Steven Mark's

Toroidal Power Unit (TPU)

TP900 - TPU PULSER

- *A useful tool for TPU and other research*

Prepared by:	Darren Kozey (z_p_e)
Document Date:	2007/AUG/04
Revision:	TP900.1

PREFACE

After folks finish reading through the SM material and feel they are ready to begin experimenting, one "must have" tool they need is a unit that can be used to pulse their coils. It is the aim of this document to provide the design for such a tool.

The core TP900 circuit provides 3 separate and independently controlled square wave generators capable of frequencies from 0.4 Hz up to about 13 MHz.

The unit comes integrated with a unique frequency divider—by changing the mode switch over to "SYNCHRONIZED", the 3 outputs are harmonically related and synchronized in time.

As an added bonus, the TP900 is equipped with a sophisticated and novel pulse generation circuit capable of pulse widths variable from 5ms to as short as 17ns. To put things in perspective, the propagation delay of a single 74AC04 inverter gate is about 4ns, so 17ns is fairly impressive. With a 35 kHz frequency for example, a 17ns pulse width translates to a duty cycle of only 0.06%.

Much time and effort has gone into this design, and it is my hope that it should prove useful in many areas of research involving pulsed coils.

As a final note, I wish to extend credit to **David Johnson and Associates** for the "Divide by 1.5" circuit, and to **Dallas Semiconductor** for inspiring the pulse circuit.

Good luck and enjoy,

Sincerely,
Darren (z_p_e)

A BRIEF THEORY OF OPERATION

The Oscillator

The core of the TP900 is the oscillator formed around a Schmitt trigger and RC timing components. This configuration is fairly well known and some information about them can be located on the web. A good place to start is here: http://www.fairchildsemi.com/an/AN/AN-140.pdf

The Harmonic Divider

I simply took the "Divide by 1.5" circuit designed by David Johnson and Associates, and modified it to provide a "Divide by 3" as well. The input frequency is thus divided by 1.5, then again by 2, and an output is taken from each resulting in the fundamental, and the second and third harmonics. The "F3" oscillator is the master clock in the **SYNCHRONIZED** mode of operation.

50% Duty Cycle

Following the Data Multiplexer U8 which is used to select either **INDEPENDENT** or **SYNCHRONIZED** frequencies, flip-flops configured for "divide by 2" are used to establish a guaranteed 50% duty cycle output before the Pulse Generator circuitry. This is required because both the Schmitt oscillators and the "Divide by 1.5" circuits yield asymmetrical wave forms.

The Current Sink and Current Mirror

The pulse circuit is composed of several key components, and the precision Ramp Generator is certainly one of them.

The operational amplifier U10A and associated transistors form a high quality current source for linearly ramping up the chosen timing capacitor. The cascode transistor Q4 was implemented to augment the current source output impedance, and limit the maximum ramp voltage. The timing capacitor charging current is determined by $2.5V/R_{\text{pulse width}}$.

Without a switch to reset the ramping voltage, we would not have a functioning pulse circuit. To facilitate this need, I implemented a rather unlikely candidate for the switch—a 74AC240 Octal Buffer/Line Driver with 3-STATE Outputs. Some may be scratching their heads right now wondering what the heck I am doing!

Well, I tried a few MOSFETs and transistors as switches, but was not completely satisfied with the results. In fact, I could not get any MOSFET to work properly. All that is required really is something that can bring down the timing capacitor's voltage quickly and completely, and through a novel approach, the 74AC240 worked quite well indeed. Being a buffer/line driver, the 74AC240 has relatively robust outputs, and as there are eight in a package, paralleling them creates an effective "switch to ground" for resetting the capacitor. I simply hard-wired the inputs HI and paralleled the outputs. Using the 3-STATE capability of the device, I now had a pseudo switch.

