

Tesla Switch Photo Voltaic Amplifier HOWTO

Taming down a PWM

Author:

Stevan Cerovec (cest73.at.Yahoo.com) 2010.A.D.

License:

GPL-v3

Version:

V:1.0 – original release

Abstract

A *PWM* is a “Pulse Width Modulator”, or in common language a controlling unit that decides just how long a pulse should last. We are up to build one our selves, otherwise we wouldn't skim this HOWTO, would we?

A Tesla Switch (*TS*) is a device that shuttles charge around a circuit, trading potential and current for each other, to gain a net benefit in the process.

To make a *TS* possible to gain net energy, we need to use rechargeable batteries. Without their Charge vs. Discharge hysteresis there is no gain. So a *TS* makes sense only in conjunction with a hysteresis device like a usual rechargeable battery is.

A Photo Voltaic array (Or “*Solar panel*”) is a semiconductor device, just like a usual *Bipolar Junction Transistor* (*BJT*). Instead of switching or power modulation, it serves as a “*IR*” (photo) to Voltage (thus “*voltaic*”) transformer. There from we gain energy from Sun's *IR* irrigation.

So this makes a ***Tesla Switch Photovoltaic Amplifier (TS-PV-Amp.)*** a device that takes electricity from a arbitrary “*Solar panel*” and converts it to short (1:1000 ratio) bursts of energy (called “pulses”). Those pulses are characterized by steep leading edges ($dI/dt=30MA/s$ (***Mega*** Amperes!) and possibly more (!!)) and usually short overall duration (about $10\mu s$), terminated without any energy allowed to flow backwards.

This sort of pulses, **Dr. Nikola Tesla** called “***unidirectional sharp pulses***” he fought so hard to generate. Our ***TS-PV-Amp.*** Develops those pulses of following amplitude:

17A peak

12V above receiving battery (about 25V total) up to 37V absolute maximum.

So, no trace of sheer amperage, yet still a formidable rate of at least 60MA/s on leading edge. You can really feel this “wavefront” knocking in a neodymium magnet held by hand adjacent to a output cable. I try hard imagine what this wavefront does to the Ions/crystals, it has ***galvanic coupling*** with, in a battery cell.

This technology is only lately extensively revisited by a tremendous number of researchers across the world, while it was brought back to the light of day by *over three decades spanning effort* of a brave research engineer (and not only him) now resident in Idaho U.S.A. His name is John Bedini, and despite leading the movement in knowledge, experience and effort, he hasn't said is last word just yet. Without his non-selfish support and sharing free information this document would never meet an eye.

Let us give him arguments in his favor when he is asked “*was it all worth it?*”

Table of Contents

Tesla Switch Photo Voltaic Amplifier HOWTO.....	1
Abstract.....	1
Preface.....	3
Introduction.....	3
Preparation.....	6
The chip.....	6
The banks.....	6
The driver stage.....	6
Power stage.....	7
Netlist.....	8
Building.....	10
Trial run.....	17
Troubleshooting.....	18
Testing.....	20

Preface

Free energy, a term so often used in English, yet and so often misunderstood.

Is “free energy” really *free*? Just how *free* is it actually?

In my opinion, we need “free energy” as “free speech”, or in other words, we need be free to produce our own energy, **at the cost it takes to be produced**. No matter be it of Sun, Wood, Oil or Wind, as long as we are **allowed** to produce in our own freedom.

Most of us came here to get “free as beer” energy, and I'm afraid some will find bitter disappointment and just lose their time (nerve?) here. You have to pay for either: *Kromrey*, *Bedini SSG*, *Bedini WM*, *Tesla Wireless*, *Radiant Energy capture*.

Be it Mr. Bedini got “filthy rich” just over night (I wish he would ;)) and just started giving away all the stuff he is building to his associates and anyone asking for it.

Be it You got it for free, You got even assembly and postage for free (just for the sake of the example here, okay?)

And even a *anonymous benefactor* (“Santa”?) landed in Your backyard about a ton of *Deep Cycle Lead Acid Batteries* (I call from now on PbS batteries) or even the ever lasting **NiCd** (same amount).

You still have to maintain the device, and maintain the batteries (Even **NiCd** needs maintainance), and to maintain Your home's installation, and to buy grease for the bearings, and to swap out broken Panels (be it “solar”) and burned out transistors (even be it solid state).

So it will still **cost** You in the end, even if You got is as a gift for free (likely **not** possible) and even with the batteries included.

So, I go on with our “free as speech” while the “*free beer*” *runners* are welcome to revisit the above paragraphs and their own math as far as I am concerned.

Introduction

A battery is a complex system. It has chemistry, it has physics, it has metal, crystal, liquid, suspension, solution; dry-, wet- and welded contacts. It has synthered, molded, folded and fiber supported parts. It has Acid and water. It can freeze in cold, it can boil of heat, it can bend, crack, shed, crystallize, bulge, flood, dry out, sulfate, melt and explode.

Last not least, it has *electricity*, it has *potential*, it has *current*, it has state of (dis-)charge, it has rate of charge, it has rate of discharge. It has resting voltage, it has working voltage. They are not the same

(NOTE: *Voltages*: they are not the same)

It is a species with a mind on it's own.

It's live like the *mountains*, or *nature* itself.

It *sags* on load, it *rises* on charge (*potential* wise). It accepts current, it produces current, it *fights* discharge, it *fights* charge.

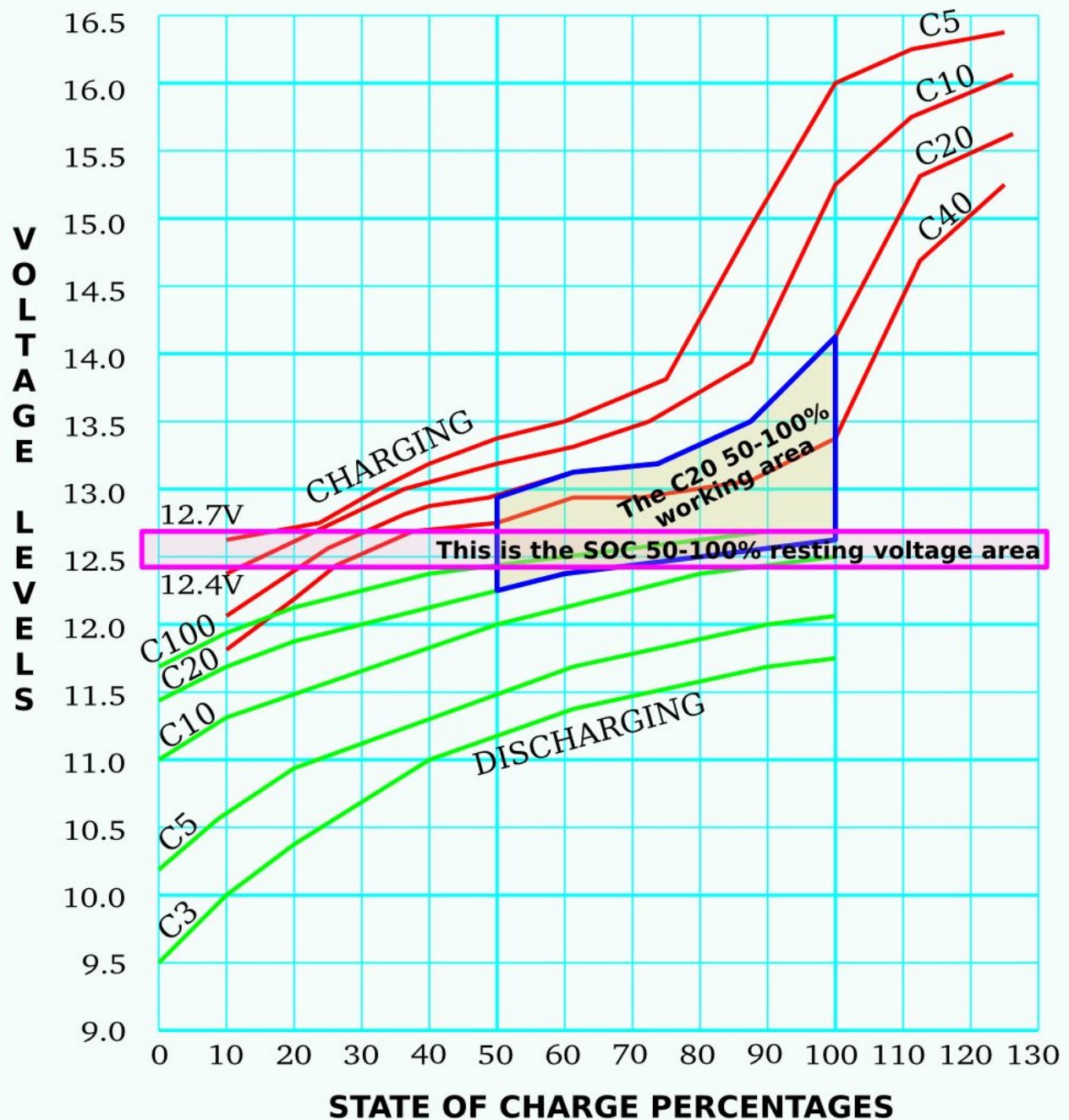
It **is** **COMPLEX**.

