Analysis and Test Results of Cell Driver Circuit K4

The cell driver circuit is a series of amplifiers which increases the power level of the gated wave train that comes from the Phase Lock Circuit K21. Output connects to the TX1 Primary Coil.

Inputs

Gated Signal from Phase Lock Circuit

Ground

VEE +12 VDC

VDD +5 VDC

NOTE: VEE Value is unknown but I expect it is +12 for reasons explained below. Actual value is determined by requirements of device.

Outputs

Amplified input signal

There is only one output, which is tied directly to one side of the TX1 Primary Coil. This comes directly from the collector of the Q9 (TIP120) the last power amplifier in the circuit.

Analysis of Circuit

The circuit below is very simple to build, as I have built it, but when I tried to test it the first stage (Q6) did not work. This has been the experience of several other people who that attempted to build this circuit. As result of it not working, there have been several questions that people have asked. I will discuss those questions below and provide some reasons why it may have been designed this why.

Simple Circuit Explanation

It is a series of four amplifiers that take a 5-volt Peak to Peak (PTP) CMOS signal and turns it into a 1-volt PTP signal that has enough current to drive a load, in this case the primary transformer. The term amplifier while true is somewhat misleading in this case. The ICs are wired more like switches than when use in an audio amplifier and function that way because they are operating on a pulse train and not a sine wave. Q6, Q7 and Q8 (2 3906s and one 2N2222) are transistors. Their primary function is to take a low current CMOS wave train and "amplify" the current in the signal so it will provide a strong enough current to drive Q9 (TIP120) which sends the higher power signal to the Primary Coil. The resistors in the circuit provide the bias for these "switches" to work correctly. Need pairs to maintain correct inversion of signals as each amp inverts the signal as it passes through

However, the circuit as drawn with the values given for the components will not work. To make it work 2 changes need to be made:

1. Replace VCC, +12VDC, going to Q6 with VDD, +5VDC. VDD is the correct value for the voltage source for base for both the 3906 and 2N2222. Data sheet limit is 5VDC. This works I tested it. (see screen shots in testing section). Note: In other chips VEE is not connected to base.

2. Replace the 22K resister on output of Q6 with 1K resistor. With 22K resister in circuit signal input to Q8 is not high enough for it to switch on. Signal gets through Q7 you can see this in screen shots in testing section but not Q8.
3. I left everything else as drawn though I did add the 100uF across VEE
4. Still not sure of value for VEE. +12VDC works as that was what I used for most of testing. I did try +10VDC for initial testing and that did not solve Q6 issue. There may be another reason for using 10-volts, but I do see it in this circuit.
5. Final load testing was done with 10-ohm resistor as that resistance of the VIC primary. (220-ohm resistor across primary is used to lower coils final resistance to 10.5 ohms).

Circuit Drawing with original values from estate information

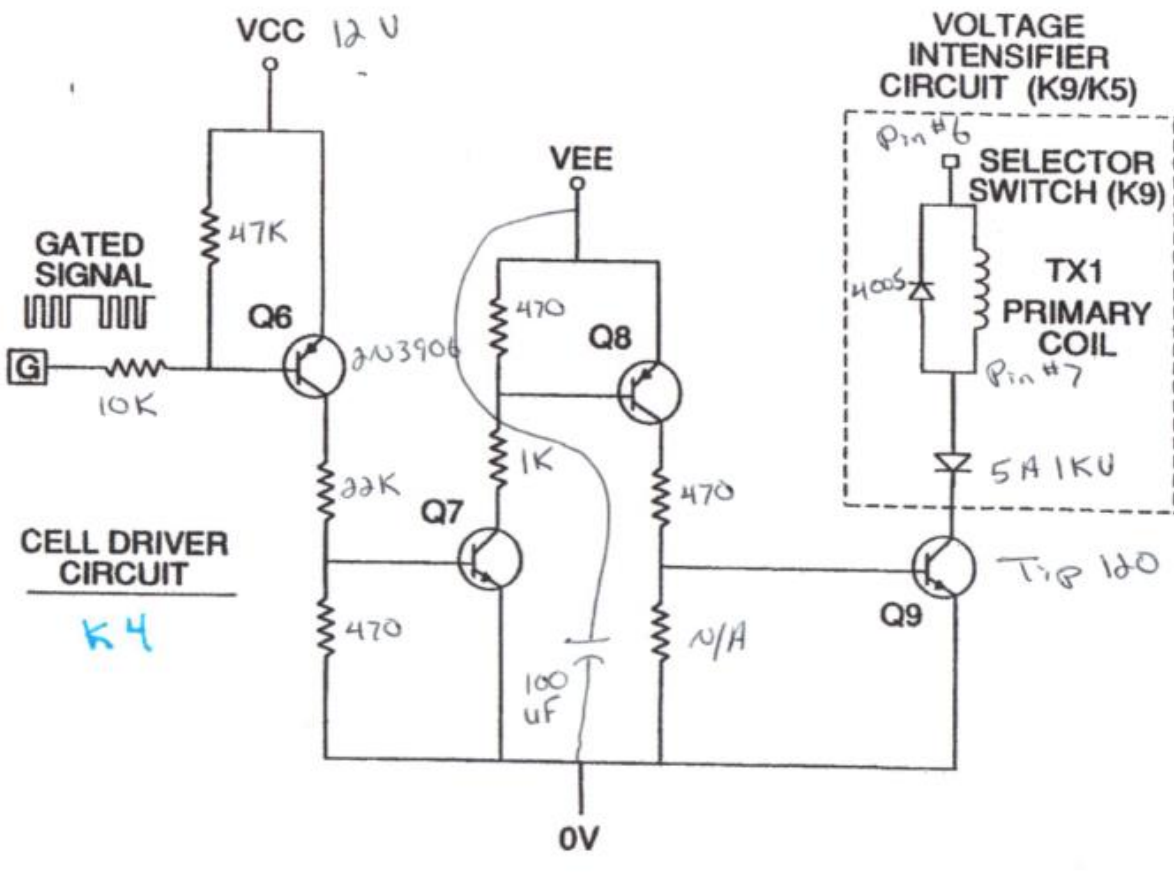


FIGURE 5

Questions with My Answers and/or Reasons

This is for those who what to know why.

First questions what is VEE and what is its value. Here is one reference that says what it is.