Delay and Detect

The basic concept of the pulse circuit is to send an edge-trigger down two paths– one directly, and one delayed by some user-chosen amount. The ramp circuit facilitates the delayed path, and now all that has to be done is implement a detector which determines when the delay is finished. This is accomplished via a precision high-speed comparator, U12. The threshold is set to 1.235 Volts by the precision voltage reference. Once the threshold is reached, the comparator goes HI, and the NOR output goes LO, ending the pulse set into motion by the direct path leading edge.

This circuit has an added benefit; it is somewhat "idiot-proofed" in that the output pulse width can never exceed half of the square wave period. Not having this failsafe would be catastrophic!

The NOR output then feeds the MAX4420 MOSFET driver.

Pulse or Square?

At MHz frequencies, propagation delays are critical, and I did not want to introduce more than was necessary in order to maintain the 17ns spec. As such, in order to implement **PULSE** or **SQUARE** mode selection, I did not want to introduce yet another device in the pulse path. The solution was easy and was achieved by "pulling down" the timing capacitor with a transistor switch in parallel with the 74AC240 switch. In this way it acts as an override and prevents the capacitor from ever charging. No additional propagation delays are introduced, and when not active, the transistor is transparent to the circuit operation.

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TP900 - TPU PULSER Revised: Saturday, August 04, 2007				
TP900.1 Revision: -				
Designed by z_p_e - Copyright Darren Kozey 2007				
Bill Of Materials August 4,2007 15:34:31				
Item	**Quantity**	**Reference**	**Part**	**Description**
1	3	C1,C8,C15	10p	Film
2	6	C2,C9,C16,C31,C46,C61	100p	Film
3	6	C3,C10,C17,C32,C47,C62	1n	Film
4	6	C4,C11,C18,C33,C48,C63	10n	Film
5	6	C5,C12,C19,C34,C49,C64	100n	Film
6	6	C6,C13,C20,C35,C50,C65	1u	Film
7	6	C7,C14,C21,C36,C51,C66	10u	Film
8	9	C22,C24,C28,C37,C39,C44,C52,C54,C57	100u	Electrolytic, 10V min.
9	30	C23,C25,C26,C27,C29,C38,C40,C41,C43,C45,C53,C55,C56, C58,C60,C69,C71,C73,C74,C75,C76,C77,C78,C79,C80,C81, C82,C83,C84,C85	0.1u	Mono or Ceramic
10	5	C30,C42,C59,C68,C70	4.7u	Tantalum, 10V min.
11	2	C67,C72	1000u	Electrolytic, 25V min.
12	3	D1,D4,D7	LT1004-2.5	2.5 Volt Reference
13	3	D2,D5,D8	LT1004-1.2	1.235V Reference
14	4	D3,D6,D9,D10	MUR1520	Diode, Ultrafast
15	3	M1,M2,M3	IRF3710	MOSFET, Power
16	9	Q1,Q2,Q4,Q6,Q7,Q9,Q11,Q12,Q14	Q2N5087	High HFE, PNP
17	3	Q3,Q8,Q13	Q2N5210	High HFE, NPN
18	3	Q5,Q10,Q15	MPS8099	Amplifying, NPN
19	6 / 3	R1,R3,R5,R7,R13,R19 / R8,R14,R20	1k	R8, R14, and R20 are Rheostats/Potentiometers
20	3	R2,R4,R6	100k	Rheostat/Potentiometer
21	6	R9,R10,R15,R16,R21,R22	100	Resistor
22	3	R11,R17,R23	22	Resistor
23	3	R12,R18,R24	4.7k	Resistor

