 (47k). If you plug an external audio signal, such as noise, a chord sound or whatever, this will be used in place of the internal noise signal for generating both parts of the Hand Clap signal. This does not trigger the Hand Clap – only the CPU can do that (from the internal sequencer or MIDI In). The signal you put in will be processed to generate the output of the Hand Clap circuit, whenever it is triggered. Be sure to experiment with different signal levels for this input. You can't overload it, as long as the signals are within +/- 15V or so.

If you gently insert a lead into this socket, so its tip touches the contact, without lifting the contact of the NC contact it normally rests on, then this will drive the internal noise source's signal onto your lead.

The most obvious way to implement this external input is to break the circuit where R208 connects to the junction of R209 (10k to ground) and the two filter capacitors C42 and C43. However, this does not work if the external signal impedance is low, which will frequently be the case. However low that impedance, this becomes the impedance of this junction within the filter, and its impedance at that point is supposed to be 47k in parallel with 10k (8.2k). This lower impedance, which will result with an external signal with an impedance of less then 47k, disrupts the filter's frequency response and can lead to self-oscillation above audio frequencies..

The solution is to replace R208 with two resistors: 15k and 33k, which total near enough to 47k. Install the 15k in place of R208. Cut the short track from R208 to C42 (the just-mentioned junction). That now-isolated end of the 15k goes via a wire A to the NC contact of the 3.5mm mono jack which accepts the external signal input. Assuming this is a ribbon cable, the second wire B will be ground. The third wire C (so having no capacitive coupling with the noise signal on A) is the contact of the jack and returns either the internal noise signal, or the externally applied signal, back to the filter. The PCB end of wire C goes to a 33k and the other end of the 33k goes to the pad on the other side of the cut, the junction between C42, C43 and R209. Now, the impedance of the junction will be at most 10k, with a very high impedance input, or as low as 10k || 33k = 7.7k, which is near enough to the original 8.2k.

Hi Hat Tuning

A new pot enables the frequency of the Hi-Hat oscillator (which controls the playback speed of the audio sample stored in ROM), from about 0.43 to about 1.7 of the original frequency. The actual range will vary from one machine to the next

Colin's mods involve a 22k pot in series with 6.9k resistor, replacing R492, which is 12k. For the first machine I worked on, I used a 10k pot in series with a 5.6k resistor, and added 180pF to C160, which is a 470pF. For the second I used a 10k pot with a 4.7k resistor, and replaced C160 with a 0.001uF capacitor. If the tuning is pushed too high, the oscillator will stop, so you may need to experiment with the resistor and/or capacitor value to ensure this does not occur.

I also check that C134, which drives the final amplification stage, is 0.01uF, rather than 10uF.

When working on the second machine in October 2018, I noticed a problem with the Open Hi Hat which may have been present in the first machine, but which escaped my attention then. When the HH tuning is low, and the OH decay is short, there is a second soft burst of HH sound some fraction of a second after the main burst. This was due to the emitters of the dual PNP transistors Q84 being driven strongly negative and this somehow causing current to flow out of the right transistor's collector and so turn on Q85. The solution is to install a diode (1N4148 is fine) with its cathode to the emitter pin of Q84 and its anode to ground, so preventing all negative voltages greater than 0.6 volts.

Document history

- 2018-04-25 Initial version for the first TR-909 I modified.
- 2018-10-10 This reflects my work on the second TR-909 I modified.

  Changed description of HH Tuning circuit to use a 0.001uF capacitor and a 10k pot with 4.7k resistor.