[What is Vcc, Vee, Vbb, Vdd and Vss stand for? | Electronics Repair ...](https://jestineyong.com/what-is-vcc-vee-vbb-vdd-and-vss-stand-for/)
https://jestineyong.com/what-is-vcc-vee-vbb-vdd-and-vss-stand-for/

> They are all supply voltages. Vcc = Collector supply voltage, **Vee** = Emitter supply, Vbb= Base supply voltage, Vdd = Drain supply, Vss = source supply. Whenever the supply to a Transistor (or TTL IC circuit) is connected between the collector and ground it is a standard to notify it as Vcc.

So, all that means is VEE is this just another term for voltage supply just and that it is connected to emitter side of device.

There was also some discussion that VEE may be 10VDC as Stans has a 10-volt rectifier in his voltage source. While it could be true it is unlikely in this circuit. Some have stated it is 10-volts because the 3906 and 2n2222 have a 5-volt limit on the base voltage supply and you would need a 10-volt source. The problem with using 10 or 12 volts in this circuit only applies only to Q6 as there it is used as source of pullup voltage source for its base. (Turns out I had to change VEE on Q6 to VDD +5VDC to make circuit work (see test results).

Still unsure of value or VEE and it's use though it appears to be used to drive LEDs which needed 10-volts.

Second question relates to the bias resistors for the amplifiers.

Why did he used 22K resistor (Turns out I had to take it out and replace it with a 1K as it pulled signal too low for Q8 stage to work)

If you are building an audio amplifier it seems 22K was a fairly standard value for the 3904 and 3906 chips. Here is one of a couple references I found that explains this which are easy to read and provides reason why values were chosen.

http://www.rason.org/Projects/transaud/transaud.htm

Third question is why 470-ohm resistors were used.

That one is harder to find an answer for as using them does not follow common guideline for bias resistors. See this good article for why you choose values. Again, easy to read and very clear on how and why to choose bias values.

http://www.physics.unlv.edu/~bill/PHYS483/transbas.pdf

For reason why this is event better this link. Nice simple explanation of how to choose pullup resistors. Near end he gives a reason why you would choose a low value. If you goal is to pullup current, a low value works better which explains using 470 ohms resistor.

https://www.youtube.com/watch?v=u3Xiy2DVnI4

What I found interesting is the almost identical circuit is being used in the Analog Voltage Generator (K8) circuit and values are different. The K8 circuit provides almost the identical function so not sure why the difference. I can tell you the K8 circuit works as I have built and tested it.

The fourth question is why used the 3906 and 2n2222 chips at all.

This is explained in couple of the articles. Article below talks about using these devices to do switching, same reason applies when used as current amplifiers. I did find one article that talked about when then are used in pairs in amplifier circuits, even had a name for that use but I can not remember it and I did not mark reference as it mainly applied to audio amplifiers.

http://www.rason.org/Projects/transwit/transwit.htm

It has to do with the current level required by higher power amplifiers to work correctly. The output of the CMOS logic chips is too low to drive them. So, their main purpose in this circuit is raise the current level high enough for the power amplifiers to work correctly.

Bottom line, they are used in this circuit to prepare input for the TIP120. If redesigning, today you would not need these chips with newer amplifier chips that are available.

General comment, most of the examples you see on these chips relate to using them as switches. I had to do more digging to find information on using them as amplifiers and many of those articles recommend using other chips as better amplifier chips are available.

Use of 100uF Capacitor

There is general agreement that 100uF capacitor needs to be added to the circuit as it appears on the VIC circuit card. Looks like it is filtering noise on power input.

Changes to Circuit Based on Testing. These values were used in my final testing.

1. Changed the supply voltage to Q6 the first 3906 in the circuit from VCC +12-volts to VDD +5-volts. The reason is the +12 supply violates the 5-volt input restriction on the base connection that was not allowing the device to function. This change does not apply to the other chips as none of them have +12-volts wired to base. Both the emitter and collector much support higher voltages.

    NOTE: This change is also consistent with the with the way the 3906 and other chips are configured in the Voltage Analog Generator K8.

2. Replaced the 22K resistor on the output of Q6 with a 1K resistor as 22K resistor pulled the input signal too low for Q8 to operate. After installing it I had no more problems.
3. I did test using a 1K instead of 10k on signal input to circuit. Both worked so I left 10K in place thought there is a difference input signal level between the two. K8 circuit uses 1K for this.
4. Did not test replacing 470-ohm resistors as circuit worked with them in place after fixed 2 issues above.

Test Procedure

Initial testing of the circuit will be done a little different that other cards I built and tested as I do not currently have the normal signal source. I am not too concerned about at this point as this circuit should not modified the shape of the signal as it should just amplify the signal to increase power output. To verify this, I will use the Variable Frequency Generator (K2) as my signal source and check across multiple frequencies.

Circuit being tested

A couple of changes have been made to circuit as drawn

The lower resistor on input into Q9 labeled N/A – Whole line is removed not just resistor

4005 diodes across the Primary Coil has been changed to 4003. This was verified with Don who collected the values that are one these circuit diagrams. Not used in testing as not testing here with coil.

Test procedure and test results

Plan is to test card left to right as that is the way signal flows through the circuit. While the normal input (G) comes for the Phase Lock Circuit, I do not have that card built yet, so instead I will be using the Variable Frequency Generator (K2) that I built as my signal source.

Test Setup Configuration:

I am using a LM317 board to convert 12 VDC it to 5 VDC for the K2 and K3 and now K4. I will also be using another LM317 to provide 10 VDC for VEE input. (More on this later). This LM317 circuit is on its' own small board mounted next to Frequency Generator and provides VDD for all the cards. NOTE:

12VDC (VCC in circuit) will be provided from a 12-volt switching power supply as I had a couple from old computer equipment.

RIGOL DS1052E – Duel Channel Digital Oscilloscope will be used to capture the wave train. Screen shots of signals at various locations through the circuit will included in test results. Scope's computer interface will be used to capture screen shots as will the clip-it function in window to get information into this document.

Variable Frequency Generator (Board K2) hard wired Testing will be conducted using one of the frequency selector switches to select frequency. The main frequency on the K2 is set to 5KHz so using switches you can select 5KHz, 500Hz, 50Hz or 5Hz. For testing this circuit, I will mainly be using 50Hz output. I will show all 4 at final output.

The Gated Pulse Frequency Generator will also be used to collect data as I want to see how it passes through the circuit. K2 will be connected to K3 provide the initial frequency. The signals will not be combined as I do not currently have a means to do that. Did not work as not enough power to drive the cell circuit.

Test Procedure

Goal is capture what is being done to the signal at every point in the circuit.

