THE SOL-20 KEYBOARD'S CAPACITIVE KEY DETECT CIRCUITRY.

HARDWARE DIAGNOSTIC TOOL FOR THE SOL-20 COMPUTER.

H. Holden. August 2020.

THE SOL-20's KEYBOARD CAPACITIVE DISCS:

Before discussing the circuitry which processes the signals from the capacitive keyboard, its worth looking at the keyboard materials.

On measurement, the original arrangement uses a 0.07mm thick dielectric (possibly mylar or polyester) on a foam disc with the conductive layer sandwiched inside the 0.07mm thick dielectric sheet. I suspect that it was made from two 0.035mm sheets with the metallized film applied to one sheet surface and the other sheet applied to that.

Assuming the metallised layer was in the middle of the 0.07mm total thickness, (which it appears to be), the metal layer then sits about 0.035mm from the dielectric's surface. This was difficult to tell exactly, the metallized coating may have been closer to one surface and further from the other.

The actual disc is about 11mm diameter. Calculating the surface area of these discs, then halving it to give a surface area for half the disc and scaling that down by an approximate factor of 0.85 (to allow for the split in the pcb tracks, between the two half discs on the actual pcb) yielded a value of close to 4 x 10^{-5} square meters for each "half disc".

An experiment, connecting fixed capacitors across the connections on the keyboard indicated that it takes around 15pF of capacitance increase to trigger the key detector circuitry reliably. What can we learn from this?

1) From this information it is possible to calculate the maximum thickness that any metal coated dielectric should have and still be able to work.

2) The voltages generated by the keyboard switch closure can be calculated or run in a Spice engine and then the expected minimum gain of the transistor amplifier can be calculated.

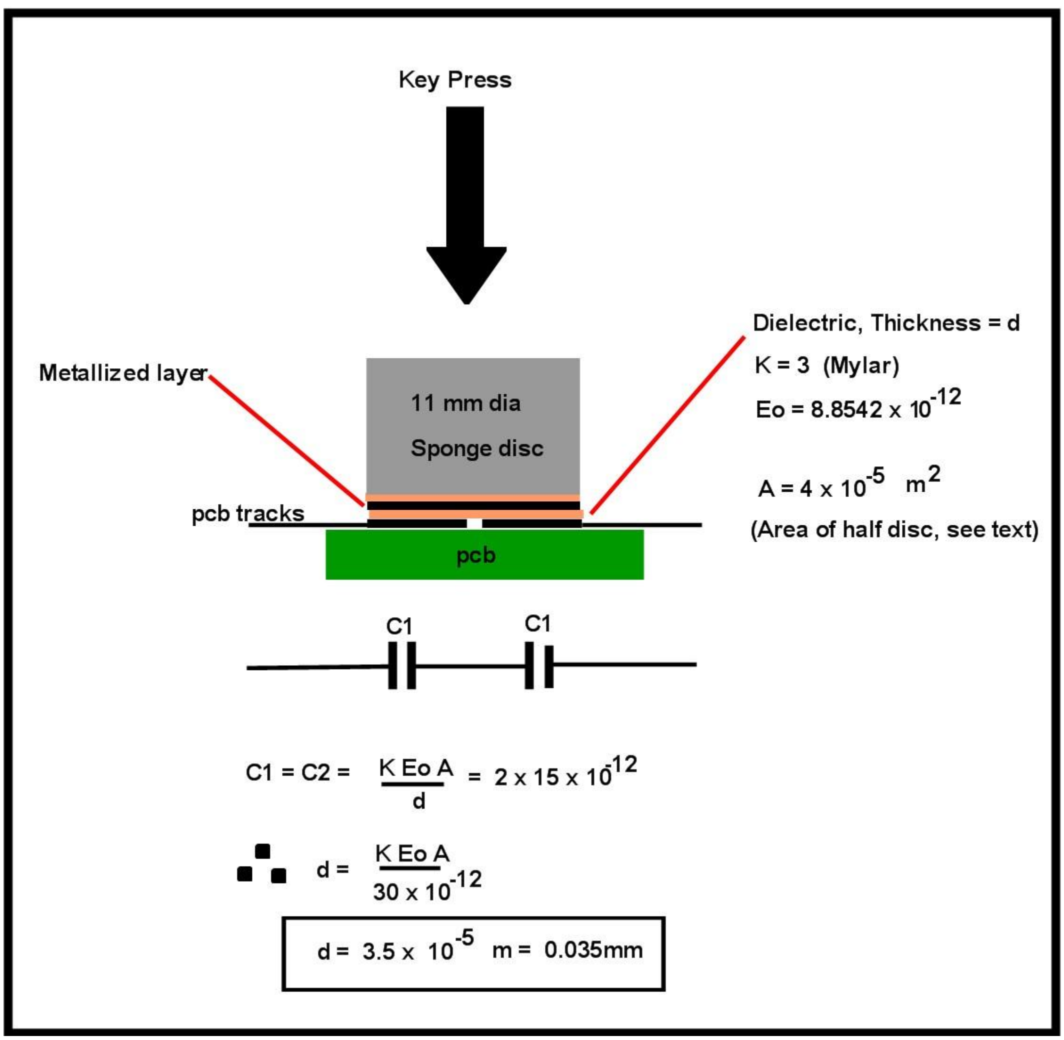
This can be compared with the actual circuit used to see if the information agrees.

Also, one can calculate the minimum current amplification (hfe) of the input transistor in the capacitive switch detector circuit. It appears that these transistors were selected for current gain at the factory. They had colour coded paint on them in some keyboards. There is a large spread in the hfe for these transistors (type 2N3640) ranging from 30 to 120. A specimen with an hfe of 30 or 40 would not be as suitable for the task as one in the range 70 to 100.

When the key is closed, the architecture of the metallized mylar disc and the keyboard's pcb pads creates ***two capacitances in series***. So to attain an overall capacitance of at least 15pF, each of those capacitors, created by the key press, needs to have a value of at least 30pF.

The panel below shows the calculation for a ***minimum overall capacitance increase to 15pF***, with mylar as the dielectric material, with a K (dielectric constant) of 3.

The maximum dielectric thickness, on this calculation, to attain an overall 15pF increase in capacitance (which just reliably triggers the keyboard) is 0.035mm. ***This calculation agrees closely with physical measurements on the original disc material.***



Examination of the actual original disc material from the Sol-20 keyboard suggested the dielectric thickness, from the surface to the metal layer, was probably somewhere in the vicinity of 0.035mm, which would raise the total capacitance to around 15pF on key closure.

I think the reason why some of the recent manufacture keyboard replacement discs wouldn't work reliably in the Sol-20 keyboard is that either the dielectric material was too thick, or the dielectric constant of the material was too low, or possibly both. But the main issue was, with the ones I tried, the metallized coating was on one side of the dielectric film. So while the overall thickness of the dielectric film was about correct, the spacing between the metallic layer and the pcb track pads on the keyboard was about double the thickness it should have been. Therefore the capacitance only rose by about 7 to 8pF on key closure, not enough to reliably trigger the keyboard detector circuits for all keys.

It will be shown in this article how the characteristics of the capacitor switch detector transistors Q8 and Q6, in the keyboard's switch detector circuit, ideally would have a current gain (hfe) minimum of 70 or greater. This is so the 15pF capacitance increase, on key closure, is enough to be reliably detected as a definite key closure. Under marginal conditions, where the replacement metallized mylar films are a little too thick and the capacitance increase on key closure borderline low, some particular keyboards might function and others not due to the hfe of the particular transistors.

The better replacement discs to restore a Sol-20 keyboard are harvested from the SUN-4 keyboard. The original SOL-20 discs were exactly 11.2mm diameter. The ones from the SUN-4 are 11.0 mm diameter. However in the versions of the SOL-20 keyboard where they click into position, this difference is not enough to cause any trouble retaining them.

In some SOL-20 keyboards, the discs were glued into place on the bottom of the nylon plungers and do not "click into place" as the small arms that hold them are not present on the white nylon plunger mechanism.

SOL-20 KEY SCANNER CIRCUIT:

This circuit is worth some discussion as it is quite interesting. This article is not to fully study the keyboard's logic (which is already outlined in the Sol hardware manual) but to primarily look at the Analog part of the keyboard.