Why do I point this out here? Tesla Switch is all about *correctly* switching a battery.

To understand this let's observe the graphic of charge and discharge for a while:

THE TREASURE OF PEUKERT'S LAND

An adventure of electronic battery pirates of XXI century



Did You notice how the battery provides a potential increase shortly upon charge start?

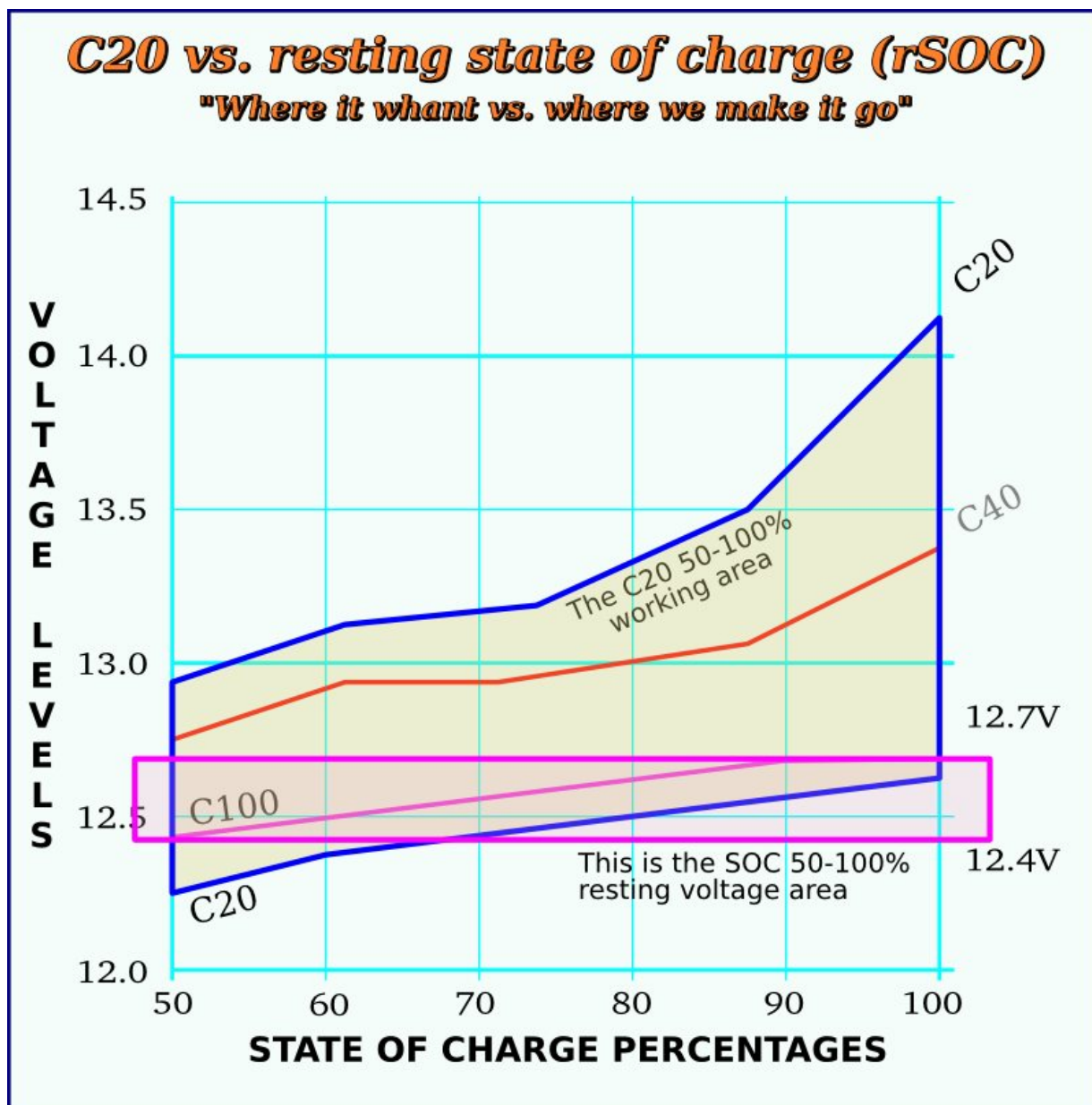
Did You notice the difference *charge* vs. *discharge* is from 0.4V (0%) up to 1.5V (100%) SoC?

Did You notice we have over 1.5V “slack” from 100% resting to 100% charging?

Any slack *from resting to discharge* is called “Peukert” and any slack *resting to charging* has no name as far as I know? Lets call it “inverse Peukert” for now.

I feel this is utterly important to have in mind when dealing with TS technology.

Let's have another look:



Consider the C100 line as resting voltage. While sagging scarcely under load, the PbS battery richly elevates voltage under charge (blue line). The same apply for each *Joule In* vs. *Joule Out*.

Here lies our chance:

Can we get some (one Joule) of the batteries electricity, scuttle it around for a while, and slam it back to the battery (now less than one Joule) and expect not to break below the C100 line?

Just how much of that one single Joule must we put back?

At what V/A ratio compared to the sourced V/A ratio (this transforms directly to the impedance of the borrowing/returning device) can we "get by"?

This questions will (hopefully) find answer by building what's described here.

Preparation

The chip

We intend to build a controller that divides a cycle into two events of same duration:

A. Getting Joules (“Que” in)

B. Returning Joules (“Que” out)

both with a pause in between, to avoid shorting a circuit and burning energy in vain (“Dead Time”)

We call “A” the “Q” and “B” the “!Q”. Dead Time will be described as “D/T”.

We are *lucky* now, for all above is provided readily in one single elegant chip (IC) named **SG3525**. And moreover, it provides reliable soft start (D/T is decayed from max to a preset value over a time period, allowing a “soft” run in), a momentarily shut down be it needed, and a fixed voltage reference of 5.1V.

In the old days, there were several ICs (47xx?) needed to get access to all this sophisticated functions.

The banks

Besides that, we need intermediate storage of electricity. I found Capacitors of 25V being enough for normal operation, but note I do use 50V ones in my testbed as I write this. I got twice an 80000 μF (80 mF) bank.