I found doing this also helps if something goes wrong as I have a record of what signal should look like at each point in the circuit. Already used this when I hooked power up wrong and had to replace a couple of ICs in one of the circuits I was testing.

Verify Variable Frequency Generator (K2) is working and set base frequency to 5KHz.

I will be capturing O-scope screen shots throughout the testing

Channel 1 (CH1) yellow trace will be connected to input source of K4

Channel 3 (CH2) blue trace will be signal being looked at

Settings at bottom of scope will show scale of each signals. I will try to note changes to scope setting if any are made.

Scope shots are from the computer interface to scope and were captured using screen capture function built into Window 10 and/or Microsoft Office suite.

Capture Input signal to K4

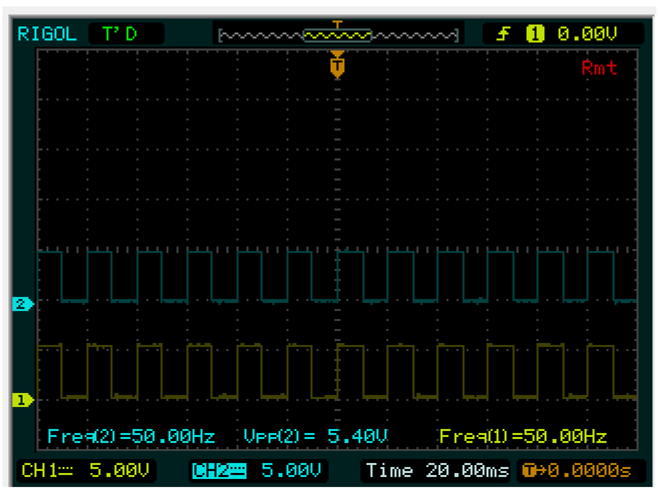
O-scope channel 1 is connected to input of K4 and will remain connected through out tests so we can see how wave is changed as it progresses through the circuit.

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 5V/Div will be test points in circuit

Trigger is on Channel one leading edge for these tests

I will try to note when I change scope settings



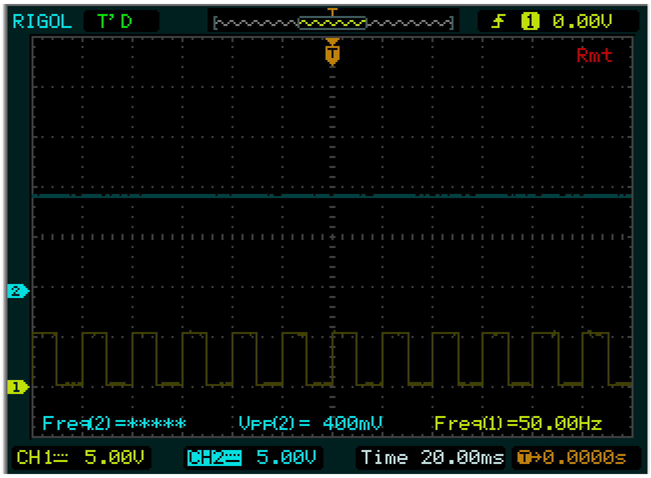
Capture Signal at base of Q6 with original 22K resistor on Q6 output

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 5V/Div will be test points in circuit

VEE +10VDC

Signal Flat lined. I expected this may happen as I left the original 22K resistor on the output of Q6. Results of testing by other recommend changing it to 1K. I wanted to verify this was needed before making that change.

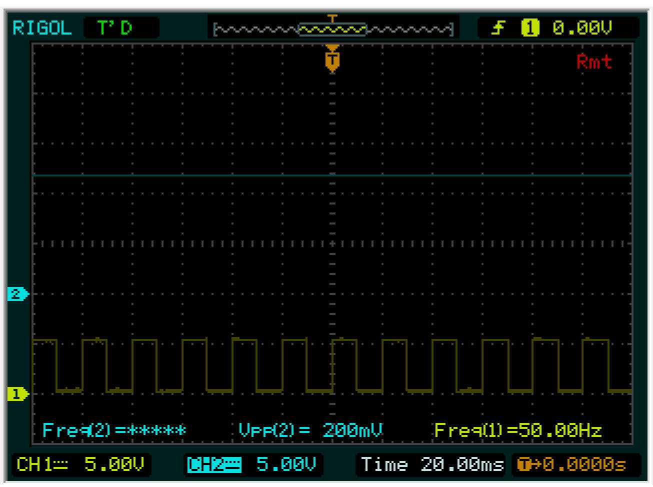


Capture Signal at base of Q6 but use +12 VDC still original 22K resistor

Changing voltage level to 12 volts was only change.

Note the 2-volt higher single level.

This test was to verify lower voltage level is not cause of signal loss. (See discussing in analysis on VEE and 10 Volt level)



Circuit configuration changed

At this point after a lot of reading I changed the source voltage to the base of Q6, 3906 in circuit, from VCC +12-volts to VDD +5-volts as the data sheet states max voltage to base is 5-volts. Circuit started to work after making this change. Based on questions, others have about resistor values I will capture screen shots showing effect of using different values.

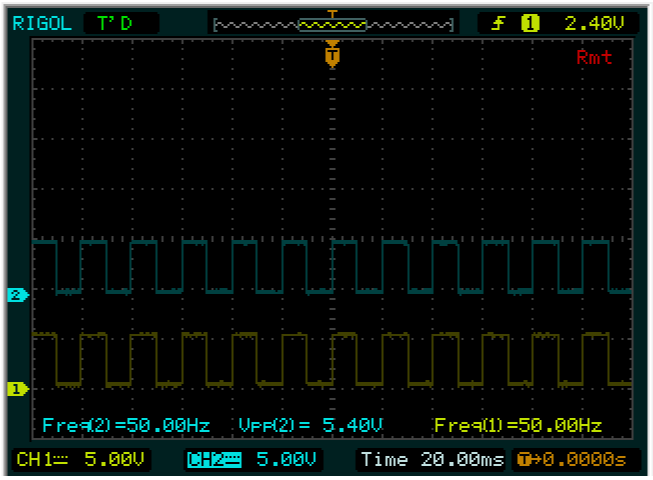
Test configuration and equipment remains the same.