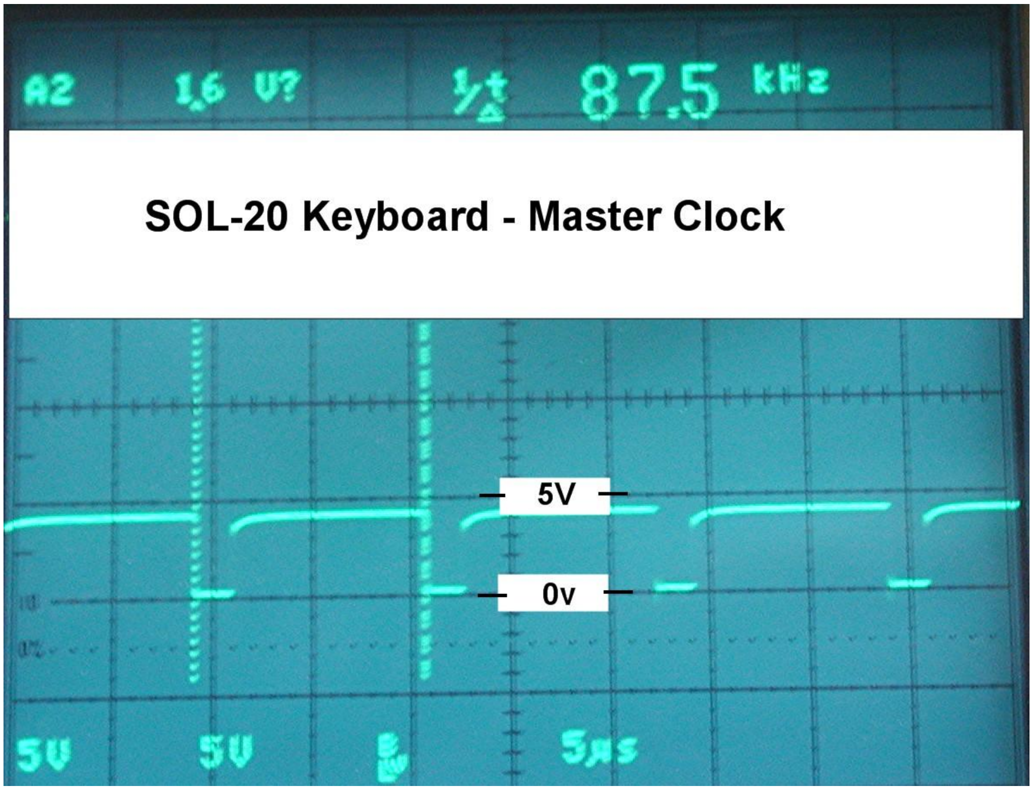
Keyboard's Master Clock:

It says in the SOL-20 manual that this clock, based on a NAND gate U7 (pin 11) wired as a Schmitt trigger and oscillator and is a "3uS clock". Testing shows it has a period closer to 6uS, consisting of 2uS being high and roughly 4uS being low. And after it is divided by the flip flop U6, the measured frequency was around 87kHz on my keyboard, or a 11.5uS clock.

As noted in the manual, U7 produces a two phase clock 01 & 02.

01 clocks the key-scan circuit and 02 clocks the output latch U14.The theory here is that noise pulses will have a shorter duration than a key press, so noise pulses will largely get ignored. However, the noise pulses are largely ignored because they are lower amplitude than the key press pulse and don't reach the trigger threshold.

The scope recording shows the master clock output 01:



From the electrical perspective, the keys themselves are arranged to link (capacitively) a row and a column conductor, on a matrix.

Data (digital pulses) with rapid rising and falling edges from the outputs of two 7442 BCD to DECIMAL decoder IC's (U17 & U21) decode their BCD drive signals into one of 10 outputs, 8 of which are used on U21 and only 7 are used on U17, to drive ***15 columns*** of the key matrix.

The key matrix has ***16 rows***, which are tied to +5V with 33k pull-up resistors. These feed the 16 inputs of two CD4051 analog de-multiplexer switch IC's, which pass their outputs to the transistorised pulse detector circuitry.

The arrangement is such that the 7442's ***drive the columns*** and the CD4051's ***look at the rows*** sequentially to detect key closure and pass that signal out to two transistorised amplifiers (to be discussed below) where the output of each amplifier is threshold detected and combined into a common pulse called "OUT".

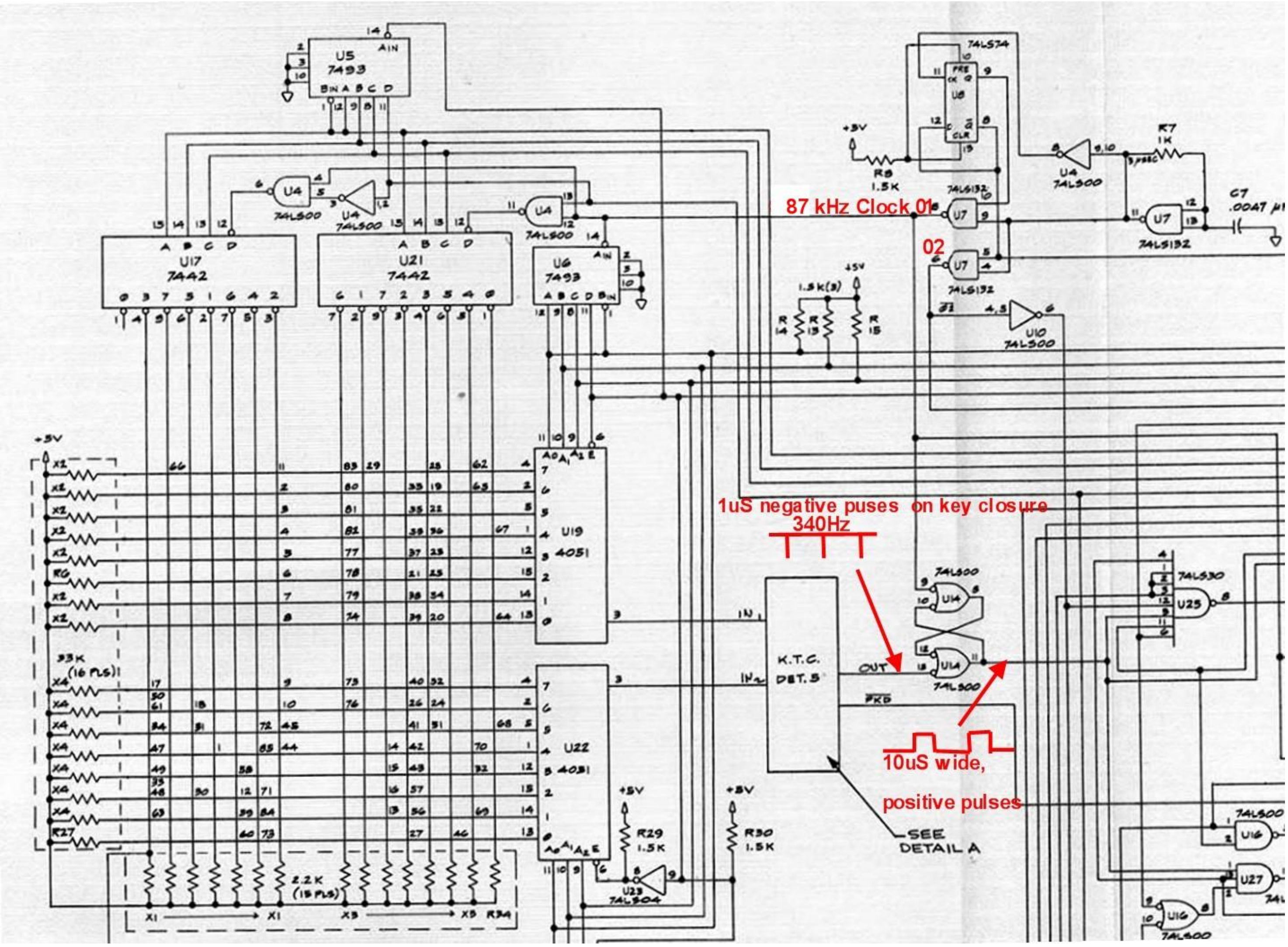
The OUT signal from the transistorised key detector circuit, is a negative going pulse from transistor Q2, has approximately a1uS duration with key closure. This OUT pulse passes into a latch, U14, which is also driven by the 87 kHz (11.5uS) master clock. This lengthens the output pulse (on pin 11 of U14) to close to 10uS duration.

The transistorized key detector responds to the *falling edges* (negative going) of the pulses from the 7442 IC's. It is an R-C capacitive coupling method where the rectangular voltage pulse is differentiated.

Since the selected row signal, or the connection to the row conductor, which consists of the pcb pads and tracks, still has a small capacitance to the column tracks (probably in the order of a few picofarads), then even with no key is closed, there is still some capacitance linking the rows and columns of the key matrix together.