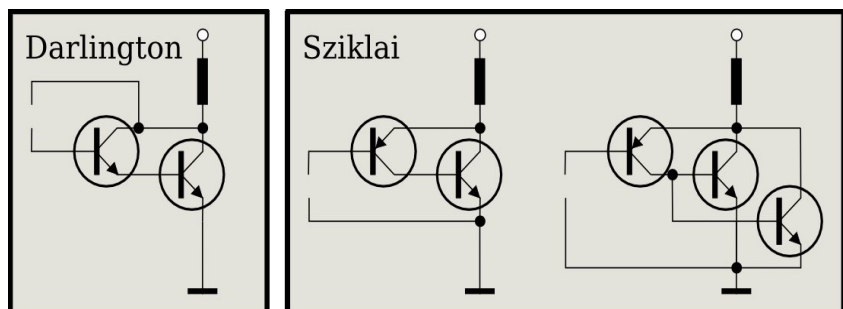
We need just so much capacity, we provide the current remains constant while we “Que in”. If current flow decays during “Que in”, we need either shorten the time or increase our bank to match the system.

The driver stage

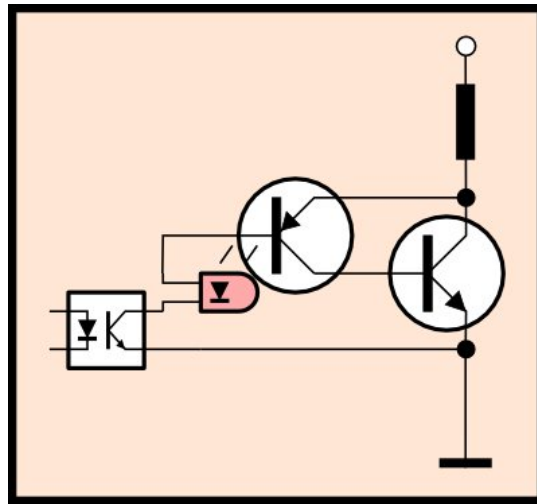
Provided we got an enough roughed power stage, don't expect to drive it off a IC directly. “Hefty” BJT need “juice” to saturate, so we use a *intermediate* device to provide it. This is the so called “*driver*”. I pick **BD140** as a reliable and readily available device, it has 6.5W rating and sustains 1.5A (compared to MJL's base 5A limit) so we can claim the (more expensive) MJL is “safe” with this driver, while properly *saturated* up to 1.5A on base, thanking to the high gain (h_{FE} 40...250) of the picked device.

Besides that, I picked (on Mr. J. Bedini's advice) a PNP to drive the NPN MJL, thus making what's now known as a “Sziklai pair” meaning I put the driver's collector on MJL's base and driver's emitter on MJL's collector; Then I switch the driver's base to MJL's emitter, avoiding the driver's own FVD (*Foward Voltage Drop*) in the driver's base circuit, provided better saturation of the driver. This in turn saturates the MJL even better providing 2V typical FVD instead of $\sim 4\text{V}$ inherent to a “Darlington pair”.

This, in turn, allows for comparatively lower control current (10..50mA typical) allowing a LED in the driver's base circuit. This actually turned out to be *super* “cool”, besides very informative.



This again allows for a *less powerful* (read *cheaper*) device to control the actual power stage transistor. I picked the widely used **PC817**.



Power stage

In my opinion, we actually don't appreciate the MJL's availability enough. In the 80's there were only 2N3055 and 2N3773. Later came 2N5885.

And that was about it. Take it or leave it.

The 90's brought the MJ15024 and 15003

All the time the MOSFETs just fried and fried.

And as the MJL21194 came to be, (although there were military grade (read *tens of hundreds* of bucks worth) BJT, they were just not **rough** enough) we finally had a "just works" BJT.

It has a 5W sustain base circuit, it can handle either 5A or 5V on the base junction (a true workhorse).

It can handle 1A at 130V (!)

It can sustain 230V forward un-clamped and un-braked

It can sustain 4A @50V (kills about every healthy strong man (or woman) plain dead

It can sustain 2.25A @80V for 1 second while 150C hot! (wanna touch it then?) Each single one!

It can indefinitely sustain 16A DC (melts awg22 midst air !) ~@12V

It can handle 30A surge (at over 5V!) repetitive!

No other BJT I know of matches it (here I count all 21194s in), the closest weaker being the MJ15024

So, long live the MJL21194!

Netlist

Let's see what we need to build the controller unit.

Control stage:

Part #	name	type	qty
1	Stripe-board	14 lines x 28 holes piece	1
2	PWM controller	SG3525	2
3	Upper divider	27k Ω	1
4	Lower divider	22k Ω	1
5	Dead Time	r100 Ω	1
6	Channel “choke”	r560 Ω	2
7	Common supply	4k7 Ω	1
8	Cycle ramp	100k Ω	1
9	Feed back	2k2 Ω	1
10	Cycle delay	4u7F	1
11	Soft start	100uF	1
12	LED blue	30mA 5mm	2
13	LED red	30mA 5mm	9
14	Opto-Coupler	PC817	9
15	IC socket	DIM 7x2 pins (or 14+7pins)	3
16	Duty cycle adjust	50k Ω lin (or 47k Ω)	1
17	Power connect	2pin header	1

NOTE: There is a reasonable surplus on parts prone to fail.

Power stage

Part #	name	type	qty
1	Driver transistor	BD140	7
2	Power transistor	MJL21194 (or MJW21194)	7 (or 14)
3	Heat-sink	Al (or copper) bar 120mm	1
4	Insulating thermal pads	MJL sized (TO-248)	7 (or 14)
5	M3 screws	Insulating, longer ones (12mm)	7 (or 14)
6	PVC copper wire	AWG16	4m
7	Control bus	Flat cable 14 wires	1
8	Audio cable litzed	2x AWG16	2m
9	Clips for PV or LAB	Nice heavy Amperage clips	4
10	Outdoors case	250mm x 125mm x 60mm (10" x 5" x 2.5")	1
11	Connector & jacks	4mm outdoors	4 pairs
12	Main switch	2,5A outdoors rated	1

Further more needed:

- Soldering skill with experience mandatory,
- soldering tools,
- dedicated working area (more days of work due),
- digital multimeter,
- Heavy amp-meter (15A recommended),
- Analog multimeter,
- PbS battery of min. 36Ah (97Ah recommended).
- PV panel of minimum 45W (2x90W recommended).
- A bench with a vice.

Recommended but not mandatory:

- o-scope (the DSO-062 is about enough),
- Lab-PSU capable of 8A @22V.

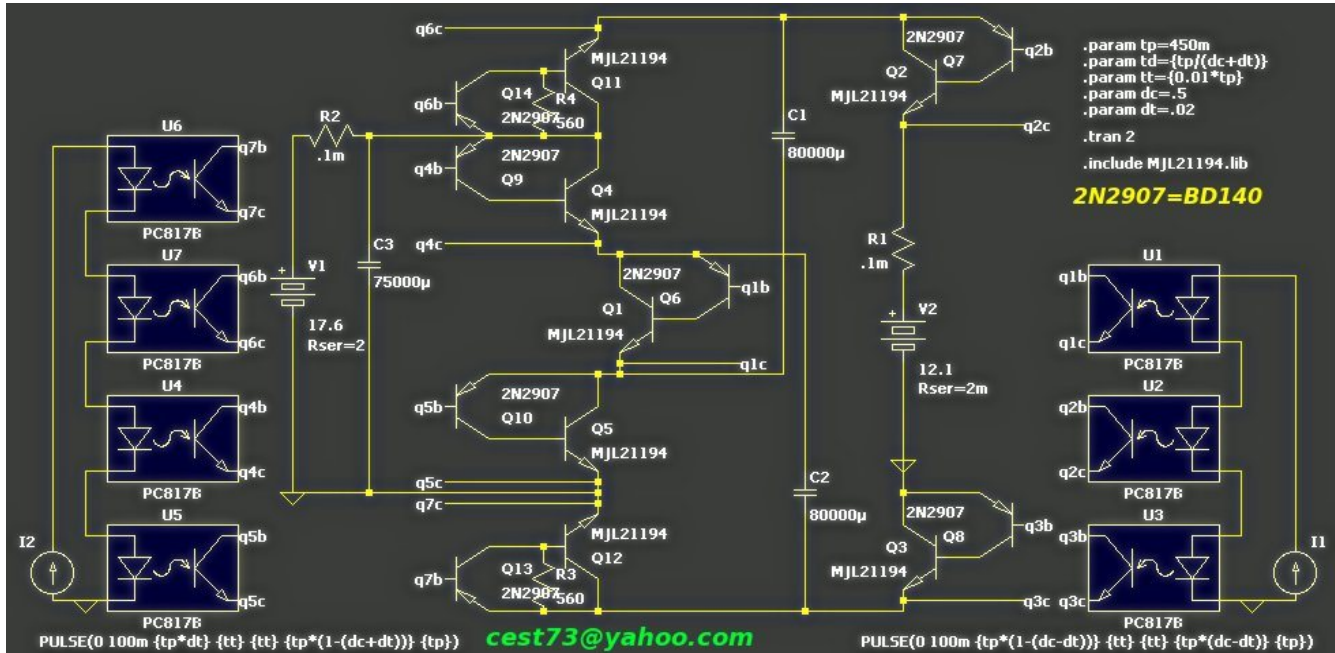
Few tools that will be built as we go on;