TP900 - TPU PULSER Revised: Saturday, August 04, 2007

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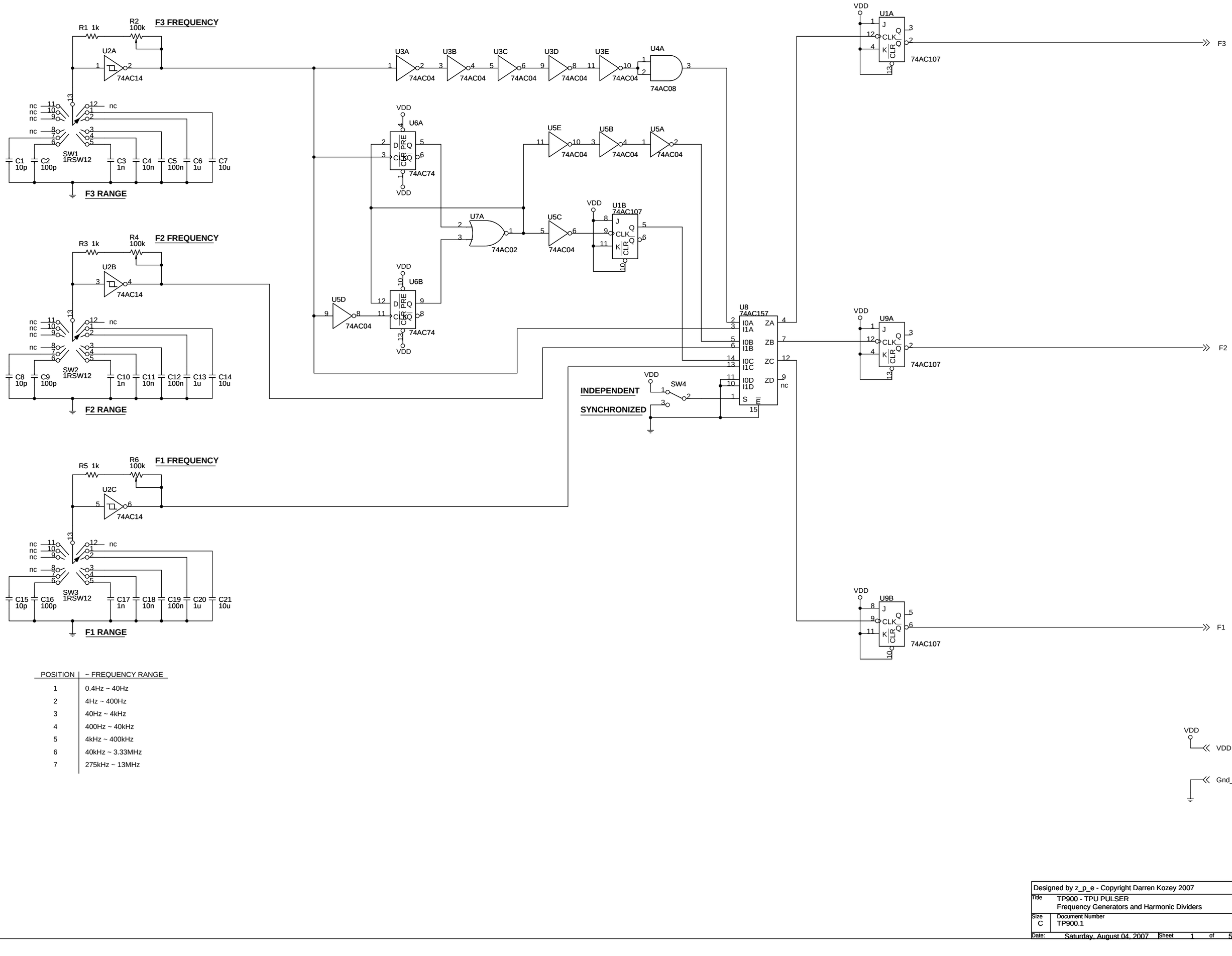
Bill Of Materials August 4,2007 15:34:31