Capture input to card before **1K/10K** resistor (one of the resistor questions is circuit shows 10K, note, K8 circuit uses 1K)

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 5V/Div

Trigger is on Channel one leading edge for all these tests

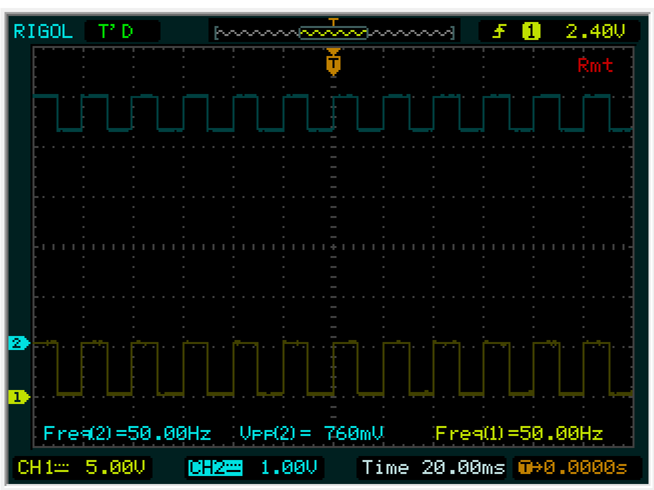


Capture input to card after **10K** resistor Input to base of Q6

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 1V/Div

CH2 Chase changed to enhance reduced signal



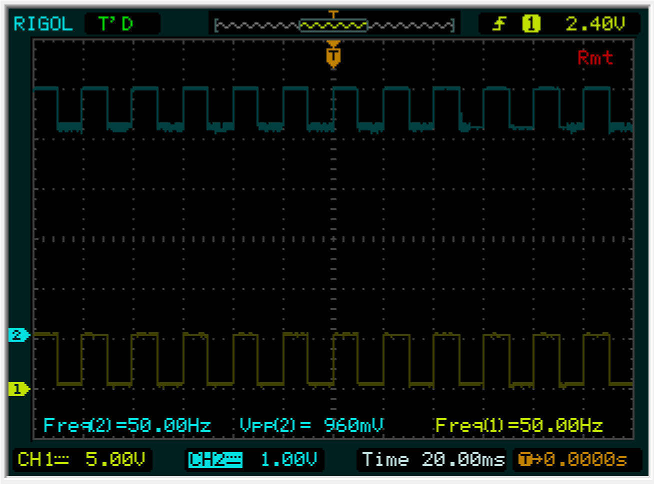
Capture input to card after **1K** resistor Input to base of Q6

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 1V/Div

PTP voltage is higher for the 1K resistor

NOTE: I did check all 4 frequencies and they were all pasted by Q6



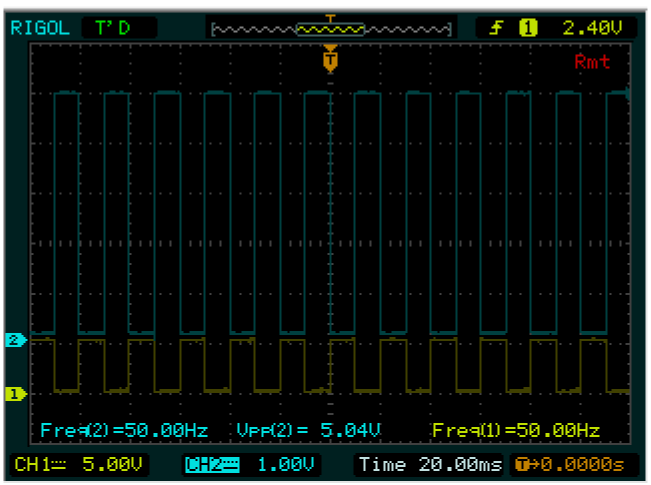
Capture signal out Q6 before 22K resistor

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 1V/Div

Signal is inverted

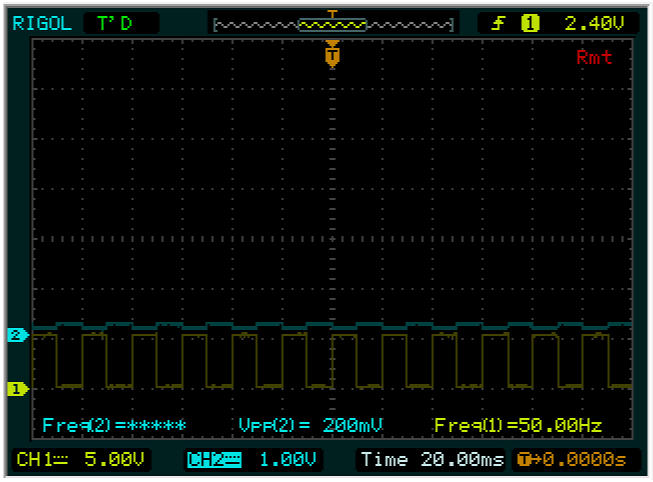
Note: Signal is back to 5V looks bigger as scale was changed. This is consistent with what I saw with K8 circuit.

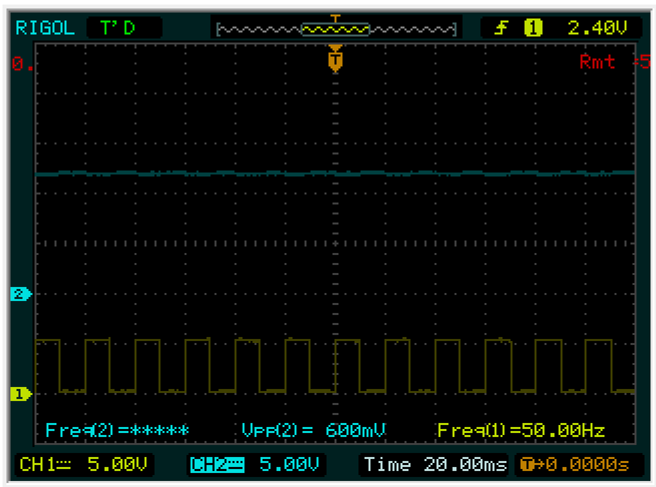


Capture signal after 22K resistor input to base of Q4 2N2222

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 1V/Div





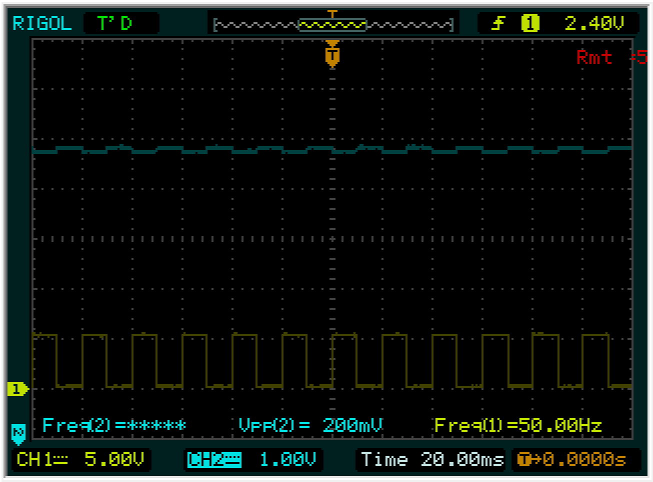
Capture signal output from Q7 before 1K resistor (same signal zoomed it to see wave form)