And a lot of patience and luck.

Building

Sadly, SPICE does not support our PWM controller IC :(

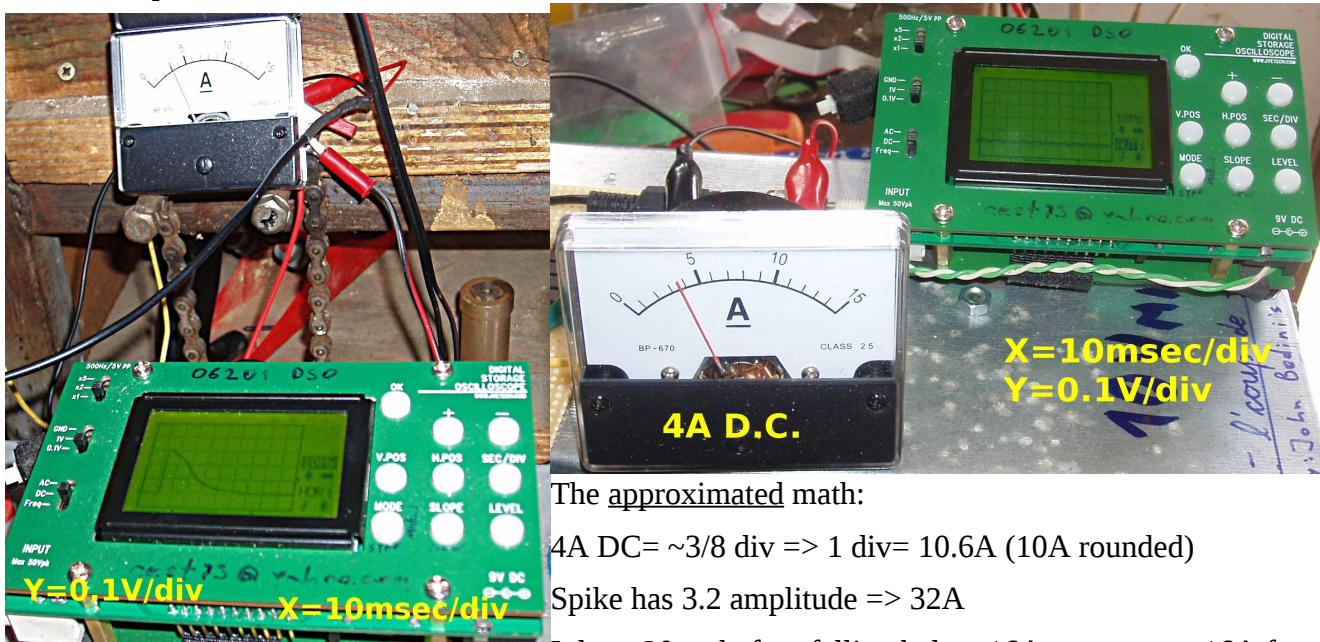
So, I had to make SPICE “act” as a PWM controller where no surprises are expected (in the “signal level” section) and there from I built a SPICE model:



I1 and I2 are the PWM's channel sources.

The 2N2907 is just *instead* for the **BD140**. The 2N2907 is a low Amp. 350V driver sort of transistor. I could use the actual BD140 in SPICE, but including it, would just unnecessarily complicate the already complex schematic in my opinion.

Besides that, all else applies. And guess what? SPICE matches the waveforms I observed on the actual TS-PV-Amp model!



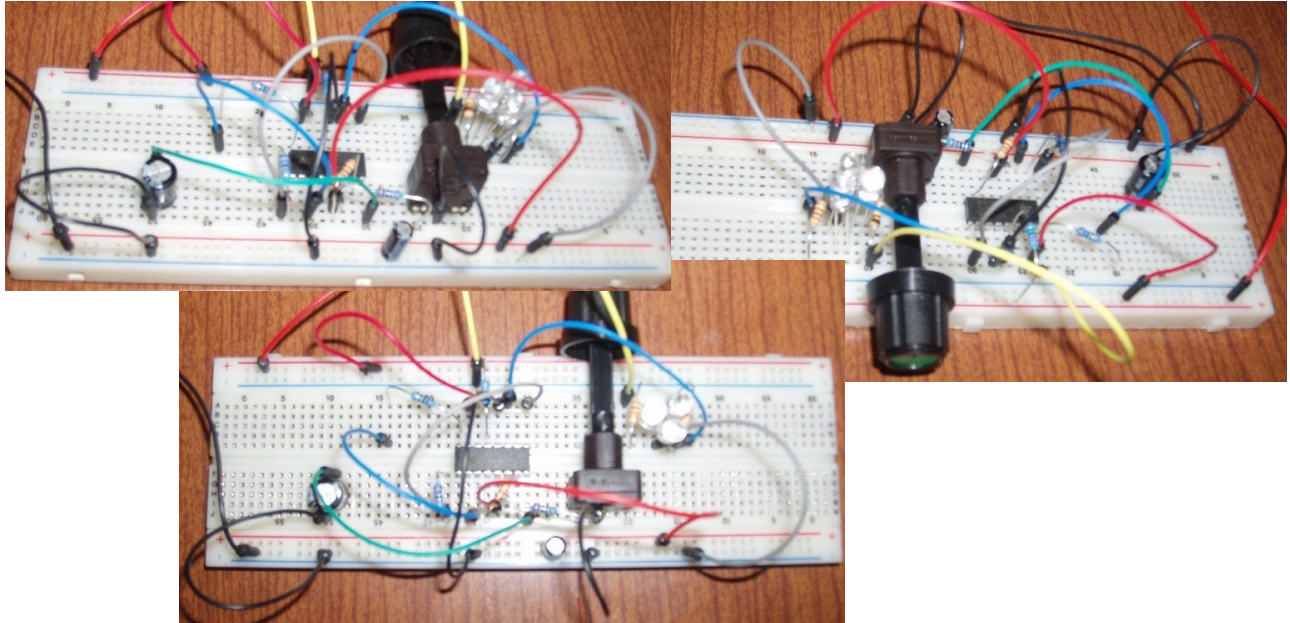
The approximated math:

4A DC = $\sim 3/8$ div $\Rightarrow$ 1 div = 10.6A (10A rounded)

Spike has 3.2 amplitude $\Rightarrow$ 32A

It lasts 20ms before falling below 16A, so average 16A for

Once we understand what's going on, and that “*it's not a crime*”, let us go on and develop the actual PWM controller on a “bread board”:



