Pulse Power Unit (PPU) for Pulsed Plasma Thrusters (PPT)

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6/25/02

PPU Operation.

The pulsed-plasma thruster system operates by charging a ~1.3 μF mica capacitor to ~2.8 kV (energy ~ 5 J). The capacitor is connected across the electrodes of the PPT, with cathode in common with the cathode a of spark plug mounted in proximity to the electrodes. A HV (~ 2 kV) pulse applied to a spark plug initiates a discharge of the capacitor across the face of a teflon bar adjacent to the electrodes, generating thrust. Each PPT assembly has two pairs of electrodes and associated spark plugs, both sides using a common PPT capacitor. A thrust pulse can be generated on either thruster (not both), depending on which spark plug is pulsed. The PPU function is to charge the PPT capacitor(s), and generate a spark on the desired thruster(s) in response to logic signals from the I/O board (5-volt logic). The system is powered by the satellite bus voltage (15-28 V for VT, 24-32 V for UW). Low level auxiliary voltages needed by the PPU are generated internally.

The PPU uses a flyback switch-mode power supply (SMPS) to simultaneously charge the selected PPT capacitor(s) and discharge initiation (DI) capacitors which provide the energy for the spark plugs. The DI capacitors (0.68 uF) are internal to the PPU. The SMPS operates at nearly constant power during charging, and is designed to fully charge 2 PPT capacitors in slightly under 1 sec, to allow a firing rate of 1 Hz when two thrusters are fired at each shot (normal UW mode). Since power is nearly constant, it takes slightly less than 0.5 sec to charge a single PPT capacitor. Logic signals to the PPU select which DI and PPT capacitors to charge and initiate charging. The thrust discharge itself is initiated within the PPU – the PPU detects when the PPT capacitor voltages reaches 2.8 kV, and then fires the selected spark plugs (via prior selection of DI capacitors charged). The charging process is indicated by the output signal "busy". This line is pulled low ($V \leq 1$Volt) during charging. The discharge occurs 1 msec after the busy line is released. This line is an optocoupled, open-collector transistor, and should have a user-provided 10 kΩ pull-up resistor to the digital positive bus voltage (5V for I/O board logic). The user should wait a period $t_d \geq 2$ msec following the lo-to-hi transition of the busy signal before initiating the next charge cycle.

Digital control is implemented by 3 lines: "F" (fire), "C" (clock), and "D" (data). They are active HI, and are optically coupled within the PPU. A digital return line is also required. The timing sequence for input control signals is shown in Fig. 1, and the internal PPU timing for charge and firing is shown in Fig. 2. The select/charge process is initiated by bringing F high. After a delay $t_{F\text{-}C} \geq 1$ msec, the C and D lines should be clocked in to select which DI and PPT capacitors are to be charged. The C (clock) line has a number of pulses equaling the number of thrusters (same as number of spark plugs) in the system (4 for VT, 8 for UW). The high and low durations of C (t_{CH} and t_{CL}) should be ≥ 20 μsec. Selection of a spark plug (and its associated PPT capacitor) is made by the state of the D (data) line at the low-to-high transition of a given clock pulse. If D is hi at the leading edge of clock pulse "i", then a corresponding DI capacitor and its associated

PPT capacitor will be charged. The setup time for D (*before* lo-to-hi of C) should be $t_{su} \geq 10$ μsec, and the hold time for D (*following* lo-to-hi of C) should be $t_{hold} \geq 10$ μsec. These (relatively long) setup and hold times are to accommodate variability of response times of the optocouplers onboard the PPU.

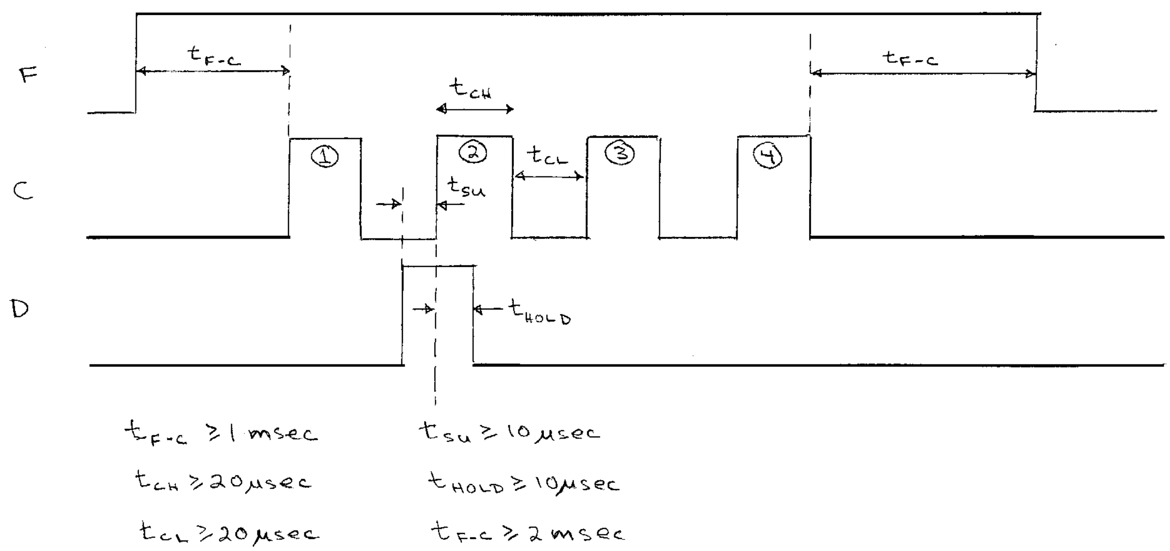


Fig. 1 Logic signal timing for PPT selection. Shown for VT to select spark plug 2A.

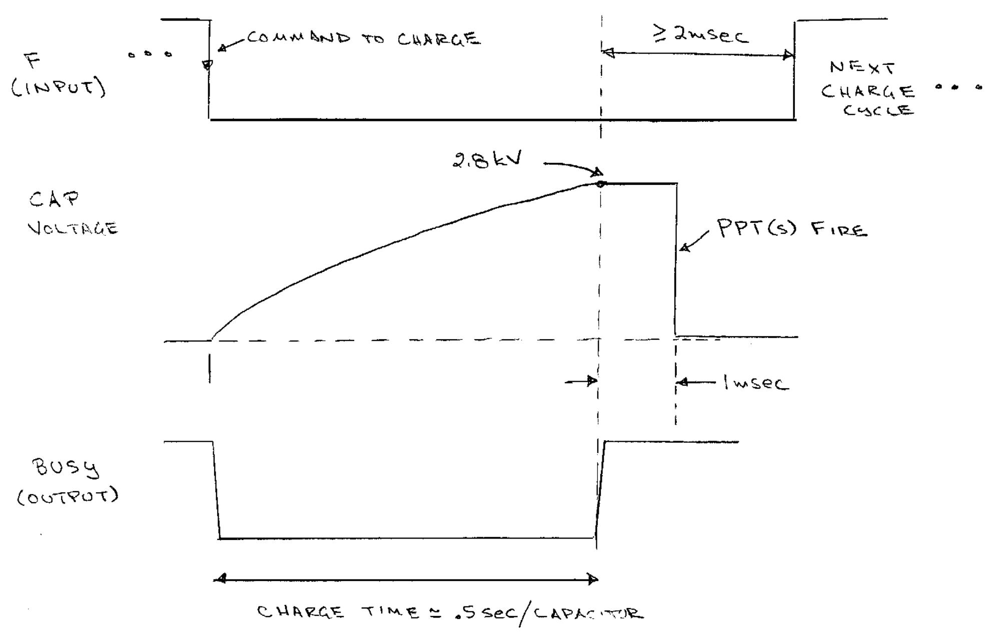


Fig. 2 Discharge timing internal to PPU.

As provided, the assembled PPU/PPT has the spark-plug lines labeled 1A, 2A, ..., corresponding to thruster assembly 1, 2, ...; implicitly, the unlabelled plugs on each assembly are 1B, 2B, etc. (VT has only 1 and 2, i.e. 2 thruster assemblies). The association of clock (and data) pulses with spark plugs is shown in Tables 1 and 2 below. The order is "reverse" in the sense that, for VT, for example, the last (4th) clock/data pulse is associated with plug 1A, second-to-last (3rd) clock/data pulse is associated with plug 1B, etc. This choice was made to allow the same methodology of plug selection for VT and UW systems. **Important note: do not select two spark plugs on the same thruster (e.g., selection of 2A and 2B is forbidden!).** One or two (on different PPT units) plugs may be selected at each shot; if only one is selected the cycle time for the shot will be ~ 0.5 sec, and if two plugs are selected, the cycle time will be ~ 1 sec.