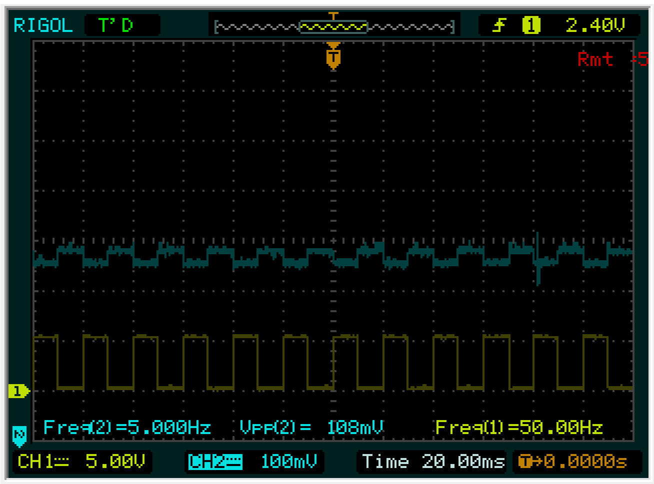
CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 1V/Div

Signal is back in sync with source

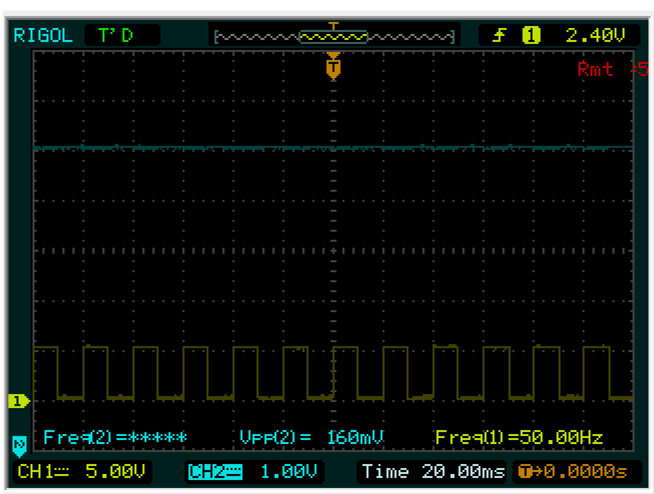
Scale changed to show signal is now at 12-volts and zoomed in to see signal shape





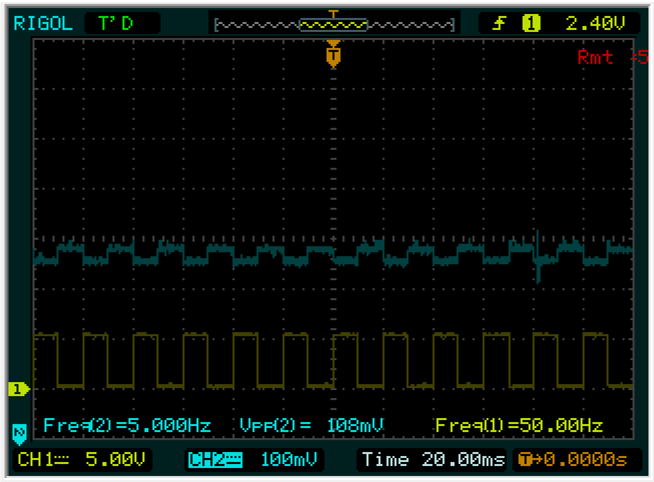
CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 1V/Div



Signal with scope zoomed in

Note scale set to 100mv



Capture output of Q8 before resistor

There was no signal output.

I expected this is caused on very low-level input to base of Q8

Note: I also checked with 500Hz and 5KHz and still no signal

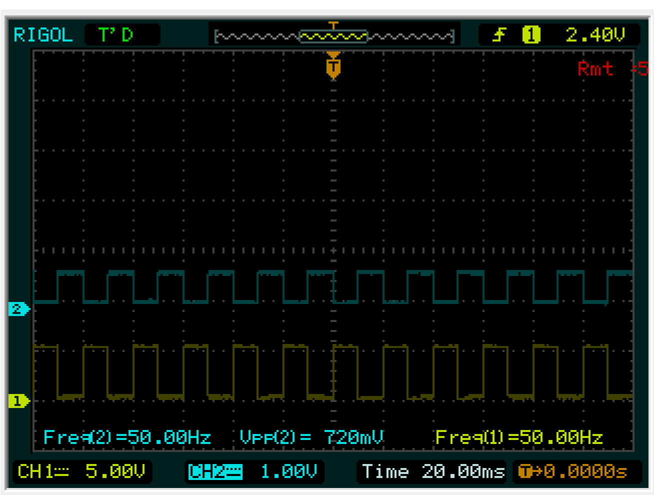
Repeat last series of test starting with output of Q6 with 22K resistor replaced with 1k

Capture signal after **1K** resistor input to base of Q4 2N2222

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 1V/Div

Note: Increase in VPP(2)