Therefore some key-scan pulse edges are passed to the transistor amplifiers, even with no key is pressed. However, when everything is normal, the pulse amplitude is below the voltage threshold to be detected as a definite key closure. It requires (by experiment) that the capacitance between the column and row conductors increases to at least around 15 pF to generate a pulse which gets to a high enough level to overcome the threshold detector settings, provided by transistors Q4 and Q3.

The arrangement from the Sol-20 hardware manual is shown below:



When a valid key-press has been detected by the sequence detector logic, the line **/PKD** is driven low. This line lowers the threshold in the transistorized key detector circuit. This is a form of hysteresis which results in a solid output signal from the transistor circuit. As explained in the Sol Systems manual, for this to occur, the key must be detected twice. This helps noise immunity.

The 87kHz clock, directly clocks U6, a 7493 counter to generate the column select data on its output lines A,B,C,D.

Outputs A,B,C (the 1,2,4) binary signals control the select inputs of the CD4051's, which selects the rows, and D is used to enable the CD4051 U19. From the count 0 to 7 (decimal) U19 is making selections, but at the count of 8 decimal, U19 is disabled by the D output of the 7493 IC U6, going high.

However, because D is inverted to feed the enable input of U22, then from count 8 to count 15 decimal, U22 takes over and does the row selection instead of U19. During this total count of 0 to15, the total of 16 rows are selected while the column selection stays unchanged.

Once the D output of U6 falls low, this clocks U5, another 7493, which also counts every time the 16 row selects have been cycled through once. This count is decoded into outputs from the 7442's. The net effect is that for each column selected, there is a full scan of the total rows.

The 87kHz clock is strobed via NAND gates U4, into the 7442's D input (though in reverse logic state for U17 and U21) Therefore, regardless of the count value on the A,B,C inputs of the 7442's, there are ***output pulses on the columns***.

The column counter U5 and the row counter U6 generate a specific address for the key encoder circuitry to work with, so that when a key closure is detected, it corresponds to a known key on the matrix.

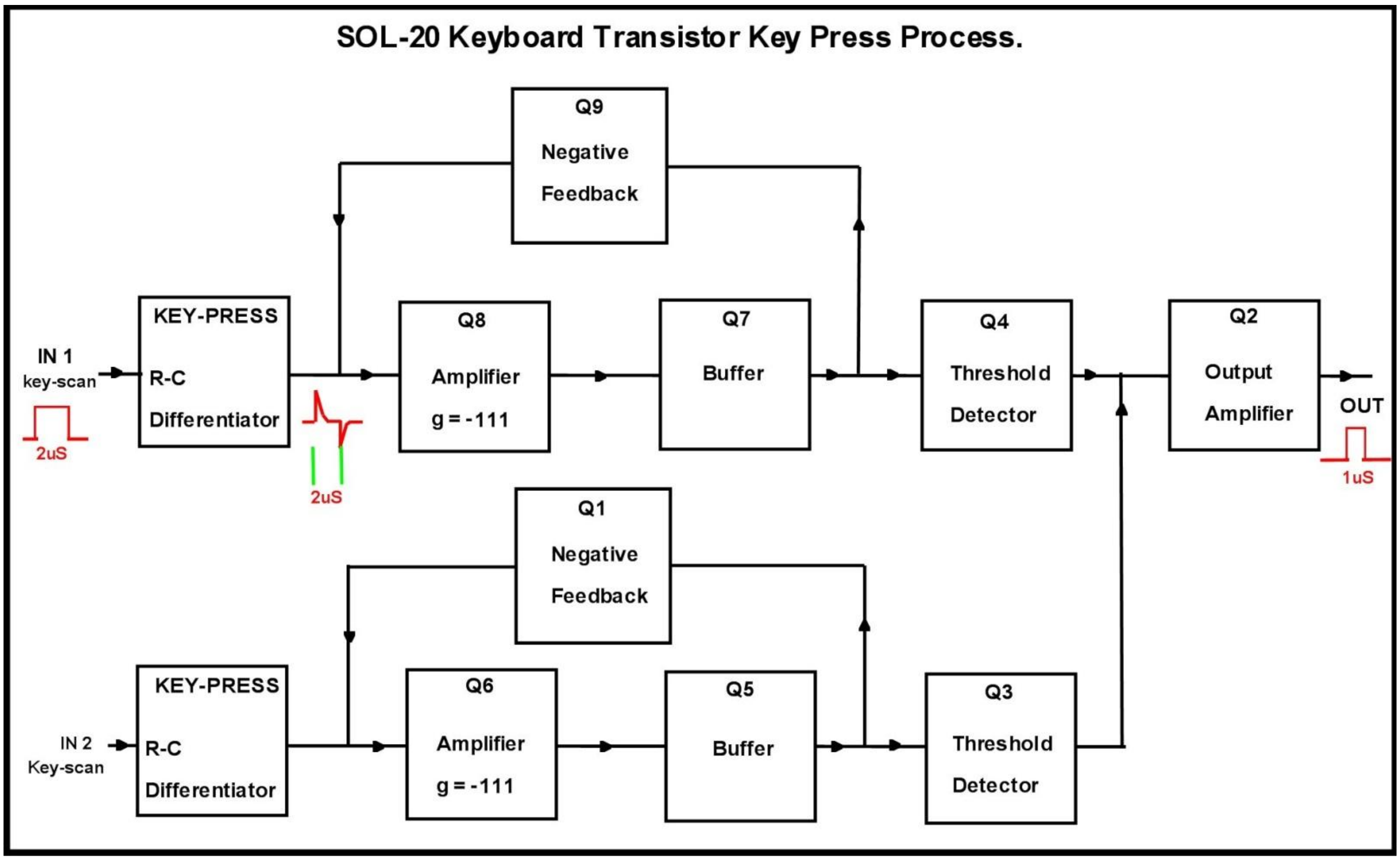
The outputs of the 7442 IC each has a 2.2k pull-up resistor so that the amplitude of the pulses is close to +5V, rather than the about 3V seen from a typical TTL totem pole output stage.

Only one column is active at any time. When these are active, they have impressed on them a positive going pulse with a period equal to the master clock, of close to 11.5uS and are high for about 2uS. When they are not active, the output of the 7442 IC pin assumes a high state.

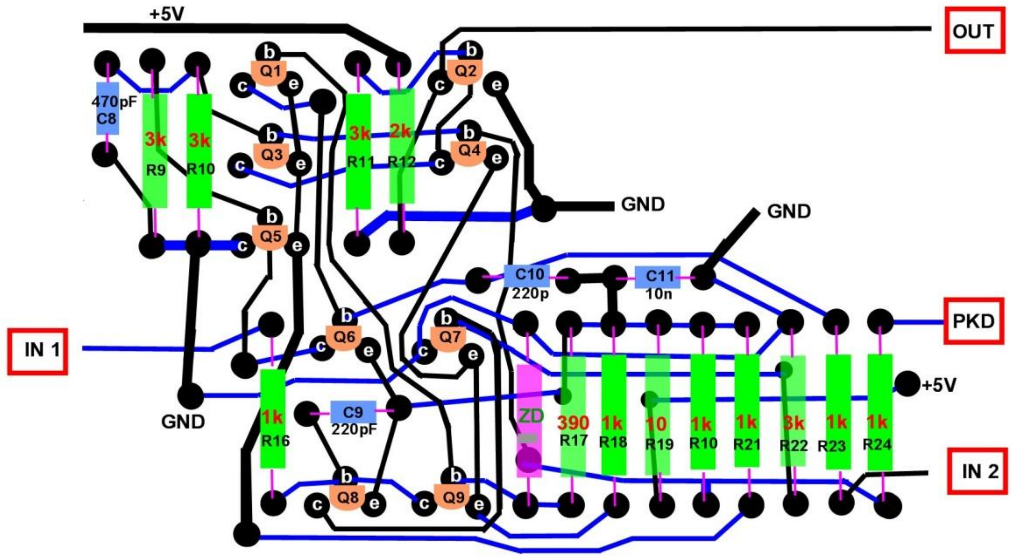
THE SOL-20 CAPACITIVE KEY CLOSURE DETECTOR CIRCUIT:

In a nutshell this is an amplifier constructed to perform as a high gain ***inverting amplifier***, with a voltage gain of around 111, to amplify the falling edges (*negative going)* pulses.