Table 1: Selection of PPT discharge via D (data) line (for VT)

D line high at clock pulse:	Spark plug selected to fire	PPT capacitor to be charged
1	2B	2
2	2A	2
3	1B	1
4	1A	1

Table 2: Selection of PPT discharge via D (data) line (for UW)

D line high at clock pulse:	Spark plug selected to fire	PPT capacitor to be charged
1	4B	4
2	4A	4
3	3B	3
4	3A	3
5	2B	2
6	2A	2
7	1B	1
8	1A	1

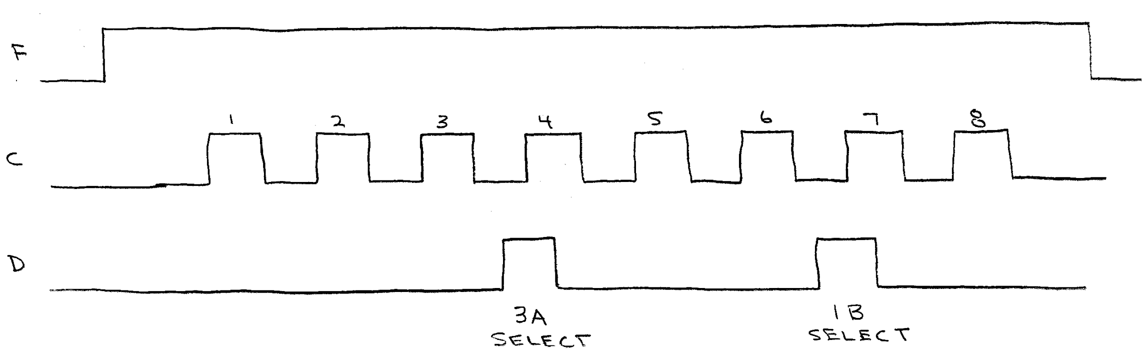


Fig. 3 Timing for UW PPU to select plugs 1B and 3A

Following the last (4th for VT, 8th for UW) clock pulse, the F line is brought low to initiate charging (F must remain high during clocking in of C and D pulses). The delay between the HI-to-LO transition of the last C pulse and the hi-to-lo transition of F must be $t_{C-F} \geq 1$ msec. This delay time allows the high-voltage selection switches (optocoupled triacs) to stabilize prior to charging. The busy line will go low at the HI-to-LO transition of F, and will remain low until the PPT capacitors are fully charged, as noted above. If some fault hangs up the charging process, the PPU will fire the selected plugs at $t \approx 2$ sec following the HI-to-LO transition of F (independent of capacitor voltage), in order to allow subsequent charge cycles.

The UW PPU has an option to double the capacitor charging rate, to allow firing thrusters approximately twice as fast as the nominal firing rate. Using the fast-charge option should allow firing a single PPT at about 4 Hz, and two PPT's at about 2 Hz. Because the power draw at this maximum firing rate (~25W) cannot be sustained continuously by the power system, this option is included to provide high thrust for only an orbit or two. Fast charge is implemented by bringing the D line HI at least 20 μsec prior to the HI-to-LO transition of F (after all data has been clocked in), and keeping it HI until the BUSY output line goes HI (capacitors fully charged). For normal charge rate, the D line should remain LO except when clocking in data. Fast-charge is not implemented on the VT PPU, and the D line should always be LO during charging.

The efficiency of the SMPS is ~ 80%, so the input power during charging will be ~ 6.25W per PPU capacitor selected. Firing 2 PPT's per shot at 1 Hz would draw an average power of ~12.5W. For the nominal UW bus voltage of 28V, the current draw would be ~ .225 A/capacitor during charging (~.45A to charge two caps). When inactive, the PPU draws ~ 10 mA.

Temperature Sensors.

The PPU/PPT assemblies are fitted with thermistor temperature sensors (negative temperature coefficient) for the SMPS transformer and each PPT capacitor (3 thermistors for VT, 5 for UW). The thermistors have a 10 kΩ nominal resistance at 25°C, and are biased (internally to the PPU) as shown in Fig. 4. Resistance and output voltage vs temperature are shown in Fig. 5. For identification purposes (PPU pin assignments given later), the thermistors will be called R_T (transformer), R_1 (PPT capacitor 1), R_2 (PPT capacitor 2), etc. The voltages on the thermistor output lines should be checked periodically to insure the transformer and PPT capacitors do not get too hot. The PPT's should not be fired if the transformer temperature exceeds $T_{T,max}$=120°C, or if the PPT capacitor temperature is out of the range -40°C ≤ T_C ≤ 125°C.

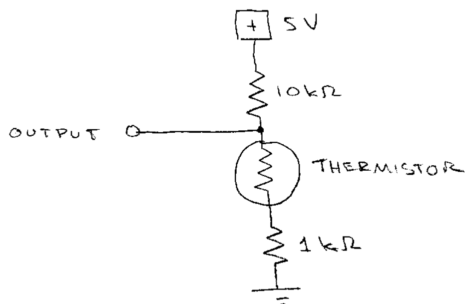


Fig. 4. Thermistor biasing. [Measurement of transformer and capacitor temperatures.]

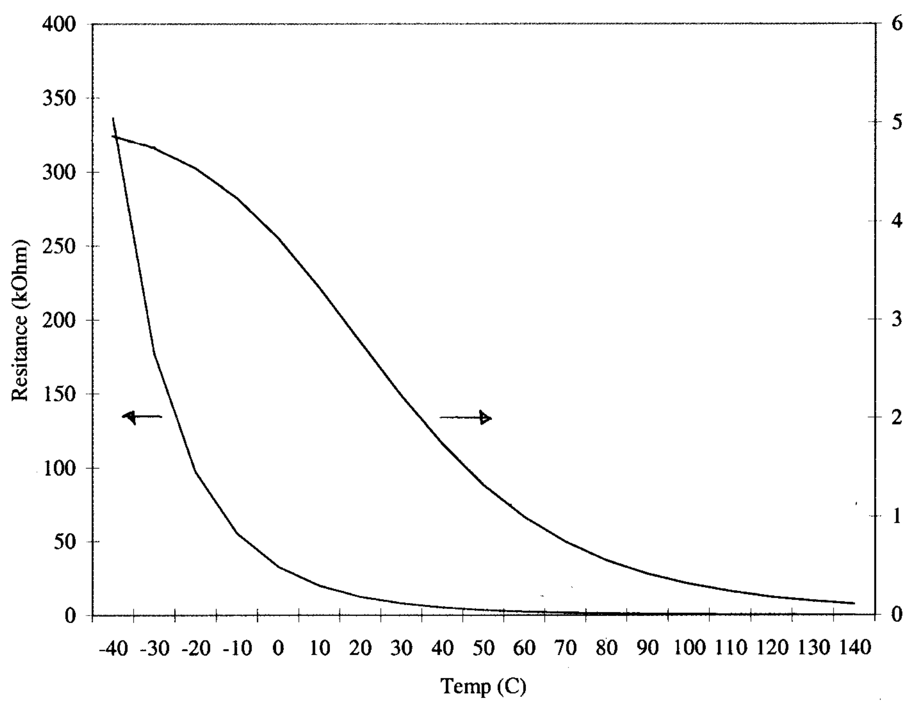


Fig. 5 Thermistor resistance and output voltage vs temperature.

The PPU has a 15-pin input connector for power, logic, and thermistor signals. External connectors are prewired, and provided with the unit. The 4 power lines (2 @ BUS+, 2@ BUS-) are joined with a 4-pin inline (2-piece) connector whose leads are connected to the relay board (PPU must disabled from firing until satellite sufficiently far from shuttle). The remaining 11 lines are joined with an 11-pin inline (2-piece) connector whose leads are connected to the I/O board. When assembling the inline connectors together, make sure the white dots are on the same side (both dots visible), since the connectors are not polarized. With this convention for the dots, the color coding of the wires is shown in Fig. 6.