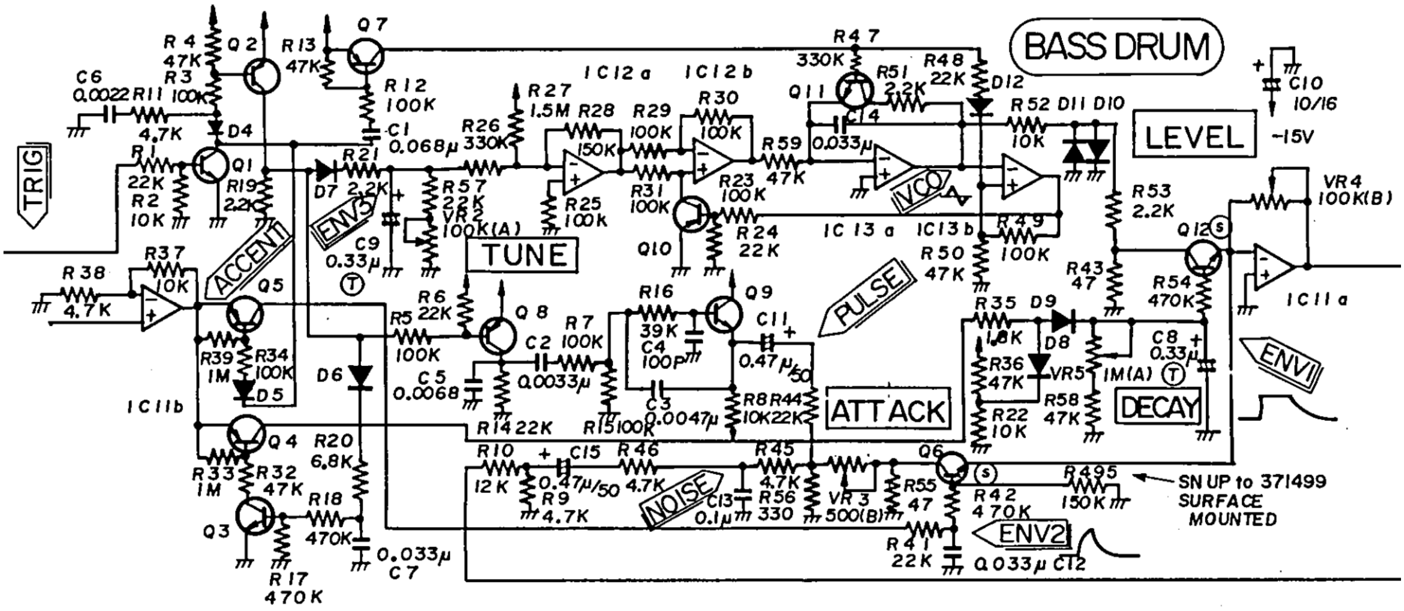
  SD Tone pot VR7 divider uses an 820k resistor instead of 560k, to ensure there is no continual noise even if Q48 (and the whole of the drum machine) is at a higher temperature and so has a lower BE voltage at which significant current starts to flow..

  Added a note about leaky Q47 and Q48 transistors in the SD Snappy circuit.

  Added an 8.2M resistor across C73.

  Added a diode to the emitters of Q84 to stop a soft second pulse of HH sound when the HH tuning is low.