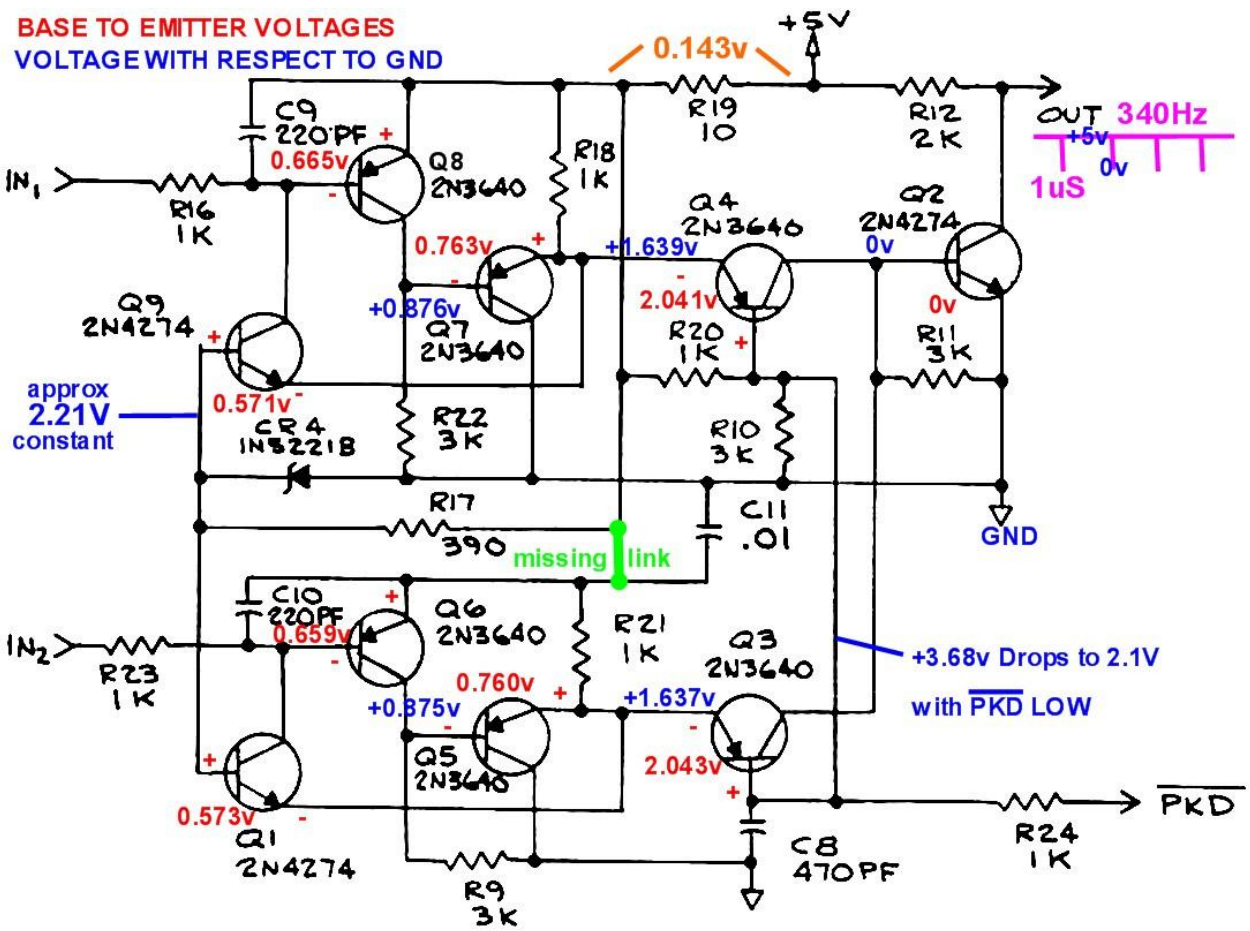
However, interestingly, the transistor circuit has low gain for a positive input pulse or a very low level input signal. This is explained below, but first a basic block diagram is shown below, to show the function of each transistor:



To help with servicing this keyboard I have drawn out the transistor layout as seen from above, the component side of the pcb. The black tracks are on top and the blue tracks are on the board's solder side below. This sort of diagram is very handy when checking this sub-circuit:



This is one of the most interesting parts of the keyboard design. The schematic is shown below and voltages have been measured to help the analysis:



SOL-20 KEYBOARD CAPACITIVE SWITCH DETECTOR

The key detector is a two channel amplifier. Q7,Q8,Q9 on input **IN1** perform the same functions as Q5,Q6 and Q1 on input **IN2**. So for simplicity the Q7,Q8 & Q9 channel is discussed.

Q3 and Q4 are threshold detectors (act as comparators) and both of their outputs switch Q2. R12 is listed as 2k, but it is a 3k in my keyboards.

The low capacitance of the closed key, in conjunction with the low input resistance to the transistor amplifier transistor Q8, differentiates the fast rising and fast falling edges of the key-scan signals. This acts to couple both the fast rising and fast falling key-scan signal edges into the amplifier.

The differentiation is such that about a 1uS duration signal is generated after the differentiated negative going pulse edge is amplified by Q8 (or Q6). Although the SOL-20 manual suggests 1.5uS, however, both of my keyboards produce a pulse closer to 1uS wide.

As will be shown, the amplifier ignores the rising (positive going edges) of the signal passed via the key's capacitance into this amplifier and only responds (with amplification) to the falling or negative going edges of the key-scan pulses.

The negative feedback around the amplifier Q8 is provided by Q9, a grounded base amplifier. This is unusual and has some interesting and helpful effects.

In this case the base of Q9 is tied to a fixed voltage of 2.21V which has implications for the feedback pathway. This uncommon configuration results in the ***negative feedback being uncoupled during key detection*** (see below).

In addition the base emitter threshold voltage of Q9, with a very small forward bias around 0.57V, acts as a comparator, in conjunction with the 2.21V reference voltage, to set the DC conditions of the amplifier with very low or no signal conditions.

Without a key pressed, the DC conditions of this amplifier can be easily checked with a digital volt meter (DVM).

Due to the nature of the design, with the DC feedback around Q8 (provided by Q9), the base-emitter voltages of the transistors under no key-press conditions will be close to correct if all of the transistors Q7, Q8 and Q9 are normal and in good working order (obviously this remark applies to Q5, Q6 and Q1).

This means that checking these B-E voltages will indicate if those six transistors are in good condition***.*** If the B-E voltages are close to normal on testing, then in all probability those transistors will be ok.

(An aside: when testing this amplifier with a DVM, connection of the meter to the circuitry around Q8 can result in instability and oscillation, upsetting the readings. A series resistor of about 10k Ohms can be placed in series with one of the meter probes, without altering the meter accuracy greatly, to prevent these effects. Typically a DVM has a 10 meg Ohm input resistance. Use of a x10 scope probe causes no difficulties).

It can be seen from the measurements shown that the base-emitter voltages indicate that all of the three transistors, Q7, Q8 & Q9 (and Q5,Q6,Q1) in the resting state (no key press) are in conduction.

To imagine how this comes about, consider what happens when the circuit is initially powered. Q7's base-emitter current flows via R22 to ground, this attempts to set (pull) the emitter voltage of Q7 down to around 0.7V above ground. As a result of this the emitter of Q9 has a lower potential than its base, the base of Q9 being clamped to close to +2.21V by the zener diode reference.

Therefore, base current flows in Q9 and so does its collector current increase. Q9 is a common base amplifier. This collector current of Q9 is also the base current for Q8.

Q8's base current results in an increase in its collector current, lifting up the base voltage of Q7, which also lifts up Q7's emitter voltage.

Therefore, after power on, the circuit, due to this negative feedback loop, results in just enough base-emitter current to keep Q9 in conduction and stabilize the DC conditions of the amplifier.

Note that the base-emitter voltage of Q9 is lower than Q7 and Q8's base emitter voltage. This is because Q9's base-emitter current is very very low. The B-E junction of a silicon signal transistors just starts to conduct around 0.55V, though most of the time we consider the B-E drop, like a silicon diode, with any significant forward bias, to be around 0.7V.

The circuit therefore, stabilizes its own DC conditions with the base-emitter voltage and base current of Q9 just on the knee of its conduction.

DC conditions (no signal) for the transistor amplifier:

In the no signal condition, the voltage developed across R22 is 0.876V, indicating a current of 292uA. This is mainly collector current from Q8 and a smaller contribution of base current from the emitter follower stage Q7.

The voltage across R18 is about (4.8 - 1.64) = 3.16V, so Q7's emitter current is 3.16/1000 = 3.1mA. Assuming Q7 has an hfe of 70, then its base current is only about 45uA. Therefore, Q8's no signal collector current contribution is about 292- 45 = 247uA.