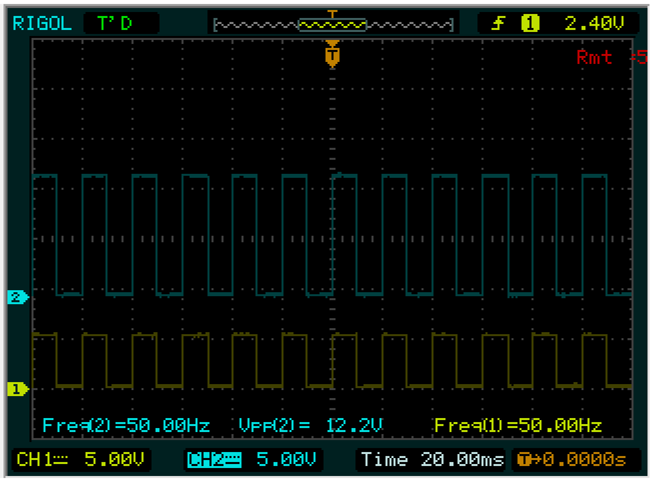


Capture output of Q7 before 1K resistor

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 5V/Div

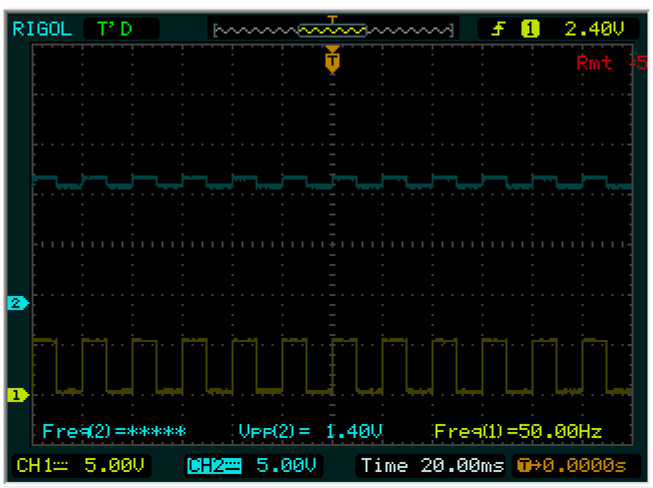
Scale change of CH2 Signal is at 12-volts



Capture output of Q7 after 1K resistor input to base of Q8

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 5V/Div

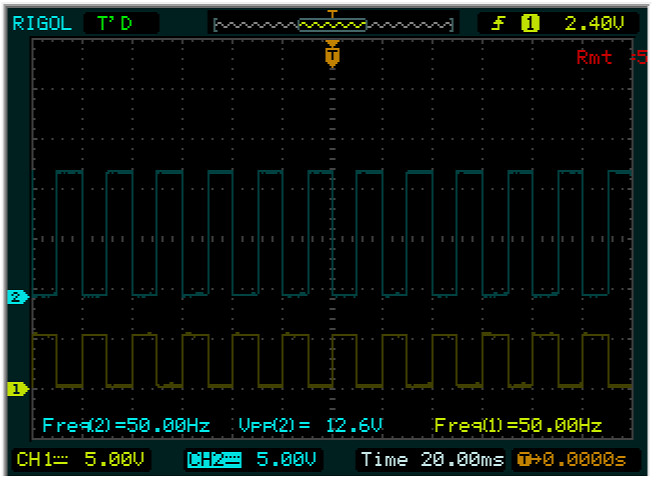


Capture output of G8 before 470-ohm resistor

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 5V/Div

Note: We have an output this time and it is back to 12-volts



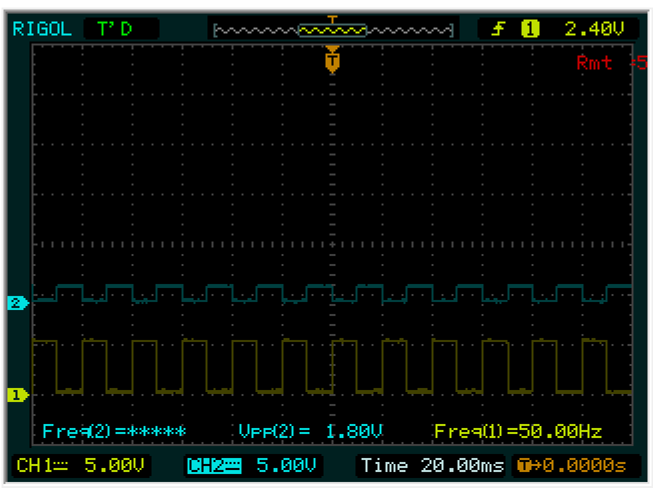
Capture output of G8 after 470-ohm resistor input to base of Q9 TIP120

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 1V/Div

Scale changed again to zoom in on output pulse

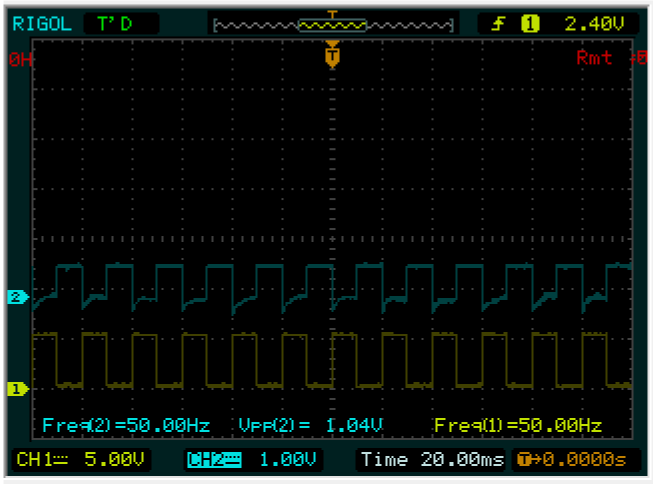
Note at this point TIP120 is unloaded as I do not have a heat sink on it. I had expected it to get hot fast with a load but it actual runs cool to touch.



Capture output of Q9 TIP120 without load

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 5V/Div

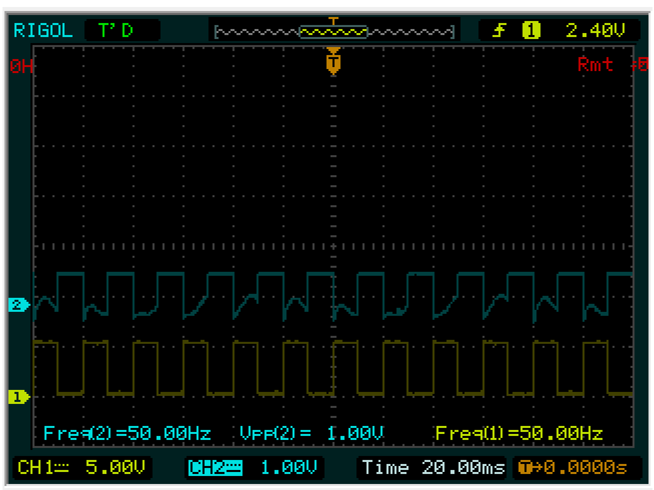


Capture output of Q9 Tip120 with 10-ohm load at 50 Hz

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 5V/Div

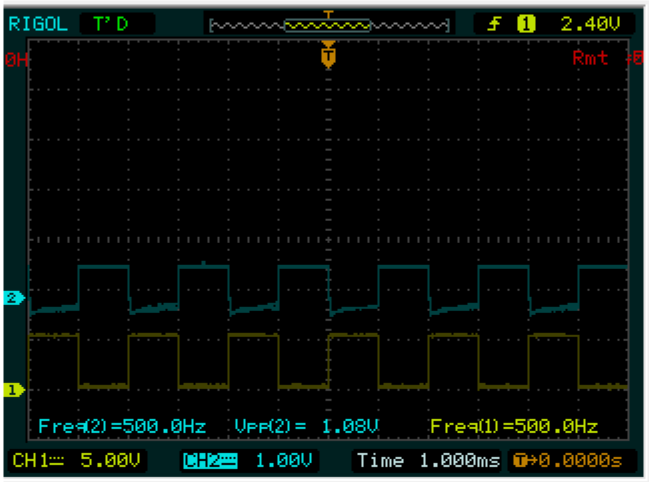
Decided to di quick load test. I had expected it to get hot fast with a load but it actual runs cool to touch. I the K8 board it get really hot fast but that has a different signal.