  Added a detailed description of the HCP External Signal Input circuit. I did not use this 15k and 33k arrangement on the first machine I modified in March 2018. It worked fine with a low impedance drive, but the filtering would not have been as it should be. When I tried this with the second machine in September 2018 there was self-oscillation and so the circuit did not work at all.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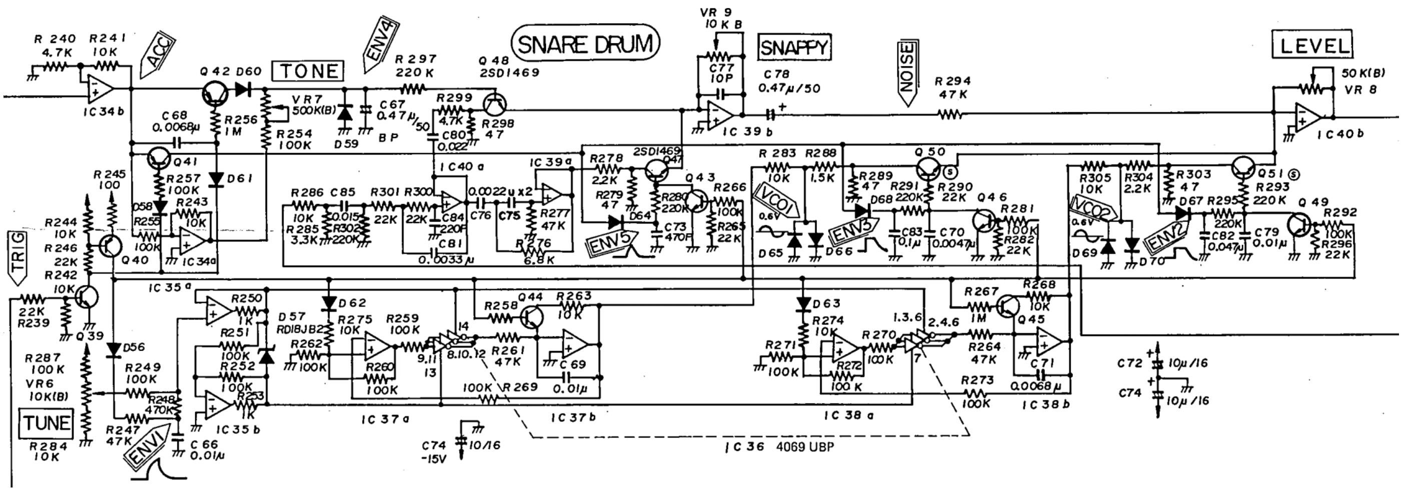
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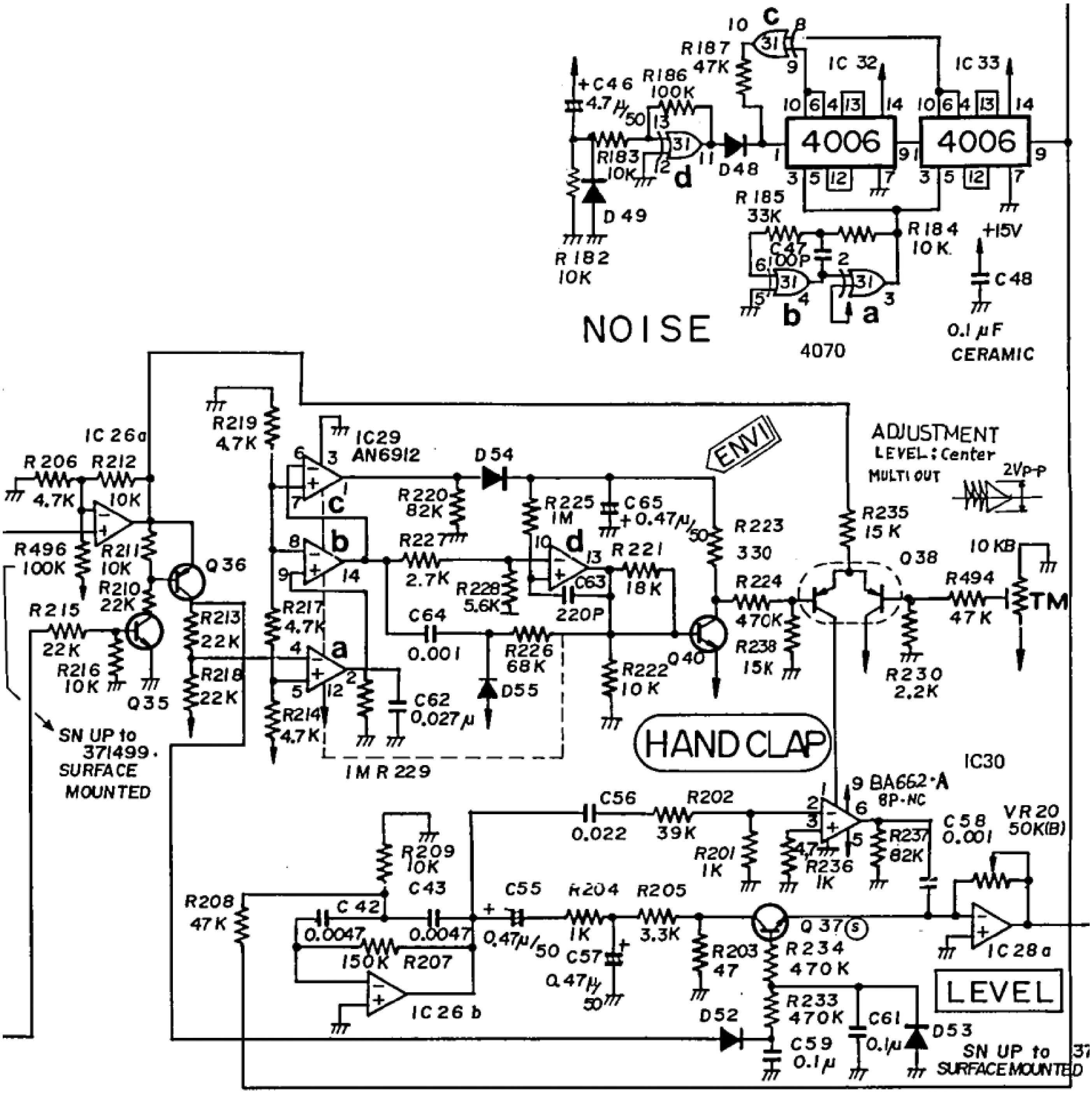