If one assumes the DC current gain or hfe of Q8 is at least 70, then Q8's base current (Q9's collector current) is only in the order of 3.5uA and the base current of Q9 could be as low as 50nA, if Q9 also had an hfe around 70.

The very low base current of Q9 is the reason why Q9's base-emitter voltage is only 0.571V on testing and is significantly lower than that of Q8 and Q7 and does not reach the typical 0.7V base-emitter voltage seen with higher range bias currents. The bias arrangement also would be roughly equivalent to biasing the base of Q8 with a 1.2M resistor, from the base to ground, but that would not correctly set the amplifier's DC conditions and it would make the threshold detector more difficult to design.

The negative feedback pathway sets the entire gain of the amplifier at a low value for any very small input signal. But this is not the case for any ***significant negative going*** input signal. This is the interesting part of the design. Looking at both the positive going and negative going input signal cases:

If the base current of the input transistor Q8 is reduced by a *positive* going transient or pulse, Q8's collector current drops and the base voltage of Q7 falls, taking both Q7 and Q9's emitter voltage with it. Since Q9's base voltage is fixed, then this increases Q9's base-emitter current. This results in Q9's collector current increasing to neutralise the change caused by the positive going input pulse. For a positive going input pulse therefore, transistor Q8, has a very low voltage gain due to the feedback pathway via Q9. In addition, large positive going pulses tend to cut of transistor Q8.

The same applies for very tiny negative going signals, that is if the feedback pathway, via the grounded base feedback amplifier Q9, is not pushed outside its dynamic range and Q9 becomes cut off.

If the applied voltage transient at the input to Q8 is ***negative going***, then Q8's base current increases as does Q8's collector current increase too. This increases the voltage developed across R22 so it lifts the voltage of Q7's & Q9's emitter. As this occurs the feedback pathway via Q9 is significantly diminished, because ***Q9 is forced out of conduction*** by its emitter voltage increasing. Since Q9's base voltage is fixed, the voltage across Q9's base-emitter drops below 0.57V and Q9 becomes cut off.

When Q9 is cut off it "uncouples Q9" from the feedback pathway. The negative feedback pathway effectively vanishes and therefore the full gain of Q8, acting as a common emitter amplifier is realised.

Therefore, when the differentiated negative going pulses coming through, from a closed key, Q9 is cut off completely and the negative feedback loop provided by Q9 completely disabled. Not only does Q9 provide a negative feedback pathway to stabilize the initial DC conditions of the amplifier (Q8) and the buffer (Q7), it is cleverly arranged to isolate the negative feedback during a detected negative going pulse transition.

AC conditions (key-press signal): What is the voltage gain of the amplifier Q8 for a negative pulse?

There are a number of considerations here. On one of the SOL-20 keyboards I have the transistors had clearly be tested and graded for gain and had coloured paint spots on them. I think they had selected specimens of Q8, with a high range hfe or current gain.

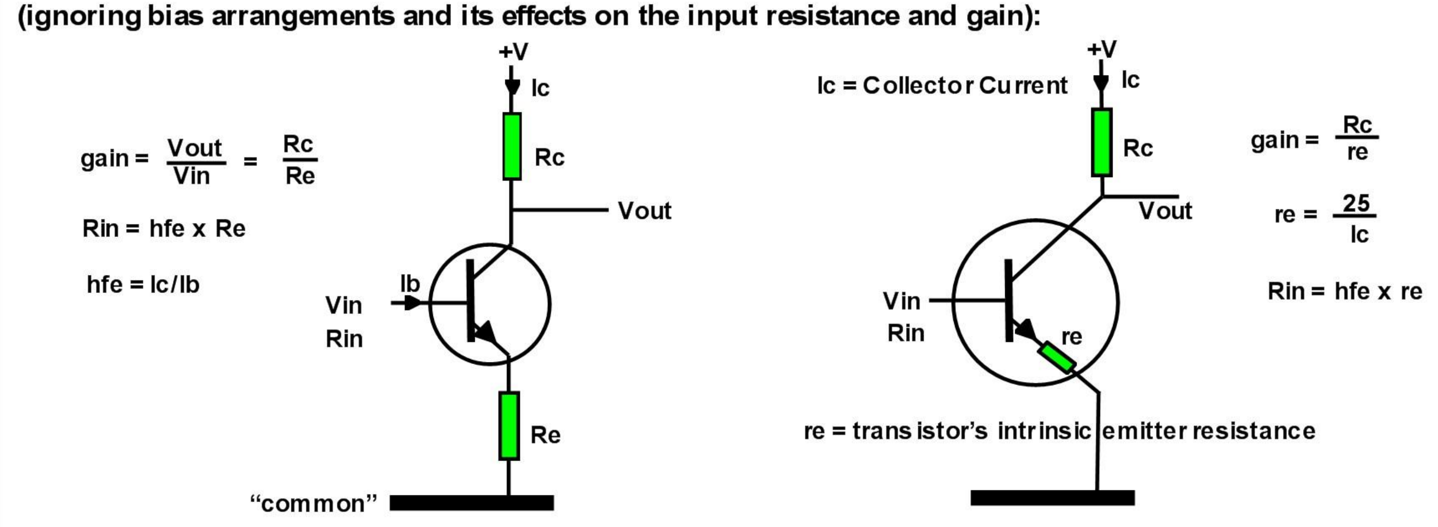
One of the most widely varying parameters of a transistor is its hfe. For example the data sheet for the 2N3640 specifies the hfe to be in the range of 30 to 120. The hfe in this case can be considered as the ratio of collector current Ic to base current Ib, or simply Ic**/**Ib.

Many transistor circuits are designed to ensure that transistor specimens, of the same type number, but with a wide range of hfe's will work. This is normally achieved with some amount of emitter resistance which is much larger than the transistor's own ***intrinsic emitter resistance re*** called "little re" or just known as **re**.

The panel below (with an NPN transistor just for an example) shows how to calculate the approximate signal voltage gain for a common emitter amplifier stage.

Voltage gain and input resistance Common Emitter Amplifier, with and without emitter resistor:

(ignoring bias arrangements and its effects on the input resistance and gain):



With capacitive coupling into the transistor's base, the driving signal is common to both ground and the positive supply voltage because the power supply impedance is very low (bypassed) to alternating currents. Therefore a common emitter amplifier can just as easily have its emitter connected to the positive supply rail and be a PNP type, as it is for Q8 in the keyboard circuit, or an NPN transistor with its emitter connected to ground (usually negative) as shown in the circuit example above.

Of note, as shown on the panel above, when there is an emitter resistor Re, much larger in value than **re**, then **re** can be ignored. The voltage gain calculation simply becomes approximated by Rc/Re, in other words basically set by the ratio of the two resistors external to the transistor.

Also, since the transistor is a current amplifier, most of the current via the emitter resistor is sourced from the collector and this effect raises the apparent input resistance seen looking into the base of the transistor. The input resistance approximates hfe x Re.

However, when the transistor's emitter connects directly to common, without an emitter resistor external to the transistor's emitter, both the voltage gain and input resistance become determined by the transistor's intrinsic emitter resistance **re,** which depends on the transistor's collector current and is 25/Ic, where Ic is in units of milliamps.

Since both the input resistance and voltage gain of the stage Q8, being a common emitter stage (emitter connected to positive for Q8 in this case with no emitter resistor***) both the voltage gain of Q8 and input resistance, looking into Q8's base, becomes very dependent on the particular transistor's hfe.*** This also explains most likely why the transistors were gain selected at the factory where the keyboard was made.

To overcome the threshold detector transistor Q4, initially at least, requires a positive going pulse on Q7's emitter of (3.68 + 0.7V) or about 4.4V, corresponding to a 3.68V amplitude positive going pulse on Q8's collector.

Therefore, with a voltage pulse from a detected key, the collector voltage of Q8 hast to rise to about 3.68V (a 2.8V increase above the resting 0.876V) initially, at least twice, before **/PKD** goes low. So the collector current of Q8 has to increase by about 2.8/3000 = 0.93mA at that moment.