<u>Cautions/notes:</u>

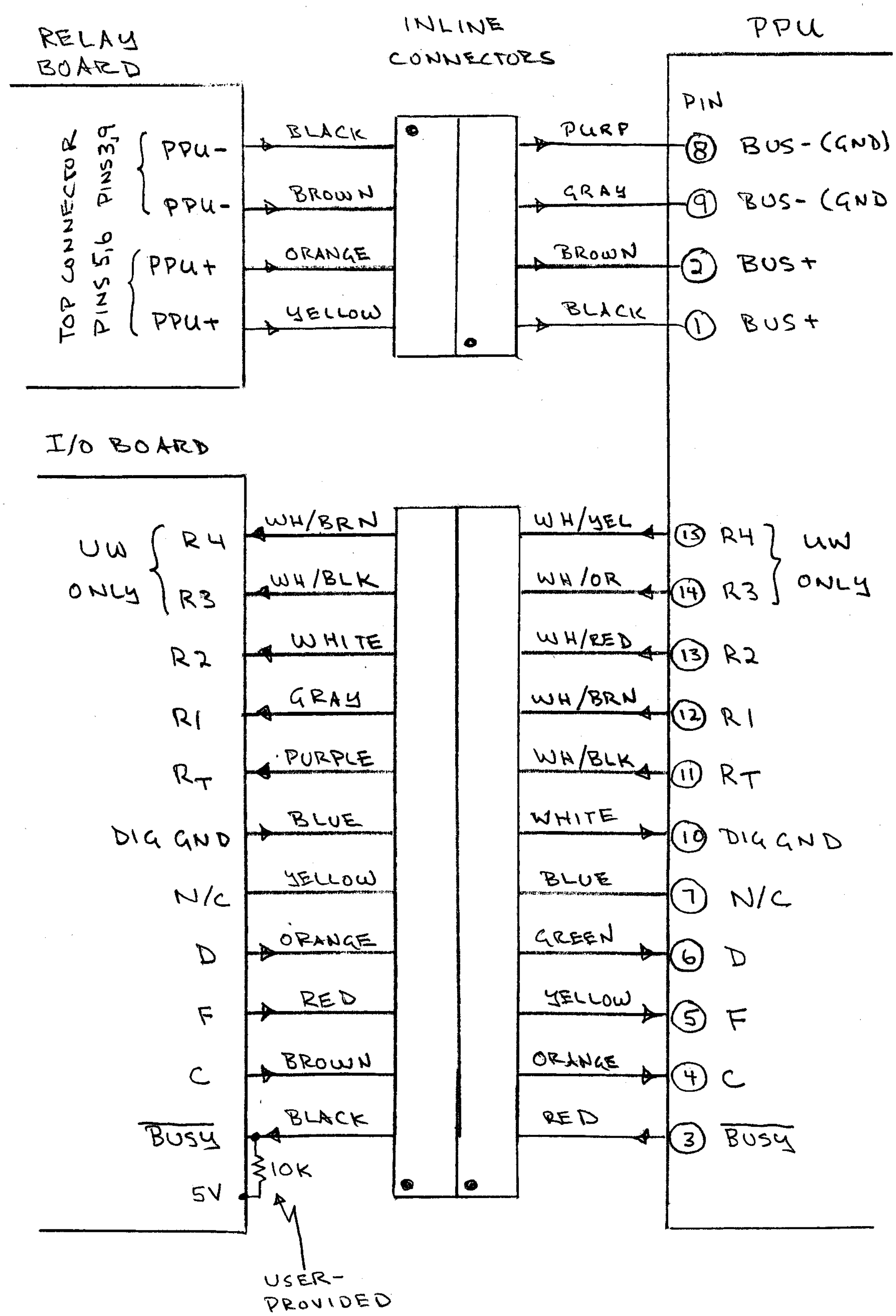
- Make sure the input signals (logic), output signals (busy and thermistors) and power are connected to the proper PPU input lines.
  The PPU can be destroyed if incorrectly connected.

- Do not fire the PPT's in air. This can destroy the PPT capacitors.
  Note that for air testing, the PPT capacitors were removed from the PPT assembly, and discharged resistively after full charge with peak discharge current < 1 Amp. The spark plugs ***can*** be fired in air.

- The busy line and thermistor output signals should be bypassed with ~0.1 μF capacitors to analog ground near the I/O board end. These are relatively high impedance outputs, and the ~20 kHz noise of the SMPS and the spark-plug discharge will otherwise result in significant noise on these lines. [The power lines are filtered, and digital control lines are opto-isolated, so little noise should appear on these.]

- Never select both spark plugs on a single PPT assembly for discharge.