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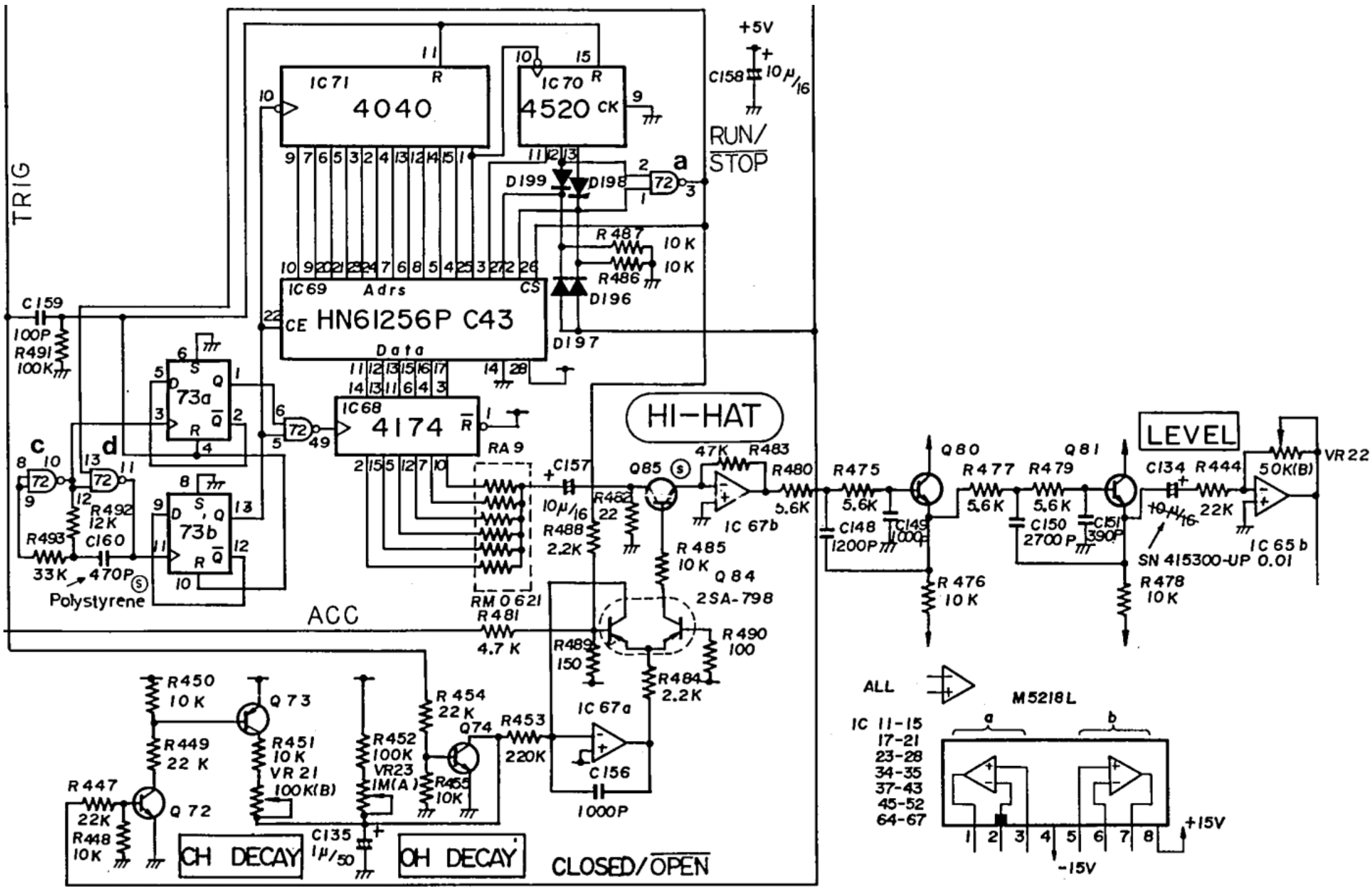
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10μ/16
R444
22K
50K(B)
VR22
IC 65b
SN 415300-UP 0.01
R492
12K
C160
R493
33K
470P
Polystyrene
73b
RM 0621
R481
4.7K
ACC
R489
150
R490
100
R484
2.2K
R450
10K
Q73
R449
22K
R451
10K
VR 21
100K(B)
R452
100K
VR23
1M(A)
R454
22K
Q74
R453
220K
IC 67a
C156
1000P
R455
10K
R447
22K
Q72
R448
10K
CH DECAY
C135
1μ/50
OH DECAY
CLOSED/OPEN
ALL
M5218L
IC 11-15
17-21
23-28
34-35
37-43
45-52
64-67
+15V
-15V