Using this figure, then Q8's **re** is 25/0.93 or about = **27 Ohms.**

This makes the voltage gain of Q8: 3000/27 = **-111** (the minus sign as it is inverting gain)

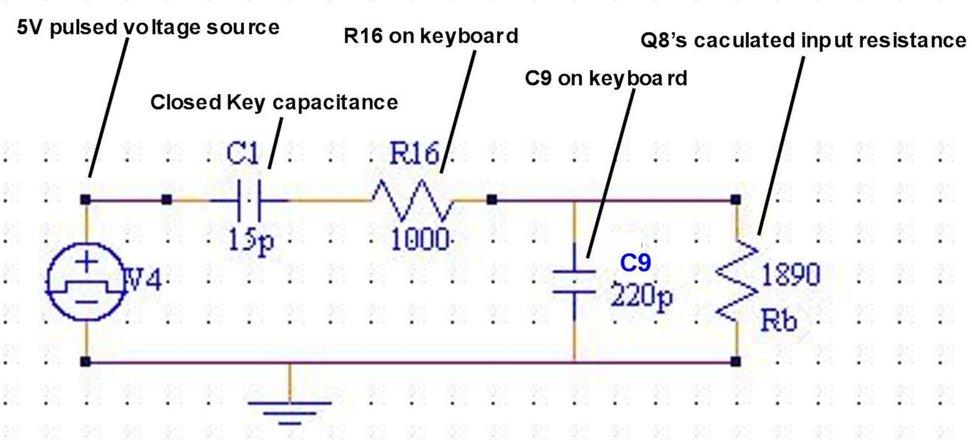
And it makes Q8's input resistance, looking into Q8's base, assuming an hfe for the particular transistor specimen, of around 70 at least (to use an intermediate hfe value between 30 and 120) 70 x 27 = **1890 Ohms**.

With the calculated voltage gain of 111 for Q8, the change in base voltage value fo Q8, which resulted in its collector voltage increasing by 2.8v, must be at least 2.8/111 or about ***25mV negative to sustain the 2.8V increase on Q8's collector***. This would be the minium requirement.

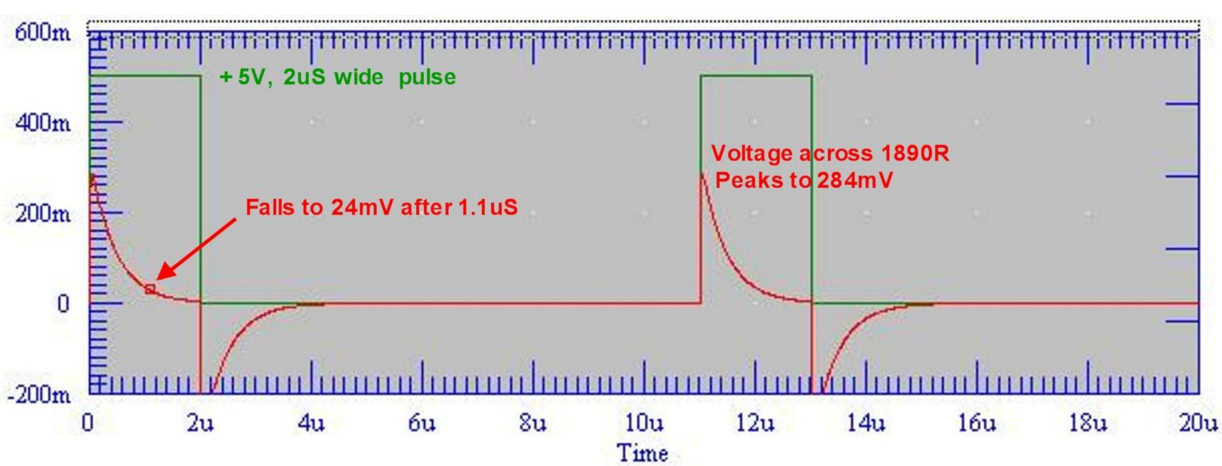
Does this analysis agree with a Spice simulation?

The base-to emitter of Q8 is also shunted by a 220 pf capacitor. Therefore the equivalent circuit of an NPN common emitter version of the circuit for convenience of the analysis and simple model looks like the schematic below.

The 1890 Ohm resistor represents Q8's calculated input resistance, for a transistor with an hfe of 70 and an **re** of 27 Ohms. R16 is the 1k resistor in the keyboard input circuit. C9 is the 220pF capacitor across the transistor's base-emitter and the 15pF capacitor is the result of a pressed key:



The result running this in Spice:



The differentiated pulse that appears across the 1890R input resistance peaks up to around 284mV then it starts to fall. After about 1.1uS it has fallen to about 24mV, below the required 25mV from the calculation of the minium voltage required to trigger the keyboard and produce a full amplitude output pulse from Q7.

(The reason the initial peak voltage is low at around 284mV is that the 15pF capacitance and the 220pF capacitance form a capacitive voltage divider of roughly about 15/220, so the initial peak before the exponential decay is nowhere near the level of the 5V pulse)

In addition, from the Spice simulation of the basic circuit constants, when the base voltage has dropped to around 24mV, the base current of Q8 will have dropped to about 0.024/1890 or to about 12.7uA.

With the hfe of Q8 being 70 in the example, then the collector current increase will be 70 x 12.7uA, or about 0.89 mA. This current, via Q8's collector resistor, increases Q8's collector voltage by 0.00089 x 3000 = or about 2.67V. This agrees closely with the measurement of a 2.8V increase being generated across Q8's collector resistor with a key press.

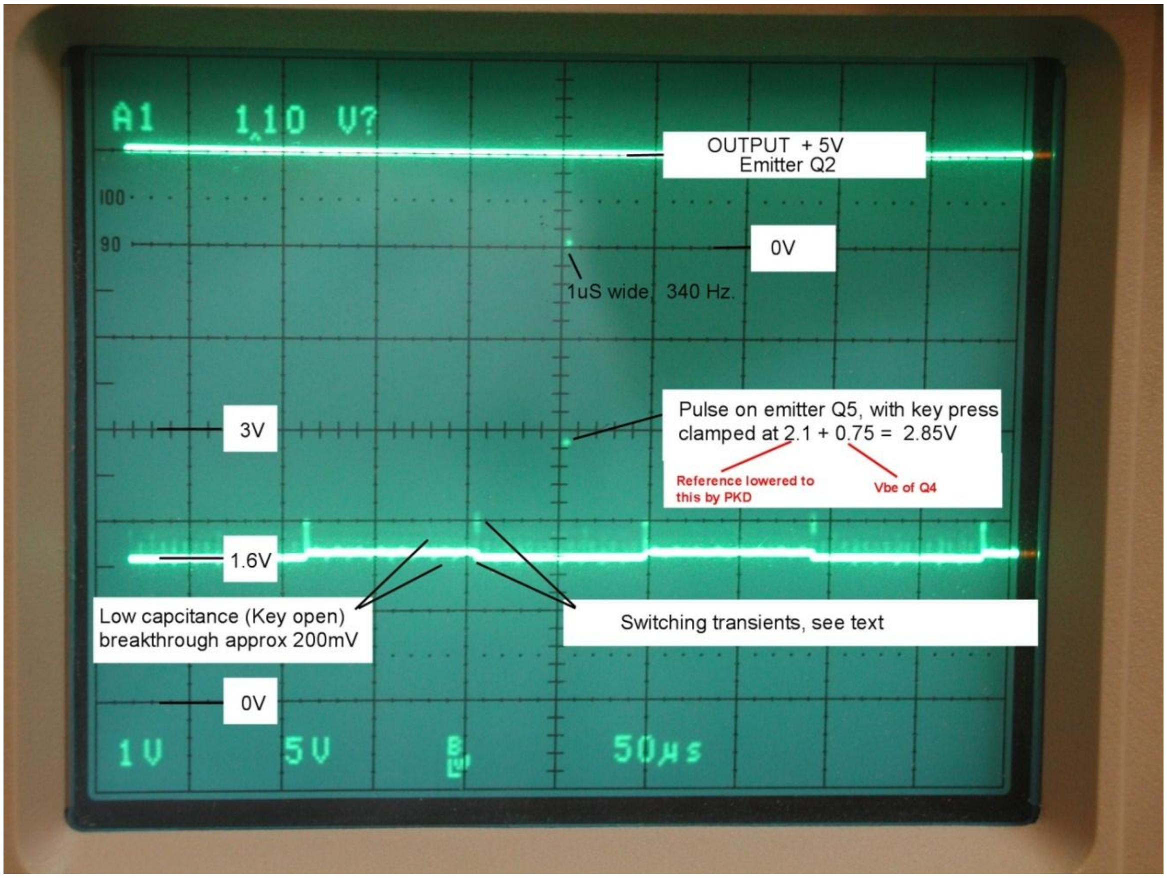
Regardless whether the transistor Q8 is examined as a current amplifier, or a voltage amplifier, the measurements agree with theory. Also the experimental finding that a 10 to 15pF capacitance increase is just enough to trigger the Keyboard, appears to be about right, in the case where the amplifier transistor Q8 (and Q6) has a current gain of around 70 at least.