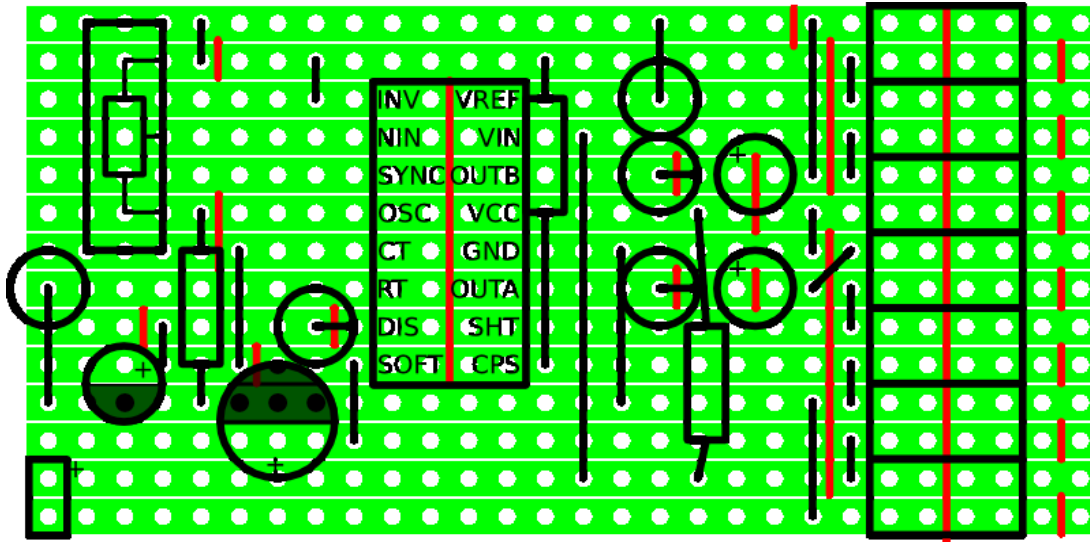
mHz PWM hacking the SG3525

The diagram illustrates a modified SG3525 timer circuit. Key components and connections include:

- Inputs:** +in and -in terminals at the top.
- Resistors:** 27k, 2k2, 47k lin, 22k, 220k lin, R100, 4k7, and R560.
- Capacitors:** 2u2 and 47u.
- Semiconductors:** A 1N4007 diode and two LEDs (one blue, one red).
- Optocoupler:** PC817 with six output channels, each represented by a diode symbol.
- SG3525 Pinout:** Pins 1-16 are shown, with specific connections for timing and control.

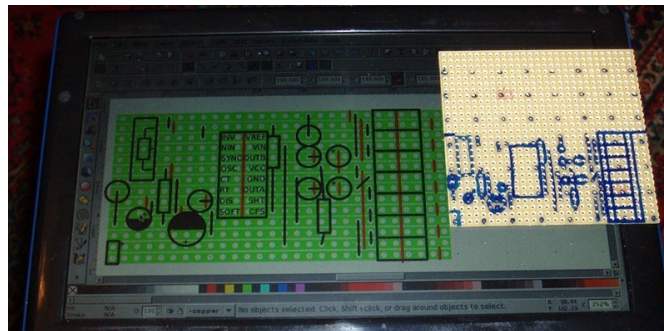
GPL: cest73@yahoo.com

Therefrom I designed a *stripe-board* design in *Inkscape* (a vector graphic drawing suite).



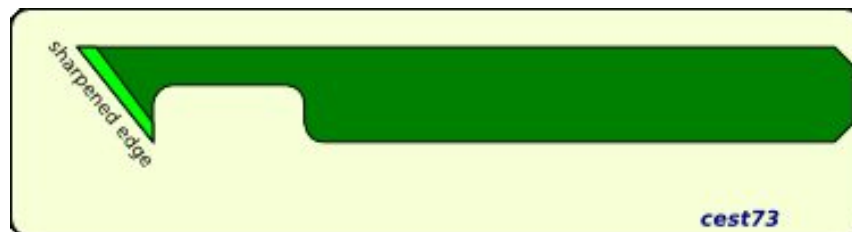
It's easy to manipulate components in a drawing program. Besides it's faster than doing it on the bench, it is considerably cheaper.

Once I was satisfied with the component layout and the area of stripe-board used (note I actually use one more column of holes than shown in the drawing), I copied the layout to the stripe-board:



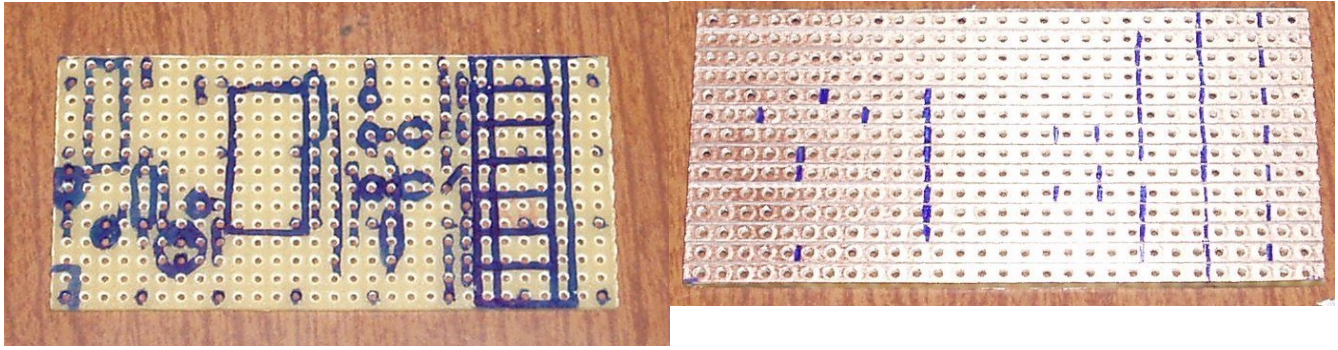
Just like “*copy, paste*”, only in real life (=bare foot, **lots** of checks...)

I made a tool out of the steel-saw blade:



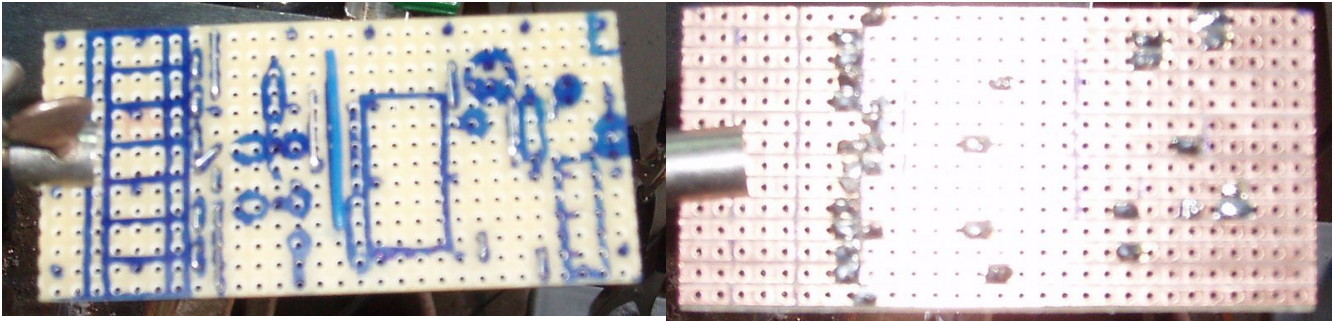
I could use to “scratch until cut” the stripe-board right in between the stripes.