Fig. 6 Input Connections for PPU Unit

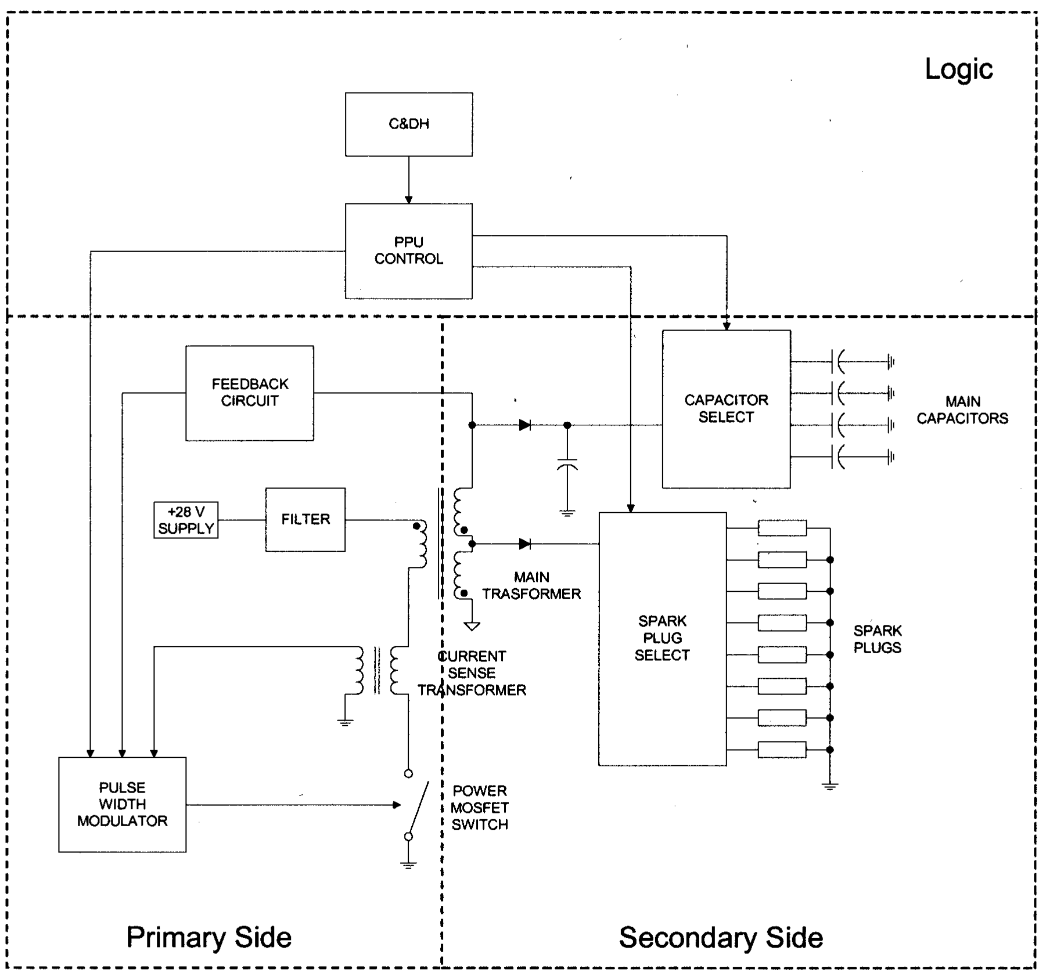


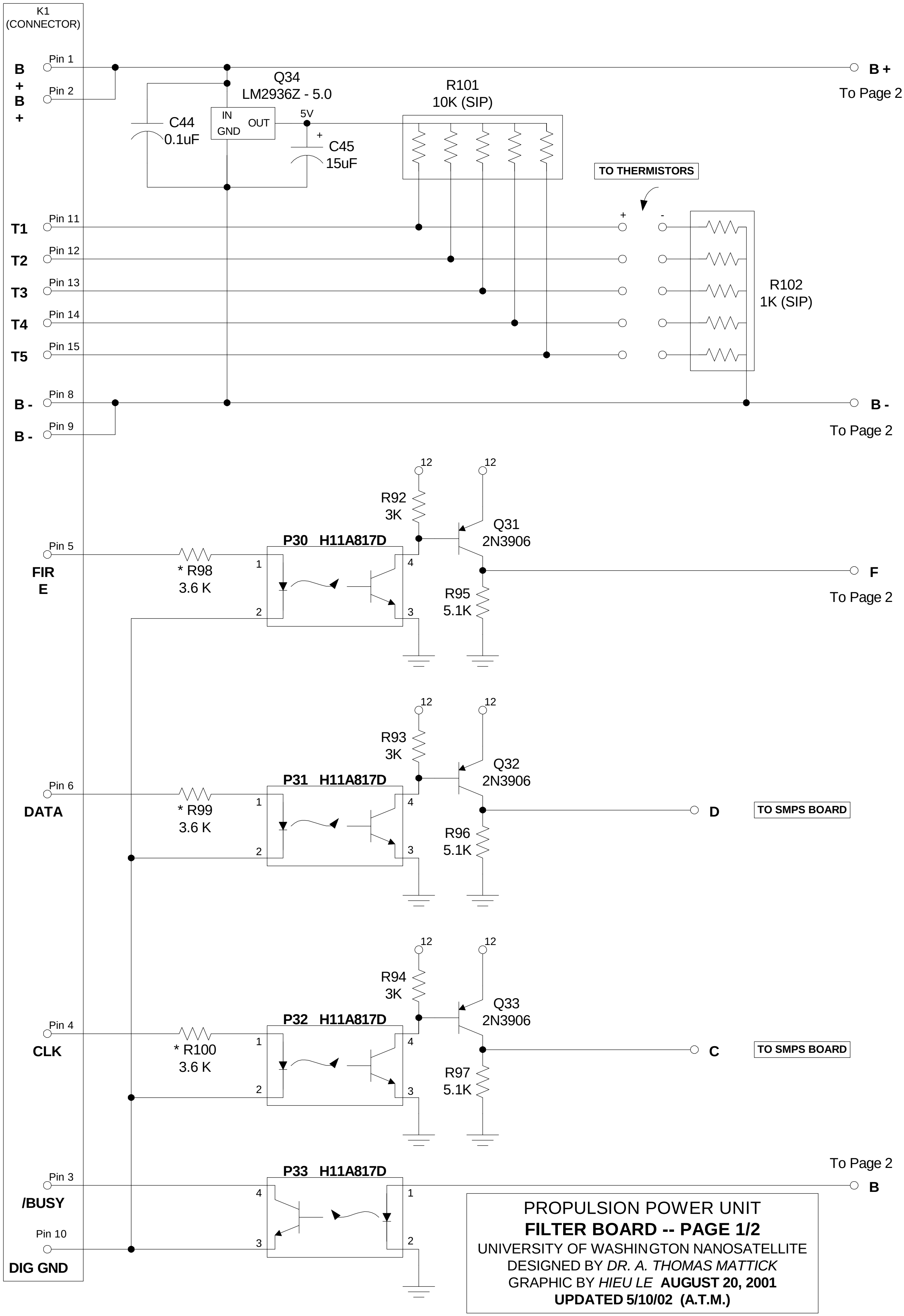
PPU Circuitry.
The PPU uses three circuit boards:

Filter Board:	I/O, timing, SMPS input filter
SMPS Board:	HV SMPS supply, HV switching circuitry
DI Board:	High current, high-voltage switching of DI plugs. 4 DI switches per board. VT uses 1 DI board; UW uses 2 DI boards.

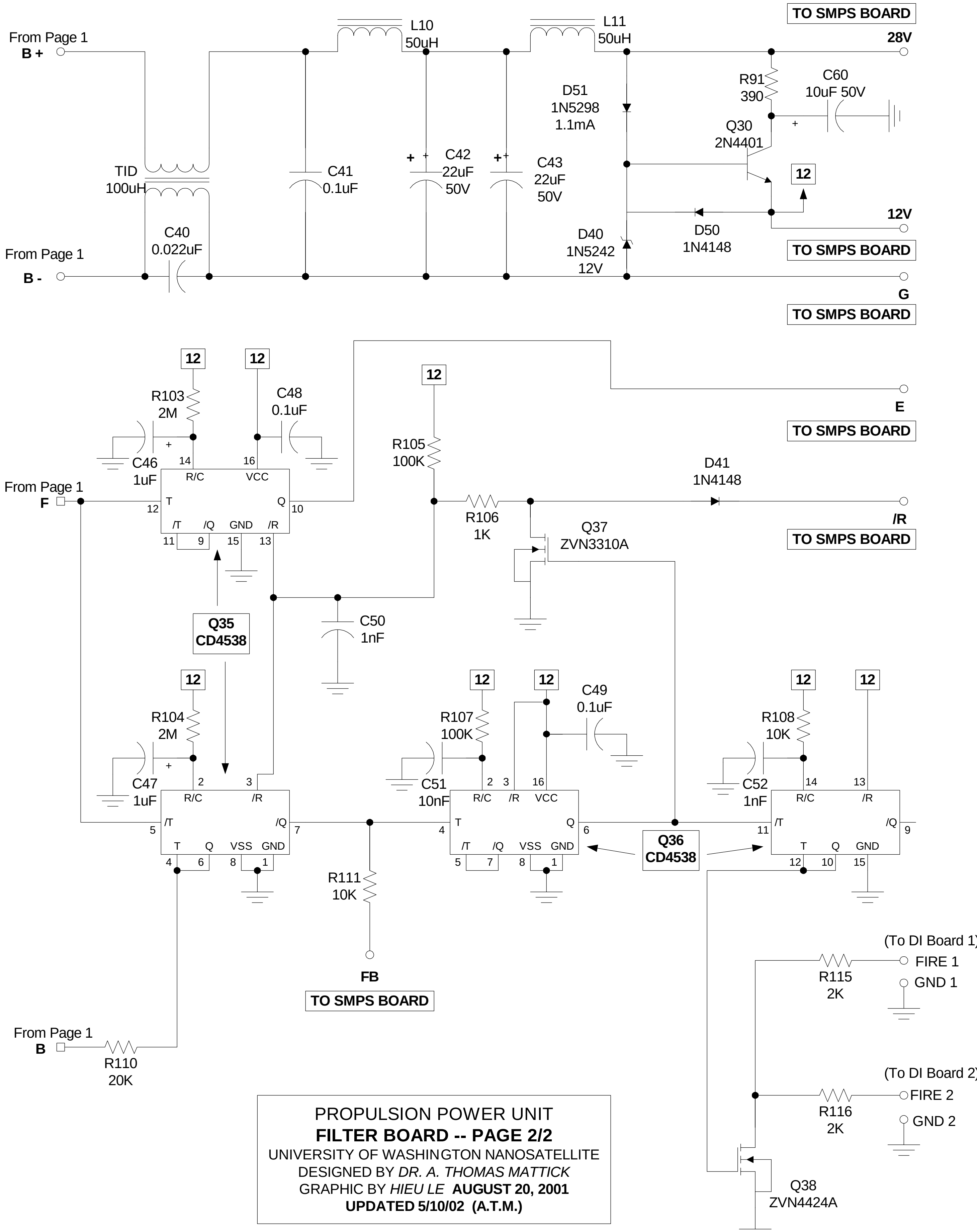
To avoid the weight and volume of high-voltage, high-current connectors, all wiring to PPT's is soldered directly onto PPU boards. A shielded wire bundle is routed to each PPT unit, including 2 DI coax lines, the positive charging lead for the PPT capacitor (white HV wire), and a wire pair for the thermistor. The negative return for the PPT capacitor is the shield of the DI coax lines, since the shells of the DI plugs are in common with the cathode of the PPT (capacitor negative).

A functional diagram of the PPU is shown below. Schematics and parts lists for the boards are given on the following pages.





K1
(CONNECTOR)
Pin 1
Pin 2
B + B +
Q34
LM2936Z - 5.0
IN
OUT
GND
5V
C44
0.1uF
C45
15uF
R101
10K (SIP)
B +
To Page 2
TO THERMISTORS
Pin 11
Pin 12
Pin 13
Pin 14
Pin 15
T1
T2
T3
T4
T5
R102
1K (SIP)
Pin 8
Pin 9
B -
B -
B -
To Page 2
12
12
R92
3K
Q31
2N3906
Pin 5
FIRE
P30 H11A817D
* R98
3.6 K
R95
5.1K
F
To Page 2
12
12
R93
3K
Q32
2N3906
Pin 6
DATA
P31 H11A817D
* R99
3.6 K
R96
5.1K
D
TO SMPS BOARD
12
12
R94
3K
Q33
2N3906
Pin 4
CLK
P32 H11A817D
* R100
3.6 K
R97
5.1K
C
TO SMPS BOARD
To Page 2
Pin 3
/BUSY
P33 H11A817D
B
Pin 10
DIG GND
PROPULSION POWER UNIT
FILTER BOARD -- PAGE 1/2
UNIVERSITY OF WASHINGTON NANOSATELLITE
DESIGNED BY DR. A. THOMAS MATTICK
GRAPHIC BY HIEU LE AUGUST 20, 2001
UPDATED 5/10/02 (A.T.M.)