Item	Quantity	Reference	Part	Description
24	1	R25	47	Resistor
25	3	SW1,SW2,SW3	1RSW12	Rotary Switch, 12-Position
26	2	SW4,SW5	SW SPDT	Switch, SPDT
27	3	SW6,SW7,SW8	1RSW6	Rotary Switch, 6-position
28	1	TB1	?	Terminal Block, 6-position
29	2	U1,U9	74AC107	Dual "JK" Flip-Flop
30	1	U2	74AC14	Hex Schmitt Inverter
31	3	U3,U5,U20	74AC04	Hex Inverter
32	1	U4	74AC08	Quad "AND" Gate
33	1	U6	74AC74	Dual "D" Flip-Flop
34	1	U7	74AC02	Quad "NOR" Gate
35	1	U8	74AC157	Quad Data Multiplexer
36	1	U10	TLC274	Quad Op-Amp, LinCMOS
37	3	U11,U14,U17	74AC240	Octal Buffer/Line Driver with 3-STATE Outputs
38	3	U12,U15,U18	LT1713	Comparator, Fast
39	3	U13,U16,U19	MAX4420	MOSFET Driver, Low-side
40	1	U21	L78M05/TO220	Regulator, 5V, Medium Power
41	3	HS1,HS2,HS3	Heat Sink	Suitable for the IRF3710 MOSFETs



POSITION	~ FREQUENCY RANGE
1	0.4Hz ~ 40Hz
2	4Hz ~ 400Hz
3	40Hz ~ 4kHz
4	400Hz ~ 40kHz
5	4kHz ~ 400kHz
6	40kHz ~ 3.33MHz
7	275kHz ~ 13MHz

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Size: C	Document Number: TP900.1
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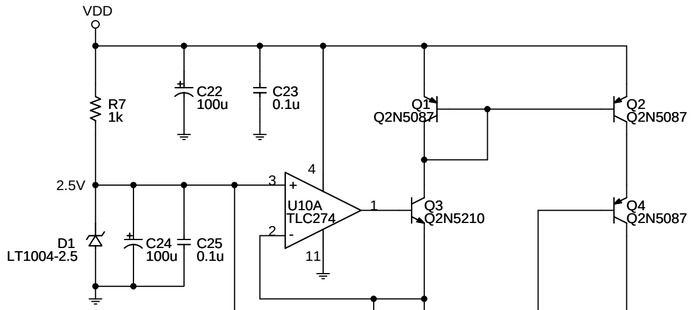
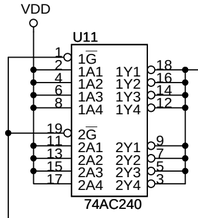
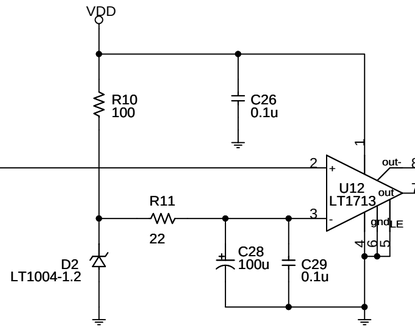
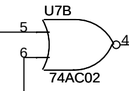
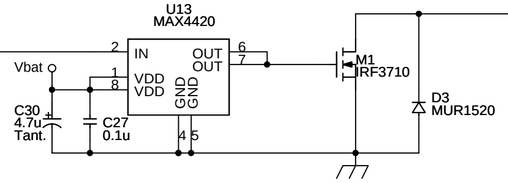
Date: Saturday, August 04, 2007	Sheet 1 of 5

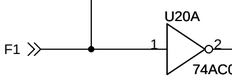


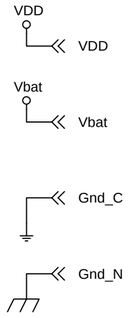




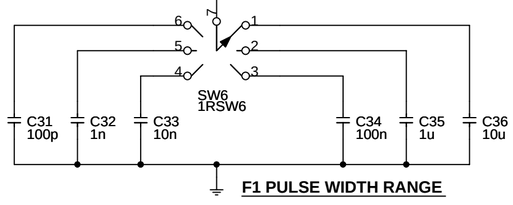








POSITION	~ PULSE WIDTH RANGE
1	5ms ~ 480us
2	500us ~ 48us
3	50us ~ 4.8us
4	5us ~ 0.5us
5	522ns ~ 63ns
6	70ns ~ 17ns