Then I cut the board to final size:

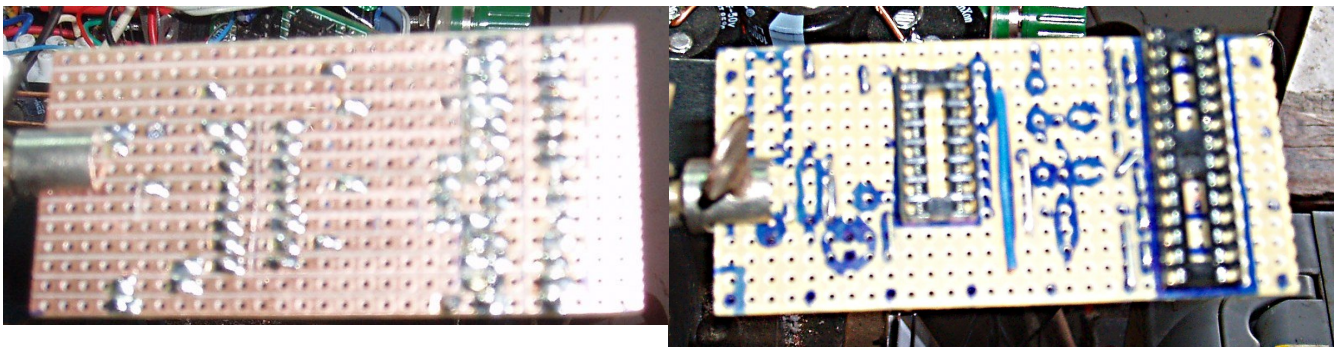


The stripe cuts where triple checked and drawn (and rechecked *again*). Then they were milled out by a “dentist like” drill/mill “pen”.

And brought the stripe-board finally to the welding workshop (the opposite bench actually) to be populated:



After the cross-connecting wires were soldered first (You need be really quick with heating, and not overdo solder: thinner soldering wire is highly recommended), we follow with IC sockets:



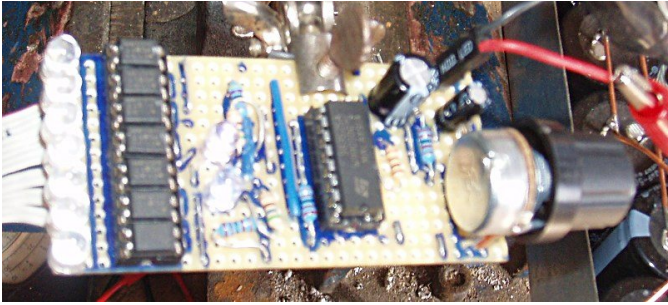
The “third hand” helps quite a lot here.

Note the tremendous importance of orientating the notch on the socket to the “**north**” of the stripe board. If You fail to do so, You unveil Your self as a *lousy beginner*, instead of leaving an impression of a **seasoned profi**. Besides that it is *really* important for orienting the IC to the socket.

After that we continue soldering resistors, putting insulation (we got from blanking AWG22 cables) on long running leads, and then we go with capacitors and active components in the end, the most expensive or most prone to damage by overheat parts as last.

Usually potentiometers come in the end, being the tallest parts on a typical PCB.

Further work done:

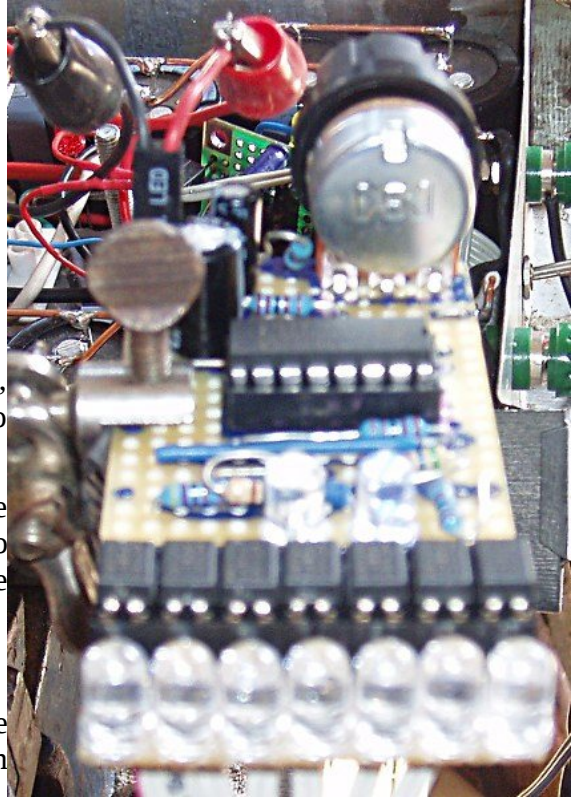


Note that opto-couplers, despite not “Que-ing” out just yet, are important in this stage of testing. They are in series to the feedback LEDs of the PWM stage.

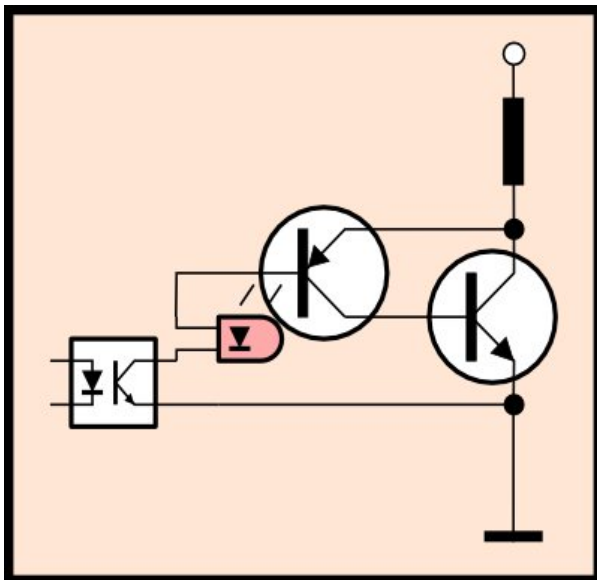
The Blue LED is picked for the 3 opto channel while the red is picked for the 4 opto channel. This is done so to compensate the different voltage drop caused by the difference of the opto/channel.

Just try otherwise and You will see what I meant by this ;).

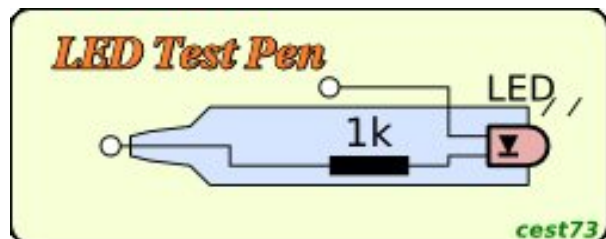
The controller is intended to work on 9V to 25V, the higher the voltage, the more desirable is to have an *LM7812* voltage regulator, for the longevity of the LEDs, or similar in the supply line. Up to 18V (~55W PV panel) it's *reasonably* stable without.



1. To connect the output of the optos to the powerstage (BD140's base and MJL21194's emitter) take a said pair and connect it to form a car head light switch.



2. Take a (red?) LED and solder a 1k resistor to it's longer leg (positive).
3. Bind the shorter leg to the lens of the LED and solder a black insulated “litzed” wire to it, ending with a clip (“GND”-negative)
4. Try to put that LED into a insulating and convenient tube (a old dry marker? A ball pen?)
5. You've just built a “LED test pen”. It's a valuable tool for circuit investigation.