PROPULSION POWER UNIT
FILTER BOARD -- PAGE 2/2
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DESIGNED BY *DR. A. THOMAS MATTICK*
GRAPHIC BY *HIEU LE* **AUGUST 20, 2001**
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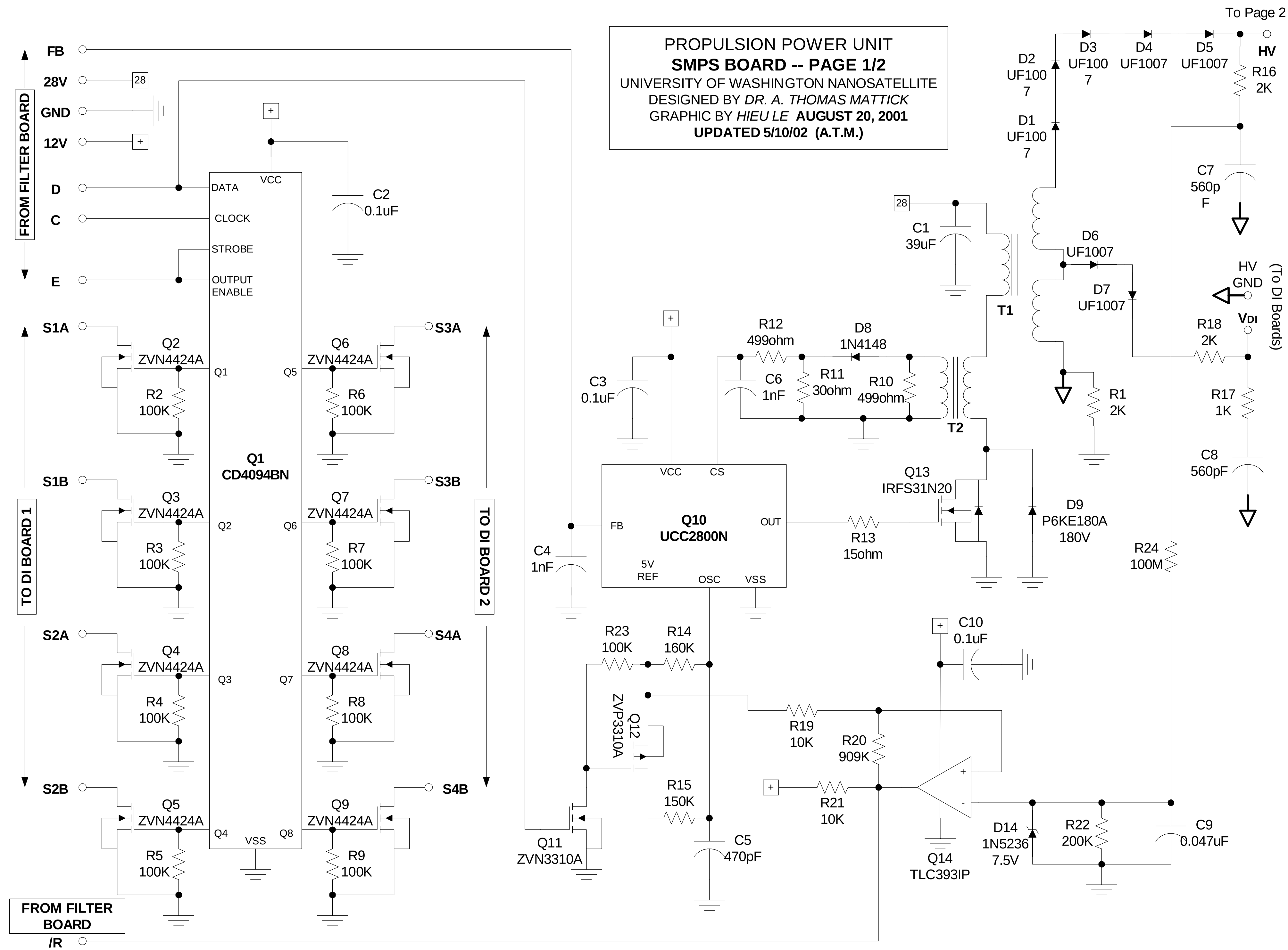
PPU - Filter Board Components - page 1 of 2

Tom Mattick 3/27/02

		Part number	Mfg	Package	Vendor	Pkg Slip
Semiconductors						
D40	12V Zener diode	1N5242B	Diodes,Inc	DO-35	Digikey	DK01-5
D41	Signal diode	1N4148	Diodes,Inc	DO-35	Digikey	DK01-1
D42	100V, 1A Rectifier	1N4002	Diodes,Inc	DO-41	Digikey	DK01-1
Q30	NPN Transistor	2N4401	Fairchild	TO-92	Digikey	DK01-1
Q31-33	PNP Transistor	2N3906	ON Semi	TO-92	Newark	NE01-3
Q34	5V Regulator	LM2936Z-5.0	NSC	TO-92	Digikey	DK01-6
Q35-36	Dual Multivibrator	CD4538BCN	Fairchild	16-DIP	E-Chips	EC01-1
Q37	N-Ch Mosfet	ZVN3310A	Zetex	TO-92	Digikey	DK01-6
Q38	N-Ch Mosfet	ZVN4424A	Zetex	TO-92	Digikey	DK01-6
P30-32	Optoisolator	H11A817D	Fairchild	4-DIP	Digikey	DK01-6
Inductors						
L10,L11	50uH, 3.3A, 0.04Ω Ind.	73120	Pico	Surf mnt	Pico	PE01-1
T10	100uH,3A,0.013Ω CMF	47560	Pico	Surf mnt	Pico	PE01-1
Capacitors						
C40	0.047uF,100V,X7R	K473K20X7RH5TL2	BC Components	axial	Digikey	DK01-6
C41,C44,C48-49	0.1uF,100V,X7R	K104K20X7RH5TL2	BC Components	axial	Digikey	DK01-6
C42,C43	22uF,50V,tantalum	T322F226K050	Kemet	axial	Mouser	ME01-4
C45	15uF,16V,tantalum	T350E156K016	Kemet	radial	Mouser	ME01-4
C46,C47	1uF,35V,tantalum	T350A105K035	Kemet	radial	Mouser	ME01-4
C50,C52	1nF,100V,X7R	K102K15X7RH5TL2	BC Components	axial	Digikey	DK01-6
C51	10nF,100V,X7R	K103K15X7RH5TL2	BC Components	axial	Digikey	DK01-5
C60	10uF,50V,tantalum	TAP106M050CRW	AVX	radial	All Amer. Semi	AS01-1

PPU - Filter Board Components - page 2 of 2

		Part number	Mfg	Package	Vendor	Pkg Slip
Resistors						
R90	12K,1/4W,1%,mf	271-12K	Xicon	axial	Mouser	ME01-4
R91	390Ω,2W,1%,mf	5083NW390R0J12AFX	BC Components	axial	Digikey	DK01-8
R92-94	3K,1/8W,5%,cf	CFR-12JB-3K0	Yageo	axial	Digikey	DK01-6
R95-97	4.99K,1/8W,1%,mf	270-4.99K	Xicon	axial	Mouser	ME01-2
R98-100	3.6K,1/8W,5%,cf	CFR-12JB-3K6	Yageo	axial	Digikey	DK01-6
R101	10K 5-resistor network	773061103	CTS	6-pin SIP	Digikey	DK01-6
R108,R111	10K,1/8W,1%,mf	270-10K	Xicon	axial	Mouser	ME01-1
R102	1K 5-resistor network	773061102	CTS	6-pin SIP	Digikey	DK01-6
R106	1K,1/8W,5%,cf	CFM-12JB-1K0	Yageo	axial	Digikey	DK01-6
R103,R104	2M,1/8W,5%,cf	CFM-12JB-2M0	Yageo	axial	Digikey	DK01-6
R105,R107	100K,1/8W,1%,mf	270-100K	Xicon	axial	Mouser	ME01-2
R110	20K,1/8W,1%,mf	270-20k	Xicon	axial	Mouser	ME01-2
R115,R116	2K,1/8W,5%,cf	CFM-12JB-2K0	Yageo	axial	Digikey	DK01-6
Other						
K1	15-pin connector	ML-263-015-435-22OS	Airborn		Airborn	
Circuit Board	Polyimide, 4.9"x1.9"x0.064"		Prototron		Prototron	PR01-3