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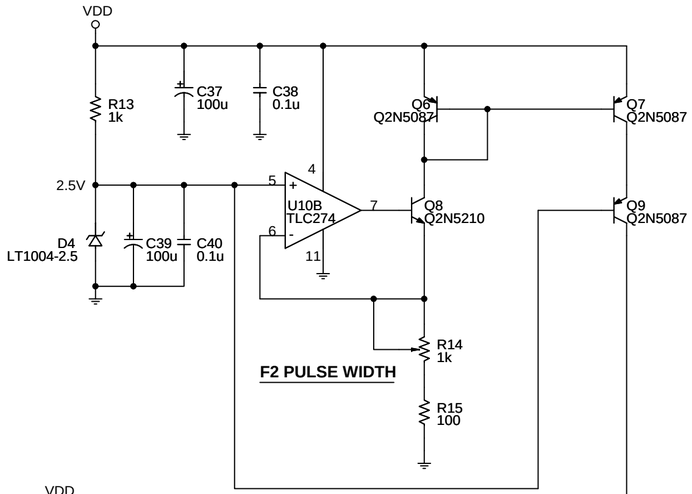
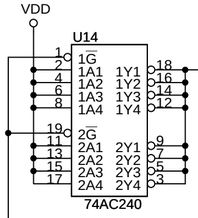
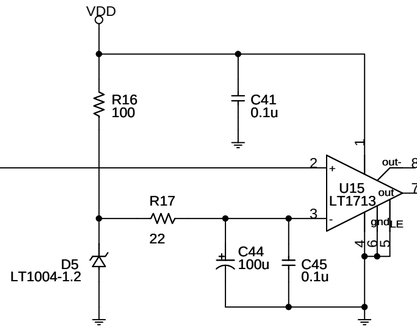
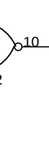
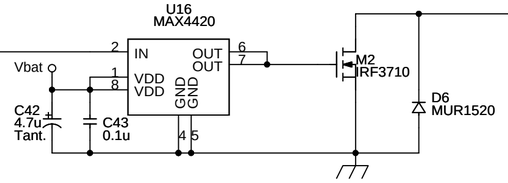
Size: C	Document Number: TP900.1	Rev: -
Date: Saturday, August 04, 2007	Sheet 2 of 5	

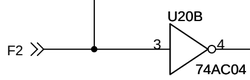


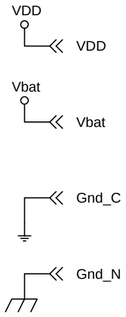




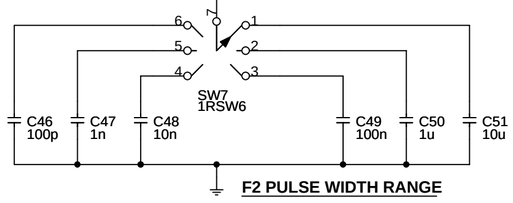








POSITION	~ PULSE WIDTH RANGE
1	5ms ~ 480us
2	500us ~ 48us
3	50us ~ 4.8us
4	5us ~ 0.5us
5	522ns ~ 63ns
6	70ns ~ 17ns