In practice though, looking with the scope, the actual pulse level seen on Q7's emitter is forced to a lower peak voltage, pulled down from 4.4V, by the base-emitter current of Q4, to about 2.85V, due to the /PKD falling low after the sequencer circuit has detected the pulse twice. Therefore the pulse seen on the emitter of Q7, with a scope, is seen to peak to around 3V, rather than 4.4v with a closed key. But prior to this it had actually peaked at 4.4V before /PKD went low.

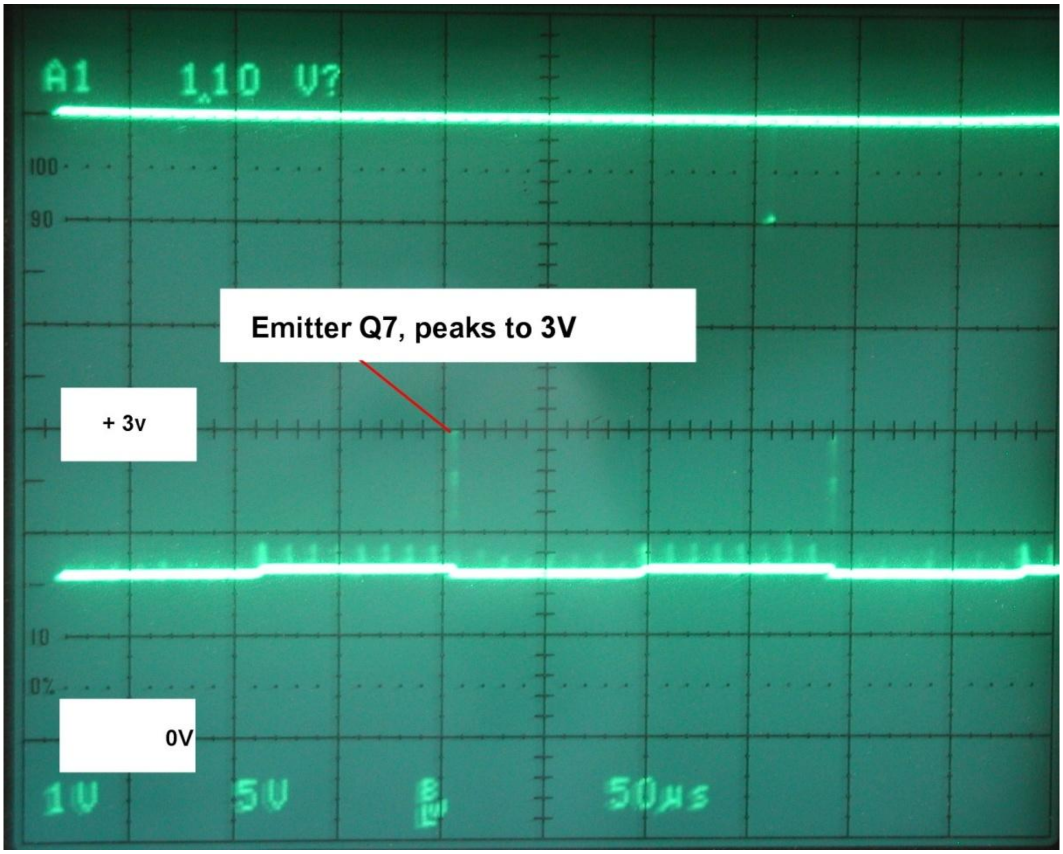
With key closure therefore, a positive going pulse on the emitter of Q7 momentarily exceeds 4.4V, this turns on Q4 for the duration of the pulse and this is passed to Q2.

The base current pulses of Q4 during the pulse, results in emitter to collector current of Q4 and that is passed to the base of Q2, which amplifies and inverts the pulses, to a 5v peak to peak, negative going pulse of about a 1uS duration on the OUT terminal.

The reason the 220pF base to emitter capacitor, on Q8 (and Q6),was included at the input of this amplifier design, is that it helps to shunt stray signals (by capacitive division) that result from the low level cross coupling, or very small capacitances of the circuit tracks, when the key is not closed. These “leak through” signals are not enough to reach the threshold of 4.4V. The recording below shows the pulses leaked trough, on the emitter of Q5 and the pulse from a detected key-press clamped to 2.85V by /PKD.



The worst offender on the board for potentially interfering pulses is the circuitry on the input to amplifier channel **IN1**, where these amplified pulses, seen on the emitter of Q7, can reach 3V in amplitude, higher than the value seen on the emitter of Q5 above on the **IN2** channel. However, these 3V pikes still fall below the approximate 4.4v value required to trigger the threshold detector:



Summary:

In short, this analysis has shown that the minimal condition to trigger the keyboard is a combination of a metallised film dielectric, where the film is no greater than 0.035mm thick with a dielectric constant K of not less than 3. Though, if the film was thinner, the K could be less than 3. Also the minimum hfe requirement of transistors Q8 and Q6 is ideally not less than 70, and probably for noise pulse immunity, not more than about 90 to100. So this is a consideration, if one day any of these transistors require replacement, it would be worth selecting them for current gain.

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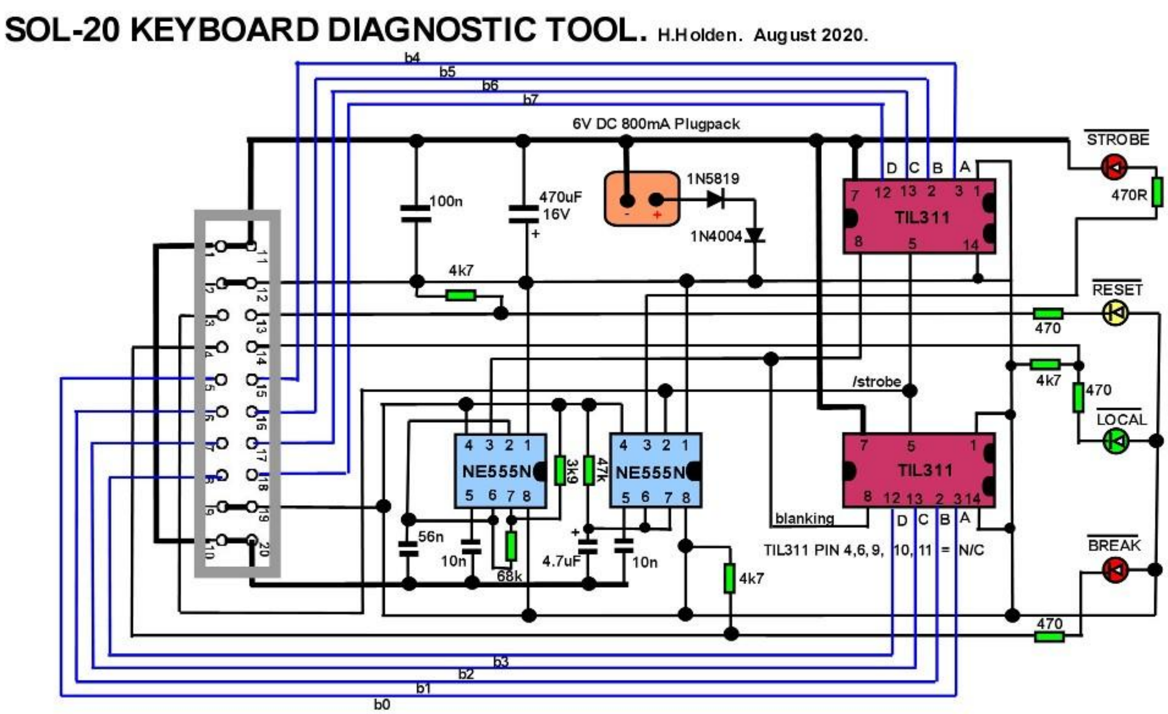
SOL-20 KEYBOARD DIAGNOSTIC TOOL:

The SOL-20 computer’s keyboard always requires repairs. The main issue is with the foam pads which carry the metallized Mylar film. The original metal part of the film was sandwiched in the middle of very thin (approximately 0.07mm) material. It required that the capacitance had to be raised by about 15pF, on key closure, for the key detector circuit to recognise the key closure.

As others had found, suitable donor foam pads can be taken from a SUN-4 Keyboard. (I tried a number of other pads of new manufacture without 100% success).