Capture output of Q9 Tip120 with 10-ohm load at 500 Hz

CH1 Yellow trace – Input to K4 Scale is 5V/Div

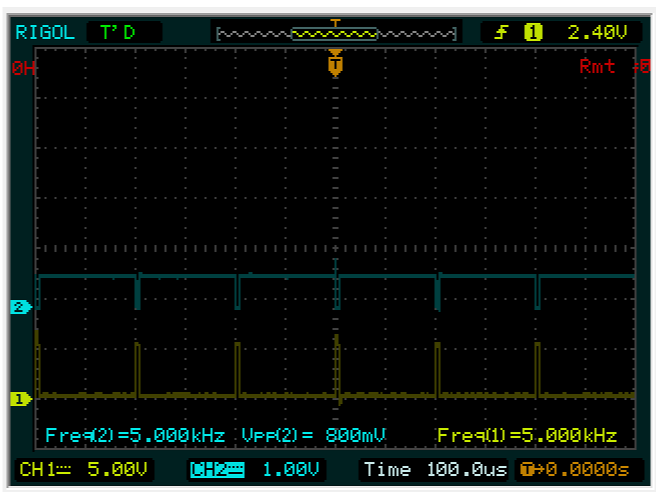
CH2 Blue trace – Scale is 5V/Div



Capture output of Q9 Tip120 with 10-ohm load at 5 KHz

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 5V/Div

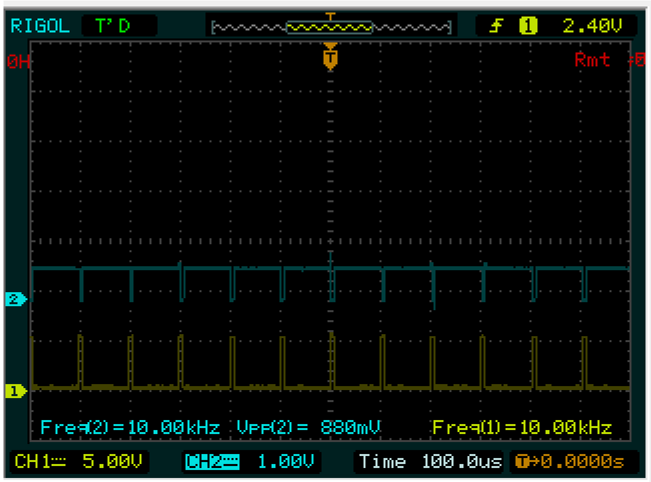


I adjusted Freq Generator base to 10KHz and will repeat the last 3 setting at these new frequencies

Capture output of Q9 Tip120 with 10-ohm load at 10 KHz

CH1 Yellow trace – Input to K4 Scale is 5V/Div

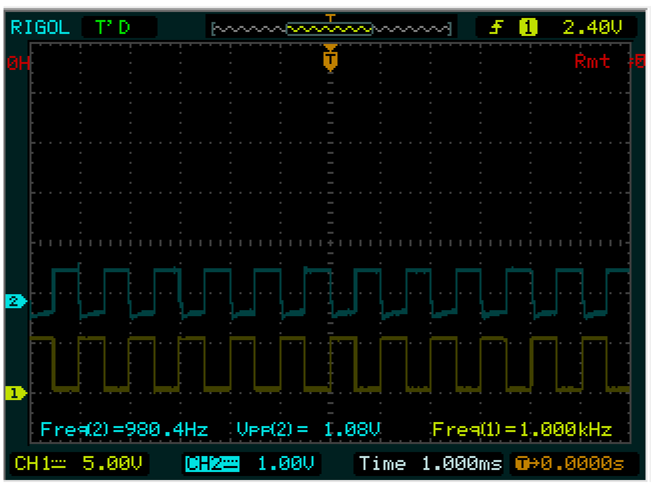
CH2 Blue trace – Scale is 5V/Div



Capture output of Q9 Tip120 with 10-ohm load at 1 KHz

CH1 Yellow trace – Input to K4 Scale is 5V/Div

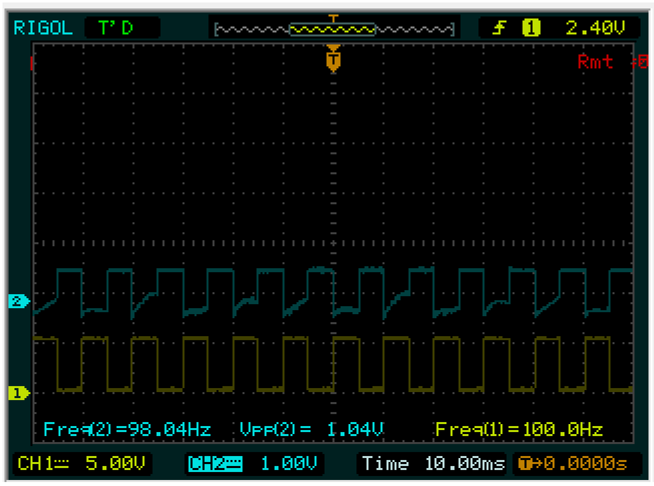
CH2 Blue trace – Scale is 5V/Div



Capture output of Q9 Tip120 with 10-ohm load at 100 Hz

CH1 Yellow trace – Input to K4 Scale is 5V/Div

CH2 Blue trace – Scale is 5V/Div

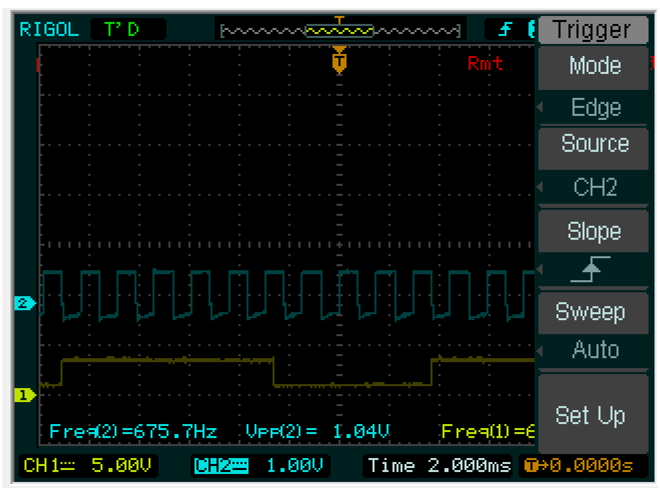


Couple more items this is with CH1 hooked to output of Gated Pulse Freq Generator K3