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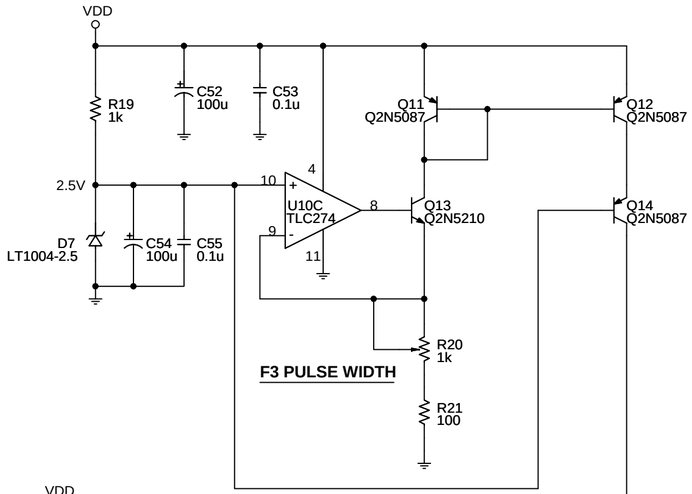
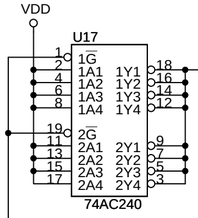
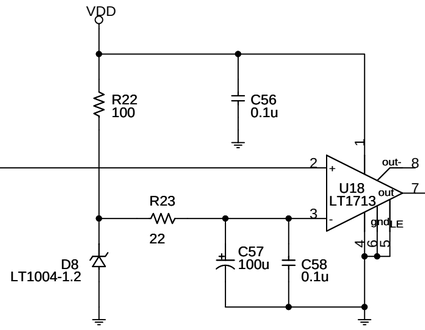
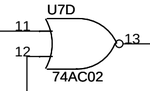
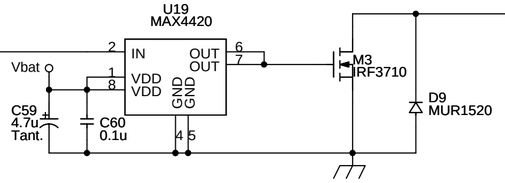
Date: Saturday, August 04, 2007	Sheet 3 of 5		

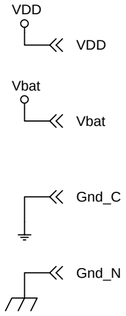












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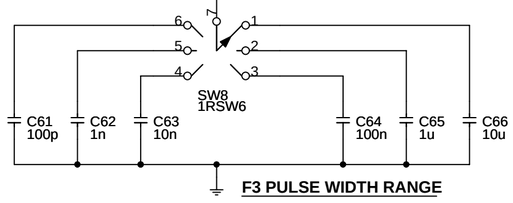


Title	TP900 - TPU PULSER F3 Pulse Generator and Driver		
Size: C	Document Number: TP900.1		Rev: -
Date: Saturday, August 04, 2007	Sheet 4 of 5		

DESIGN NOTES:

1) The "74AC" series was chosen for its high speed and low propagation delay, which becomes quite significant at 13MHz. Care has been taken in selecting device types; for best performance, please adhere to them if possible.

2) Additional gates in the F3, F2, F1 divider section were added for propagation delay matching. As shown, all rising and falling edges are within 4ns. If further custom matching is necessary, unused gates are available.

3) Outputs are guaranteed 50% duty cycle.

4) Place the MAX4420 and IRF3710 as close together as possible.