PROPULSION POWER UNIT
SMPS BOARD -- PAGE 1/2
UNIVERSITY OF WASHINGTON NANOSATELLITE
DESIGNED BY DR. A. THOMAS MATTICK
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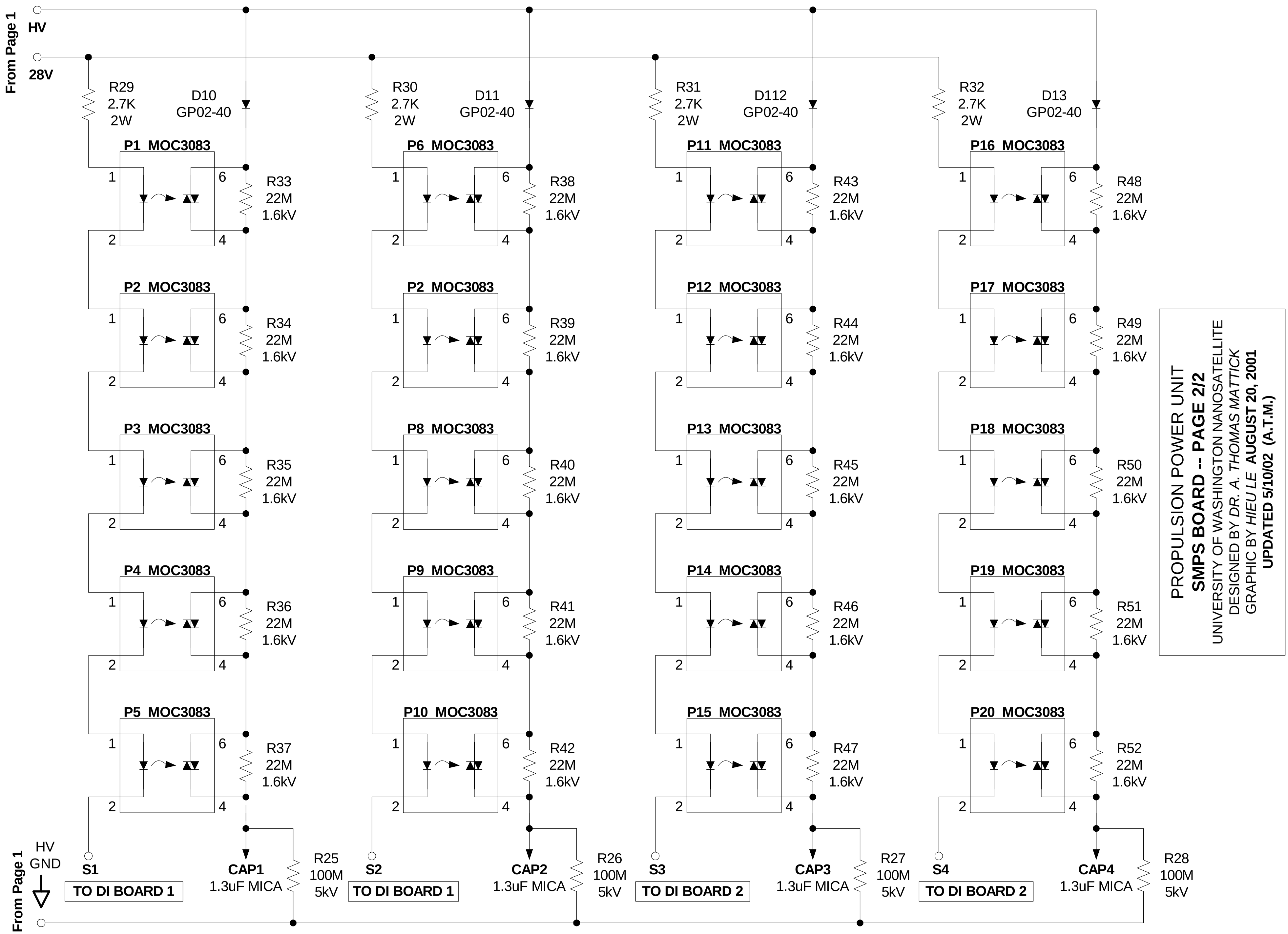
UPDATED 5/10/02 (A.T.M.)
FROM FILTER BOARD
FB
28V
GND
12V
D
C
E
TO DI BOARD 1
S1A
S1B
S2A
S2B
FROM FILTER BOARD
/R
Q1
CD4094BN
DATA
CLOCK
STROBE
OUTPUT ENABLE
VCC
VSS
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
C2
0.1uF
Q2 ZVN4424A
R2 100K
Q3 ZVN4424A
R3 100K
Q4 ZVN4424A
R4 100K
Q5 ZVN4424A
R5 100K
Q6 ZVN4424A
R6 100K
Q7 ZVN4424A
R7 100K
Q8 ZVN4424A
R8 100K
Q9 ZVN4424A
R9 100K
S3A
S3B
S4A
S4B
TO DI BOARD 2
C3 0.1uF
C4 1nF
Q10
UCC2800N
VCC
CS
FB
OUT
5V REF
OSC
VSS
R12 499ohm
D8 1N4148
C6 1nF
R11 30ohm
R10 499ohm
T2
C1 39uF
28
T1
Q13 IRFS31N20
R13 15ohm
D9 P6KE180A 180V
R23 100K
R14 160K
Q12 ZVP3310A
R15 150K
C5 470pF
Q11 ZVN3310A
R19 10K
R20 909K
R21 10K
C10 0.1uF
Q14 TLC393IP
D14 1N5236 7.5V
R22 200K
C9 0.047uF
R24 100M
D1 UF1007
D2 UF1007
D3 UF1007
D4 UF1007
D5 UF1007
D6 UF1007
D7 UF1007
R1 2K
To Page 2
HV
R16 2K
C7 560pF
HV GND
VDI
(To DI Boards)
R18 2K
R17 1K
C8 560pF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HV
28V
R29
2.7K
2W
D10
GP02-40
R30
2.7K
2W
D11
GP02-40
R31
2.7K
2W
D112
GP02-40
R32
2.7K
2W
D13
GP02-40
P1 MOC3083
P2 MOC3083
P3 MOC3083
P4 MOC3083
P5 MOC3083
P6 MOC3083
P2 MOC3083
P8 MOC3083
P9 MOC3083
P10 MOC3083
P11 MOC3083
P12 MOC3083
P13 MOC3083
P14 MOC3083
P15 MOC3083
P16 MOC3083
P17 MOC3083
P18 MOC3083
P19 MOC3083
P20 MOC3083
R33 22M 1.6kV
R34 22M 1.6kV
R35 22M 1.6kV
R36 22M 1.6kV
R37 22M 1.6kV
R38 22M 1.6kV
R39 22M 1.6kV
R40 22M 1.6kV
R41 22M 1.6kV
R42 22M 1.6kV
R43 22M 1.6kV
R44 22M 1.6kV
R45 22M 1.6kV
R46 22M 1.6kV
R47 22M 1.6kV
R48 22M 1.6kV
R49 22M 1.6kV
R50 22M 1.6kV
R51 22M 1.6kV
R52 22M 1.6kV
HV
GND
From Page 1
S1
TO DI BOARD 1
CAP1
1.3uF MICA
R25
100M
5kV
S2
TO DI BOARD 1
CAP2
1.3uF MICA
R26
100M
5kV
S3
TO DI BOARD 2
CAP3
1.3uF MICA
R27
100M
5kV
S4
TO DI BOARD 2
CAP4
1.3uF MICA
R28
100M
5kV
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SMPS BOARD -- PAGE 2/2
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PPU - SMPS Board Components - page 1 of 2