While repairing my SOL-20 keyboard, I realised it would be very handy to fully test the keyboard without the actual SOL-20 computer. So as to be 100% sure that the keyboard itself was in perfect working order and generating the correct output codes for any key/s combination pressed. The codes (8 bit data) generated by the keyboard are very well documented in Processor Technology’s SOL-20 computer hardware manual.

So I decided to design a small module, which plugs onto the keyboard to test every keyboard function. The schematic shown below:



In addition to displaying the ASCII codes generated by the keyboard and the extended codes related to Mode Select, Load , arrow keys and the Home key, this test module also monitors the keyboard outputs of: /STROBE signal, the /RESET (generated by the upper case & repeat keys) the /LOCAL key and the /BREAK key.

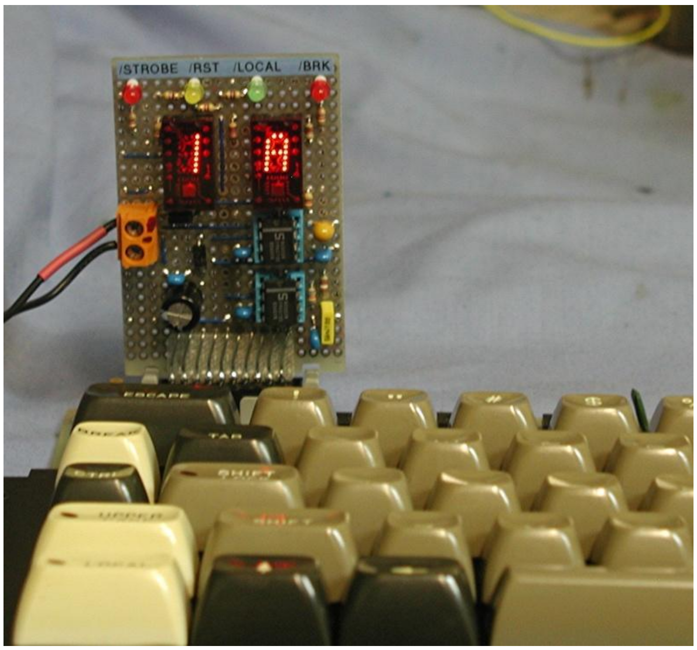
The /STROBE signal is a very brief negative going pulse, which in itself would be impossible to see on an LED. So to remedy this, a 555 timer was use to pulse stretch this to see a flash on an LED of around 200mS duration. The module also confirms the N-Key rollover is working, if you hold down a key and make the next key press it still works normally.

The hexadecimal displays are the vintage TIL311. These are fairly bright, so in the interests of taming that down a little and efficiency, another 555 was used to provide an approximate 50% duty cycle to the blanking inputs of the TIL311's. The strobe signal is also used to load the keyboard data into the internal latches of the TIL311's.

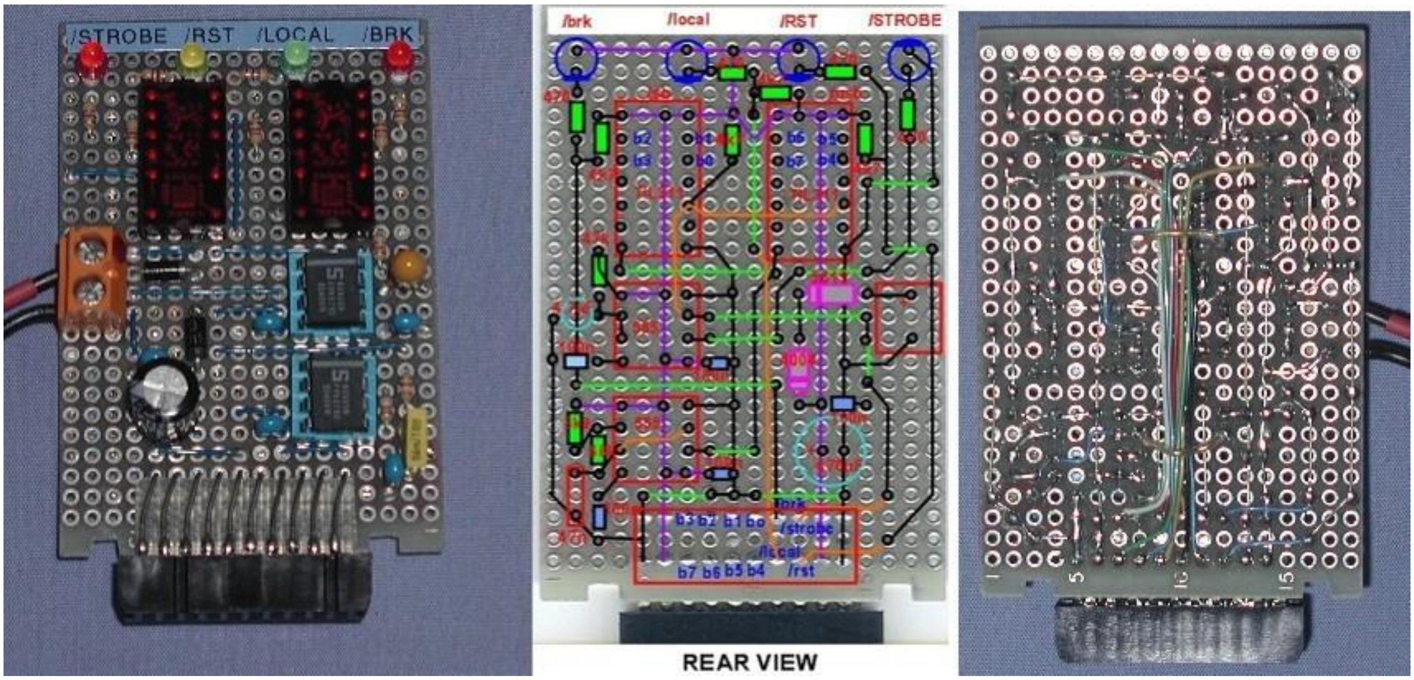
The module is powered from a 6V (rather than 5V) mini line powered *smps*, 800mA rated off the shelf "plug-pack" from Jaycar Electronics, part MP-3145. The reason is that reverse polarity protection diodes were added (a 1N4004 and a 1N5819) which drop in total about 1V. This way the module powers the keyboard. The current consumption of the entire keyboard, plus the module is just under 500mA.

(I would recommend if you are powering this keyboard, outside the confines of the SOL-20 computer, be very careful with the connections, double check the power supply voltage and applied polarity and always add reverse polarity protection diodes to avoid an accident).

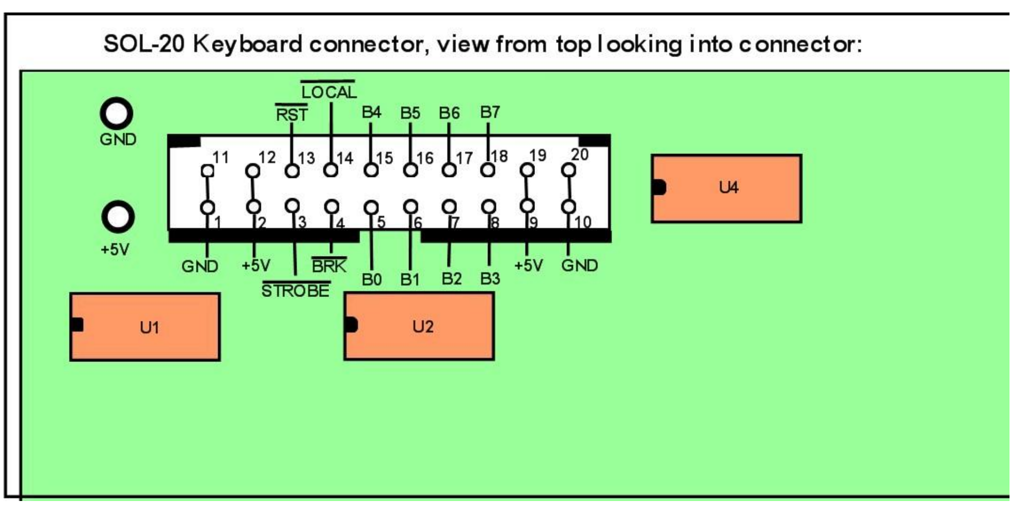
The photo below shows the module powering the keyboard and the result pressing CTRL & Z:



The following diagram shows the layout I used on some plated through hole spot board. Clearly this project would be worthy of a professional PCB at some point when I have time to do this:



The diagram below is also handy when working with the SOL-20 keyboard:



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