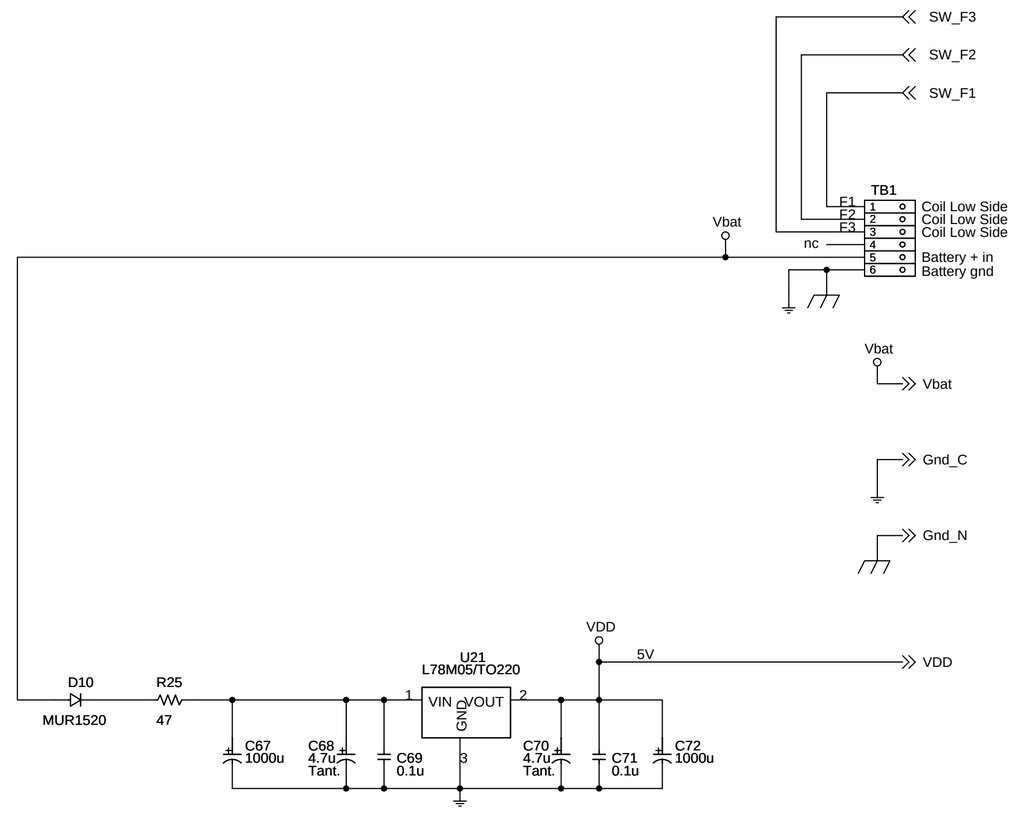
5) Keep the noisy "Vbat" ground separate from the CMOS "VDD" ground until the Terminal Block TB1 where they are tied together.

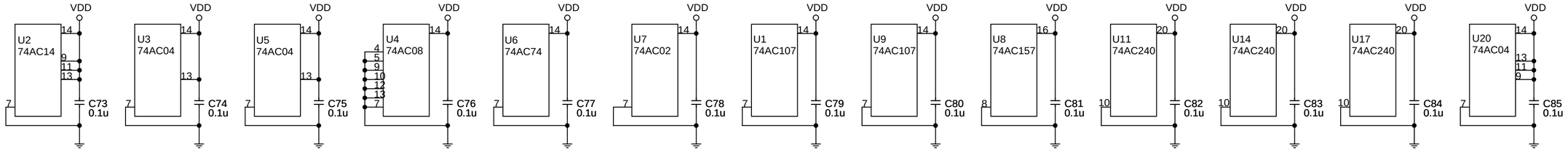
6) In the "SYNCHRONIZED" mode, only the "F3" FREQUENCY and RANGE controls are used.

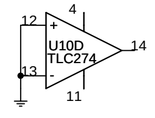
7) Q1/Q2, Q6/Q7, Q11/Q12 pairs should be matched as close as possible for best performance and matching. 5% matches for HFE and "Diode Check" readings with a good digital meter are adequate.

8) Use good quality film types for all "timing" capacitors. Examples include polyproylene, polystyrene, and polyester (last choice). Recommend "polystyrene" for 10pF to 10nF values, and "polypropylene" for 100nF to 10uF values.

9) If a "FINE" frequency adjust is desired, insert a 10k rheostat/potentiometer in series with R2, R4, and R6. Note that this will extend the low end of the frequency ranges by about 10%.







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Title	TP900 - TPU PULSER 5V Supply and External Interface	
Size: C	Document Number: TP900.1	Rev: -
Date: Saturday, August 04, 2007	Sheet 5 of 5	