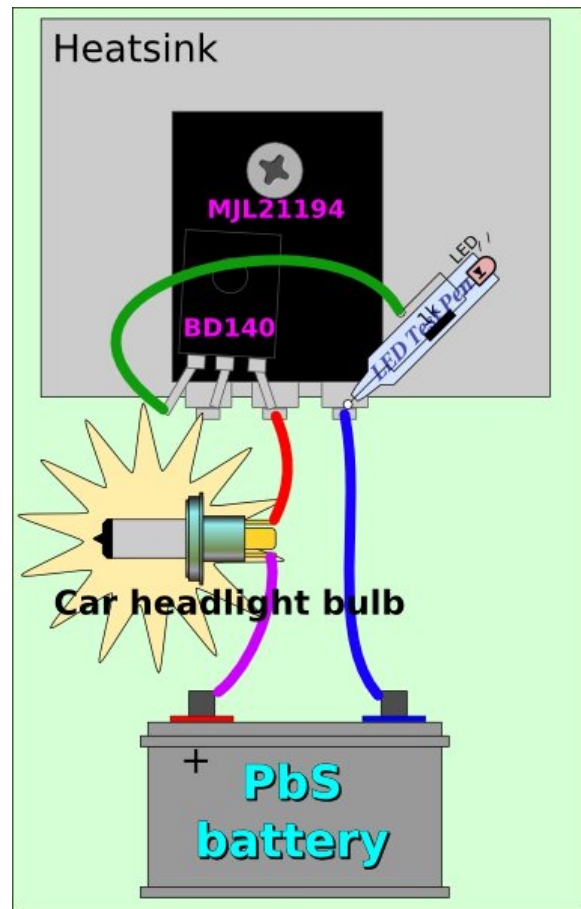
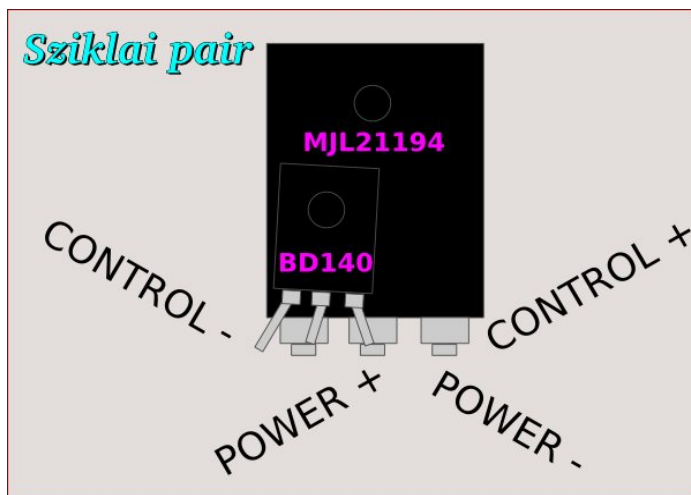
6. Try now lit the car headlight by connecting the BD140's base and collector with that “Led test pen” Where goes the GND, and where the tip?

7. Try now to lit the car headlight lamp by connecting the BD140's base and the MJL21194's emitter?
8. Apply this experience to the 14 wire control bus

Note: seasoned builders rarely bother to remember *what goes where*, they rather **take care** to **make sure** and then they **check** and **wonder why**.

Never **assume** , **always check**.

You now are ready to “marry” the powerstage and the controller:



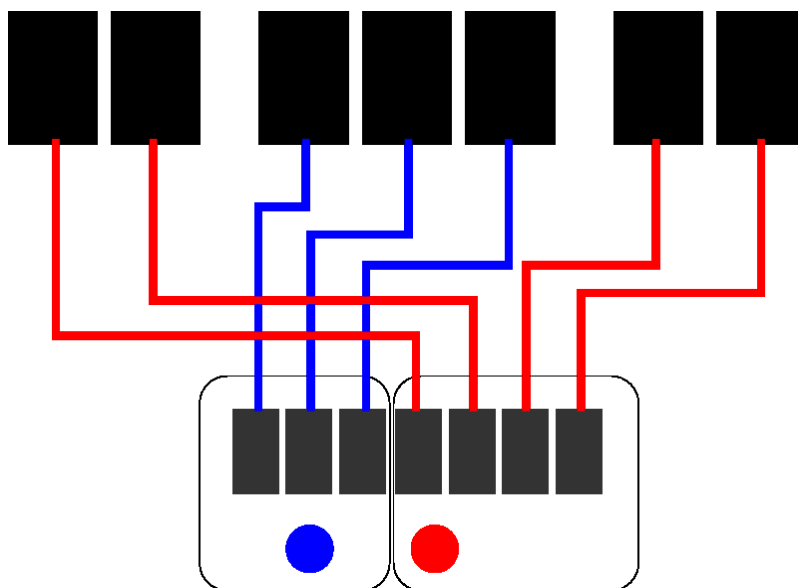
Make M3 threads on the thermal bar, making sure there is place for few M5 threads that will serve to affix the bar to the case.

Fasten the MJLs (**insulated** from the heat-sink) and fold their legs “up”, solder the BDs so heir base is free “left side” and the MJL's emitter is free “right side”.

Solder the buss ribbon cable (I cut it out of a “floppy” 25 wire data cable) to the controller fist. Make sure You tear the controller side pairs just enough (12mm apart) and power side pairs accordingly (50mm apart or so). Each pair I tear about 7mm apart, de-cap, twist and wet the bare tip with solder.

It takes considerable time to do so, be patient.

Once the controller is soldered to the cable, and MJLs are affixed to the case, it is time to solder the buss to the MJLs:



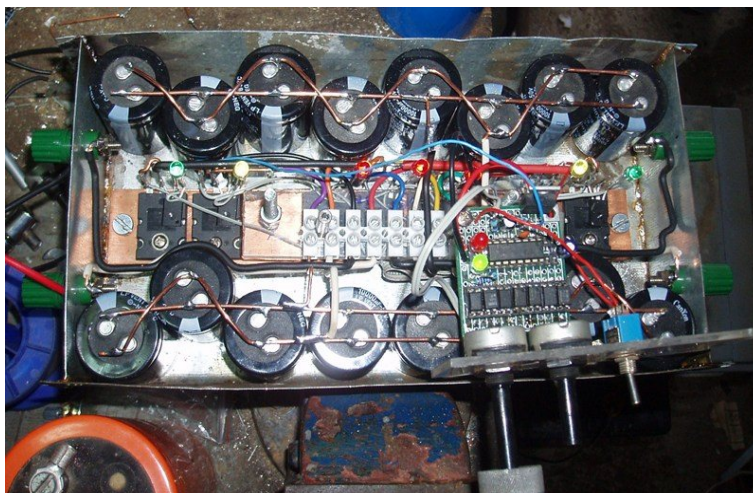
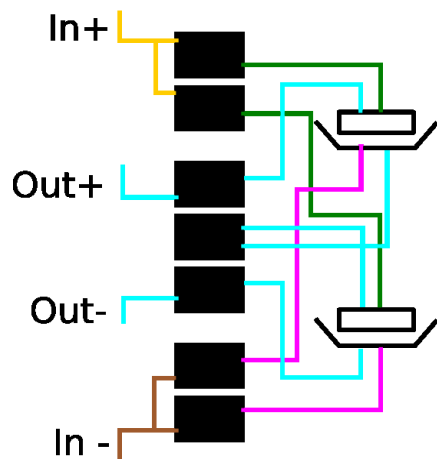
The “BLUE” channel's three optos go to the “middle three” power stage units (=“output”)

The “RED” four channels control the tow outer unit pairs.

Once You checked the “dot side output pin” on the opto goes to the BD's base and the other pin to the the MJL's emitter.