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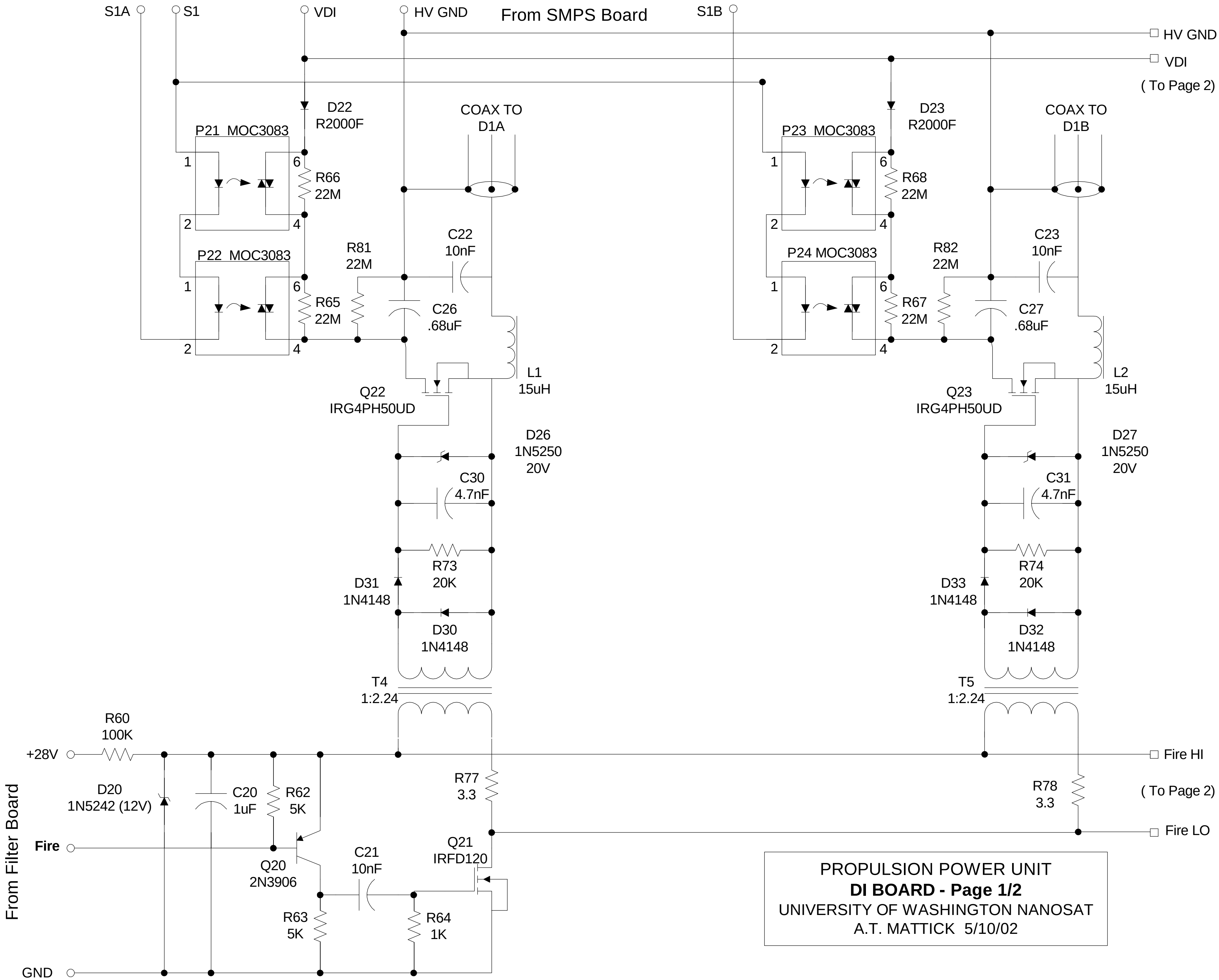
		Mfg. part #	Mfg.	Package	Vendor	Packing List
Semiconductors						
D1-7	1kV,1A,Ultrafast Rectifier	UF1007	Diodes,Inc	DO-41	Digikey	DK01-4
D8	Signal diode	1N4148	Diodes,Inc	DO-35	Digikey	DK01-1
D9	170V TVS diode	P6KE170A	MicroSemi	DO-204	Digikey	DK01-4
D10-13	4kV,1A,rectifier	GP02-40	Gen Semi	DO-41	All Am Semi	AS01-1
D14	7.5V Zener diode	1N5236B	Diodes,Inc	DO-35	Digikey	DK01-6
Q1	CMOS Ser-to-parallel	CD4094BCN	Fairchild	16-DIP	Echips	EC01-1
Q2-9	N-Ch Mosfet	ZVN4424A	Zetex	TO-92	Digikey	DK01-6
Q10	PWM	UCC2800N	TI	8-DIP	Arrow	AR01-2
Q11	N-Ch Mosfet	ZVN3310A	Zetex	TO-92	Digikey	DK01-6
Q12	P-Ch Mosfet	ZVP3310A	Zetex	TO-92	Digikey	DK01-6
Q13	200V,31A,N-Ch Mosfet	IRFS31N20D	IRF	D2PAK	Newark	NE01-2
Q14	Comparator	TLC393IP	TI	8-DIP	Arrow	AR01-2
P1-20	800V opto-triac	MOC-3083	Fairchild	6-DIP	Digikey	DK01-6
Transformers						
T1	E-core	E30/15/7	Philips		Allstar Magn	AM01-1
	Bobbin	CSH-E20/7-1S-10P	Philips		Allstar Magn	AM01-1
	Clip	CLA-E20/15/7	Philips		Allstar Magn	AM01-1
	20AWG H Magnet wire	20HAPT	Wiretronics		Wiretronics	WT00-1
	32AWG H Magnet wire	32HAPT	Wiretronics		Wiretronics	WT00-1
	Interwinding tape	1N012	Lodestone		Lodestone	LP01-1
T2	Cur. Sense xfmr,1:100	PE68280	Pulse Engg.	Surf mnt	Arrow	AR00-1

PPU - SMPS Board Components - page 2 of 2

		Mfg. part #	Mfg.	Package	Vendor	Packing List
Resistors						
R1,R16,R18	2k,2W,5%,mf	5083NW2K000J12AFX	BC Components	axial	Digikey	DK01-6
R2-9,R23	100k,1/8W,1%,mf	270-100K	Xicon	axial	Mouser	ME01-2
R10,R12	499Ω,1/8W,1%,mf	270-499	Xicon	axial	Mouser	ME01-1
R11	30Ω,1/8W,1%,mf	270-30R0	Xicon	axial	Mouser	ME01-4
R13	15Ω,1/8W,5%,cf	CFR-12JB-15R	Yageo	axial	Digikey	DK01-6
R14,R15	150k,1/8W,1%,mf	270-150K	Xicon	axial	Mouser	ME01-1
R17	1k,2W,5%,mf	5083NW1K000J12AFX	BC Components	axial	Digikey	DK01-6
R19,R21	10k,1/8W,1%,mf	270-10K	Xicon	axial	Mouser	ME01-1
R20	909k,1/8W,1%,mf	270-909K	Xicon	axial	Mouser	ME01-1
R22	178k,1/8W,1%,mf	270-178K	Xicon	axial	Mouser	ME01-4
R24-28	100M,1W,5kV	MOX750F-100M	Ohmite	axial	Digikey	DK01-4
R29-32	3k,2W,5%,mf	5083NW3K000J12AFX	BC Components	axial	Digikey	DK01-6
R33-52	22M,1/4W,1.5kV	5043DM22M00J	BC Components	axial	Allied	AL00-1
Capacitors						
C1	39uF,50V,ceramic	87106-D39	JDI	20-DIP	[Provided by Genl Dynamics]	
C2-3,C9	0.1uF,100V,X7R	K104K20X7RH5TL2	BC Components	axial	Digikey	DK01-6
C5	470pF,100V,5%,COG	K471J15COGH5TL2	BC Components	axial	Digikey	DK01-6
C4,C6	1nF,100V,X7R	K102K15X7RH5TL2	BC Components	axial	Digikey	DK01-6
C7-8	560pf,6kV,ceramic	140-CD602P9-561K	Xicon	radial	Mouser	ME01-4
Other						
Circuit Board	Polyimide, 6"x4"x0.064"		Prototron		Prototron	PR01-2