K3 is getting its signal from another Switch on K2 I am do this just to show what pulse looks like. Normal signal be a combined signal. As I am using two independent signals they are not synced.

CH1 – Yellow is from K2 output

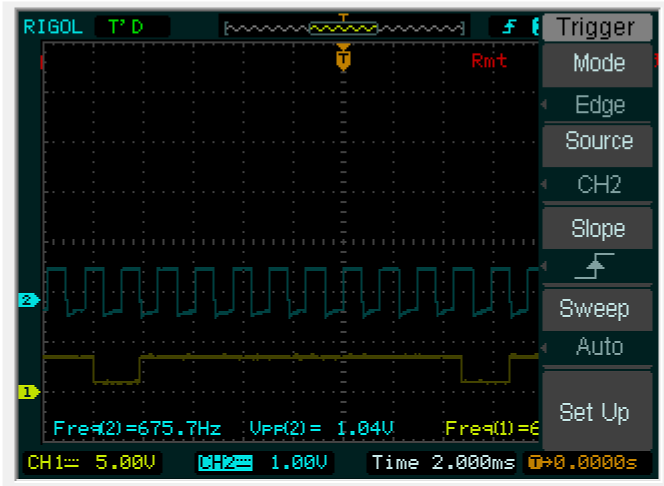
CH2 – Blue output of K4



CH1 – Yellow output of K2

CH2 – Blue output of K4

Show K3 output with different pulse width



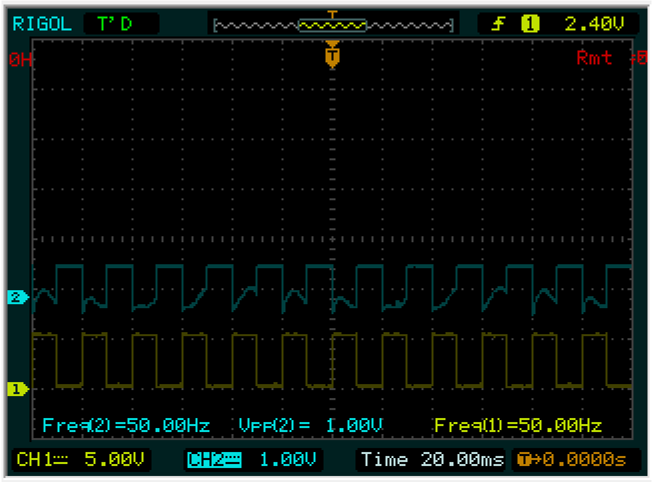
Test results and conclusions

With the changes I made I believe the circuit is operating the way it is intended to operate.

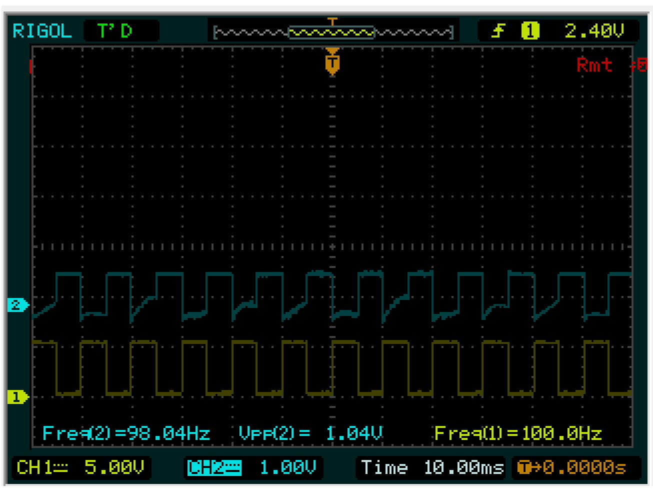
This circuit does not have any means of modifying its function during operation. Only way to change anything is to make change to the bias resistors. Once they are set it accepts a 5-volt PTP pulse train increase the current level and output 1-volt PTP signal to one end of the primary coil.

Based on the testing it appears to operate the same across a wide range of frequencies. I tested select frequencies from 5 Hz to over 10 KHz.

There appears to be some distortion in the 50 Hz signal not sure if is from this circuit or from the wiring on the 3 stage of the K2 as it has more wires crossing over and running next to each other than the other stages due to the way the bread board circuit is laid out. By distortion I mean in the negative portion of the signa in has a lot of ripples in it that does show up in the screen shots. This one best illustrates what I am talking about. It could also as be caused by noise in the O-scope as I know I am picking up some low level 60 cycle noise. Not surprised as I have several switching power supplies for my computer equipment and the voltages source all on the same power circuit. It is also possible it has something to do with the way the TIP120 operates as I recall see this in wave train others have posted.



The other frequencies are more like this one



I have seen others post wave trains very similar to this.

What this circuit does not tell you based on this testing is what the operating signal looks like as this was not the input signal I tested. However, I do feel confident that this signal will past it through with only the changes noted above.

I have seen others post wave trains very similar to this.

Again, a reminder this is not the operational wave train and that this testing was mainly to determine that the card I built for this circuit is functioning correctly.

Picture of Breadboard

Normal I would lay circuit out more compressed, but this layout made it easier to test and by spreading it out it made it easier to change the resisters when I was trying different values.

VEE +12VDC is on top of board

VDD +5VDC is on bottom of board

Both fed from same 12-volt power supply I am using for testing. I built a simple wiring harness to provide power to boards. Color code helps me kept voltages separate and to avoid hooking things up backwards already did that once and fried three ICs. I like these connectors as it is easy to change wires and they are labeled + and – and were not very expensive. I am using an LM317 mounted by Freq Gen board to get +5-Volts. I bought 5 of them for $10-$15 from Amazon with all the parts including heat sink and connectors.