I prefer the power stage being managed before powered out of experience ;)

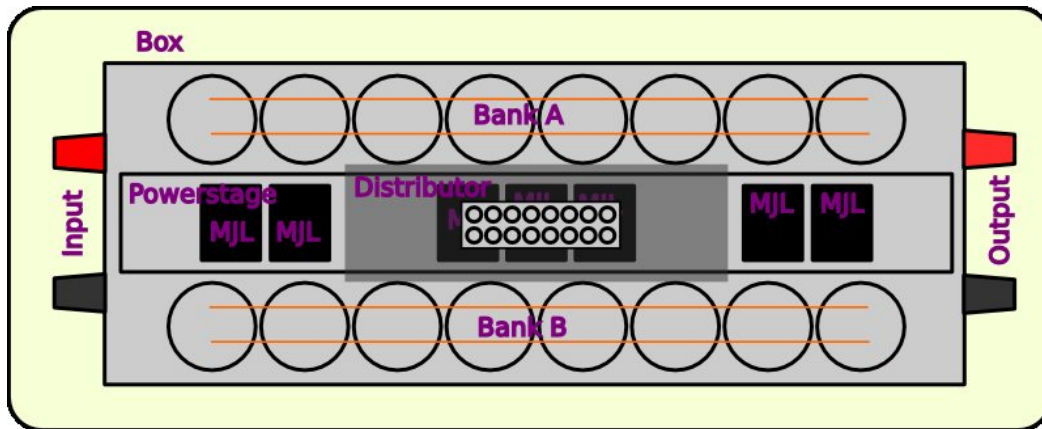
Now we supply the power lines to our project (before we affix the cooling bar to the box). The cabling should be about 16AWG and as short as practical.



I put a screw clamp as an interface to:

- input
- output
- capacitor bank A
- capacitor bank B

Now we can affix the cooling bar and unite the power stage and the box. On each side of the power stage we see room for an capacitor bank.



We lineup a capacitor array and connect each to Bank A and Bank B connector respectively.

Trial run

Gosh, did we already got up to here?

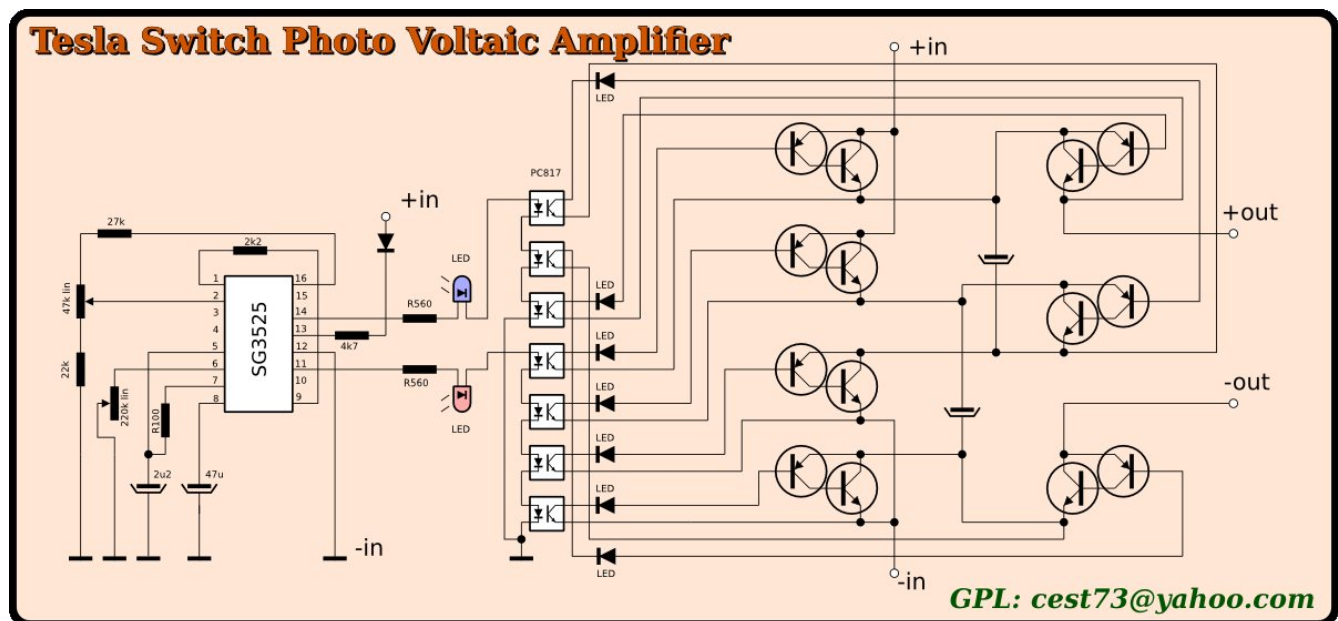
Now it's time for a gradual power up:

The PWM controller (PCB) is to be connected directly to the input, running trough a switch.

We switch the unit on and supply voltage from 12V (idling) slowly increasing up to 20V (full power)

The output should go 37V if un-loaded and up to 8A on a *Analog Ampere Meter* if loaded. The scope should readout *much* more in the spike.

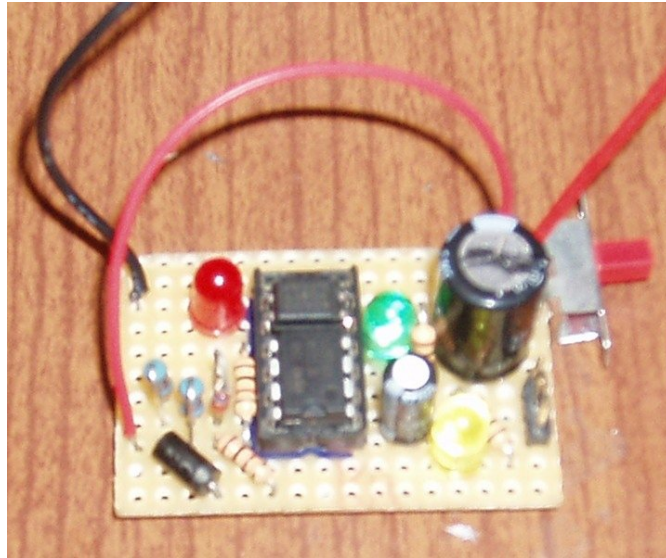
The actual final schematic I used:



Troubleshooting

1. In case any opto fails it's input (IR diode), it will be immediately obvious by the appropriate channel's LED stopping to shine.
2. Should any power BJT burn, it's appropriate driver LED will stop to shine.
3. Should a driver BJT fail, it's LED will stop shining.
4. Should the output be disconnected, the seven LEDs will stop shining
5. Should the input be disconnected, all nine LEDs will stop shining

It is very practical to have the optocouplers tested one by one on occasion or in case of any failure. To speed up this I built a 555 based **opto-tester**:



1. The yellow LED shines to show the 555's "Que"
2. The green LED shines to show opto's IR LED conducts:
 2. a. If no light – it's *shot through*
 2. b. If constant light, it's "*welded*" dead
3. The Red LED shows opto's output:
 3. a. if no light – the output is burned out
 3. b. If always lit – the output is "*welded*"

Only if all three LEDs "Que", the opto is "nominal"

This **opto-tester** will not be further subject of this document, it's mentioned just as an exercise for the reader to build or construct.

Testing

To my surprise, the unit really doubled the readout on a analog amp meter?

It is important to understand that the value the tip reaches has nothing to do with *actual peak* values the device attains, nor the *swing time* has anything common with the *actual dump time*.

It merely shows a ratio of energy density time-wise of input vs. output, integrated by the mechanics of the Analog meter.

The device ***packs*** energy ($0.64\text{J/s} \rightarrow 0.64\text{J}/0.04\text{s}$), thus providing ***rest*** to the battery.

Besides that, I had success lighting a LED across the ends of a single output wire (5V peak!) when under standard operation.

I've also been witness of ever increasing active power of an discarded battery.

Now bare in mind this is only a *test* unit. Here from we can discuss, fiddle and tweak up to compare to a commercial unit.

One of the schematics already has such a tweak. I leave to the respected reader as an exercise to find out.

Finally, If You pick the RT/CT pair just right (4u7F vs. 100k?) You might get “does exactly what I say it does” J.B. Had on YT (once upon a time). I know I had this morning.

Serbia, March 2010., Stevan C.

P.S.

Thanks to all (you know who you are people) on BM2 for help and support.