S1A
S1
VDI
HV GND
From SMPS Board
S1B
HV GND
VDI
(To Page 2)
D22
R2000F
D23
R2000F
COAX TO
D1A
COAX TO
D1B
P21 MOC3083
P23 MOC3083
R66
22M
R68
22M
P22 MOC3083
P24 MOC3083
R81
22M
R82
22M
C22
10nF
C23
10nF
R65
22M
R67
22M
C26
.68uF
C27
.68uF
L1
15uH
L2
15uH
Q22
IRG4PH50UD
Q23
IRG4PH50UD
D26
1N5250
20V
D27
1N5250
20V
C30
4.7nF
C31
4.7nF
R73
20K
R74
20K
D31
1N4148
D33
1N4148
D30
1N4148
D32
1N4148
T4
1:2.24
T5
1:2.24
R60
100K
+28V
Fire HI
D20
1N5242 (12V)
C20
1uF
R62
5K
R77
3.3
R78
3.3
(To Page 2)
From Filter Board
Fire
Q20
2N3906
C21
10nF
Q21
IRFD120
Fire LO
R63
5K
R64
1K
GND
PROPULSION POWER UNIT
DI BOARD - Page 1/2
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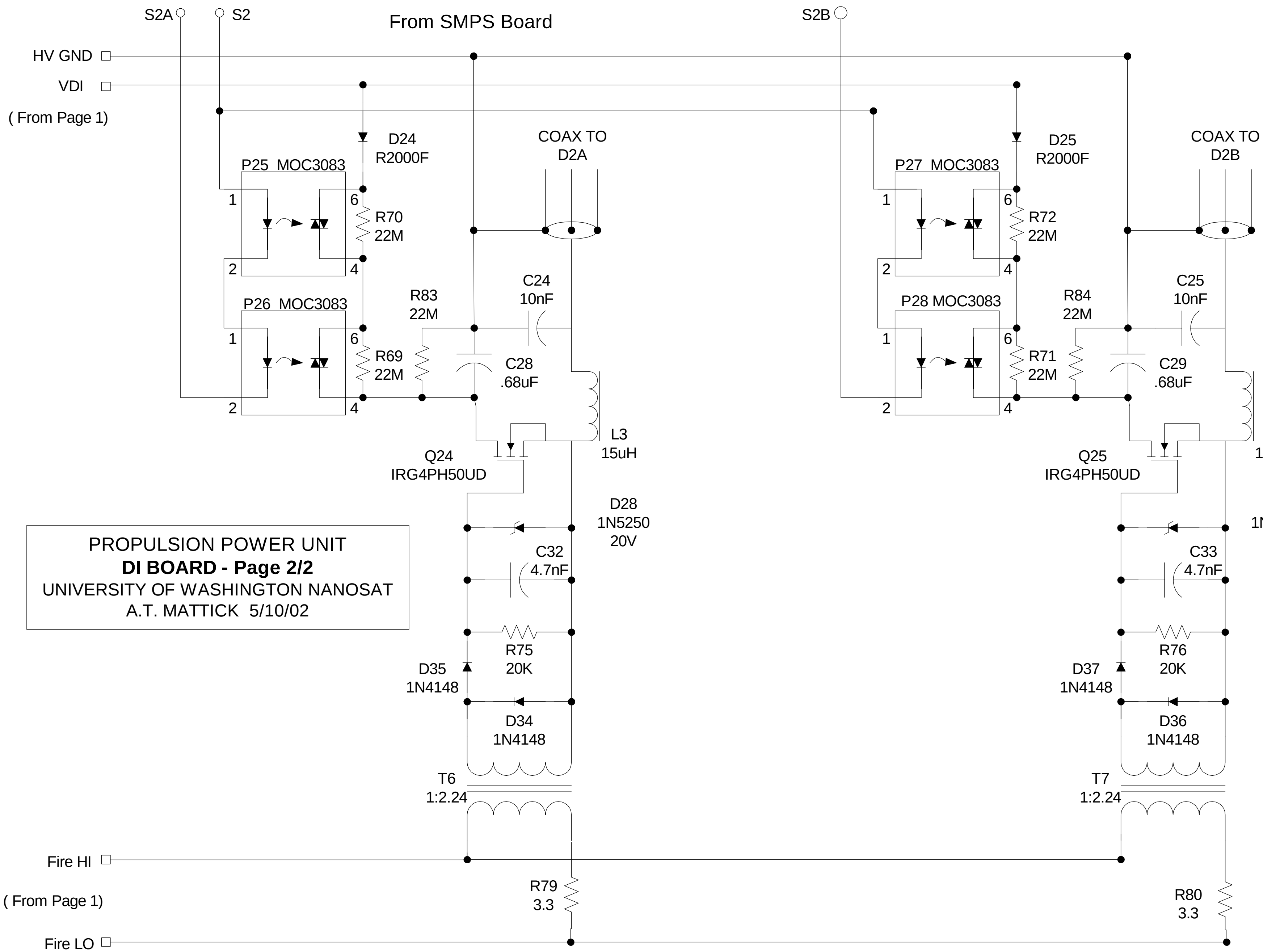

S2A
S2
From SMPS Board
S2B
HV GND
VDI
(From Page 1)
D24
R2000F
COAX TO
D2A
D25
R2000F
COAX TO
D2B
P25 MOC3083
P26 MOC3083
P27 MOC3083
P28 MOC3083
1
2
4
6
R70
22M
R69
22M
R72
22M
R71
22M
R83
22M
R84
22M
C24
10nF
C25
10nF
C28
.68uF
C29
.68uF
L3
15uH
L4
15uH
Q24
IRG4PH50UD
Q25
IRG4PH50UD
D28
1N5250
20V
D29
1N5250
20V
C32
4.7nF
C33
4.7nF
R75
20K
R76
20K
D35
1N4148
D37
1N4148
D34
1N4148
D36
1N4148
T6
1:2.24
T7
1:2.24
Fire HI
(From Page 1)
Fire LO
R79
3.3
R80
3.3
PROPULSION POWER UNIT
DI BOARD - Page 2/2
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PPU - DI Board Components - page 1 of 2

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		Mfg. Part #	Mfg.	Package	Vendor	Packing List
Semiconductors						
D20	12V Zener diode	1N5242B	Diodes,Inc	DO-35	Digikey	DK01-5
D22-D25	2kV rectifier diode	R2000F	Rectron	DO-41	Mouser	ME01-3
D26-D29	20V zener diode	1N5250B	Gen. Semi.	DO-35	Mouser	ME01-3
D30-D37	Signal diode	1N4148	Diodes,Inc	DO-35	Digikey	DK01-1
Q20	PNP Transistor	2N3906	ON Semi	TO-92	Newark	NE01-3
Q21	N-Ch Mosfet	IRFD120	IRF	4-DIP	Digikey	DK01-5
Q22-Q25	1.2 kV IGBT	IRG4PH50UD	IRF	TO-247	Allied	AL00-2
P21-P28	800-V opto-SCR	MOC3083	Fairchild	6-DIP	Digikey	DK01-6
Inductors						
T4-T7	1:2.24, 4kV gate xfmr	78253-35V	CD Tech	6-DIP	Mouser	ME01-3
L1-L4	15uH Iron-core Ind.	434-10-150M	Xicon/Fastron	axial	Mouser	ME01-3
Resistors						
R60	100k,1/8W,1%,mf	270-100K	Xicon	axial	Mouser	ME01-2
R61-63	4.99k,1/8W,1%,mf	270-4.99K	Xicon	axial	Mouser	ME01-2
R64	1k,1/8W,1%,mf	270-1K	Xicon	axial	Mouser	ME01-1
R65-72,R81-84	22M,1/4W,1.5kV	5043DM22M00J	BC Components	axial	Allied	AL00-1
R73-76	20K,1/8W,1%,mf	270-20k	Xicon	axial	Mouser	ME01-2
R77-80	3.3Ω,1/8W,5%,cf	CFR-12JB-3R3	Yageo	axial	Digikey	DK01-5

PPU - DI Board Components - page 2 of 2

		Mfg. Part #	Mfg.	Package	Vendor	Packing List
Capacitors						
C20	1uF,50V,mf	ECQ-V1H105JL	Panasonic	radial	Digikey	DK01-5
C21	10nF,100V,X7R	K103K15X7RH5TL2	BC Components	axial	Digikey	DK01-5
C22-25	10nf, 3kV,ceramic	30GASS10	Ceramite	radial	Allied	AL01-2
C26-29	0.68uF, 1kV, X7R	SV08AC684K	AVX	radial	Kent	KE01-1
C30-C33	4.7nF,100V,X7R	K472K20X7RH5TL2	BC Components	axial	Digikey	DK01-5
Other						
Circuit Board	Polyimide, 6"x4"x0.064"		Prototron		Prototron	PR01-1