

DMC1500

*Technical
Reference*

DMC1500

Technical Reference

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TRADEMARKS

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About This Manual

This document describes the board level operations of the DMC1500. This Digital Motor Controller module is designed to be used with the F240, F243, or LF2407 DSP Starter Kit (DSK), or eZdsp™ LF2407 supplied by Spectrum Digital.

The DSKs or eZdsp™ LF2407 and the DMC1500 make up a table top motor development system which allows engineers and software developers to evaluate certain characteristics of the TMS320F240, TMS320F243, and TMS320LF2407 DSPs to determine if the processor meets the designers application requirements. Evaluators can create software to execute onboard or expand the system in a variety of ways.

Notational Conventions

This document uses the following conventions.

The F240, F243, and LF2407 DSK will sometimes be referred to as the DSK. The eZdsp™ LF2407 will sometimes be referred to the eZdsp. The DSK and eZdsp can be used interchangeably with the DMC 1500.

The DMC1500 will sometimes be referred to as the DMC.

Program listings, program examples, and interactive displays are shown in a special italic typeface. Here is a sample program listing.

```
equations  
!rd = rw &!strobe;
```

Information About Cautions

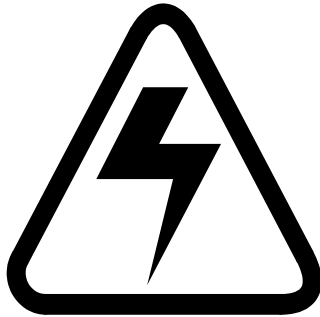
This book may contain cautions.

This is an example of a caution statement.

A caution statement describes a situation that could potentially damage your software, or hardware, or other equipment. The information in a caution is provided for your protection. Please read each caution carefully.

Related Documents

Texas Instruments TMS320F240 Users Guide
Texas Instruments TMS320 Fixed Point Assembly Language Users Guide
Texas Instruments TMS320 Fixed Point C Language Users Guide
Texas Instruments TMS320 Fixed Point C Source Debugger Users Guide
Spectrum Digital F240 and F243 Technical Reference



IMPORTANT WARNING !

Please read this entire manual before making any connections to the Digital Motor Controller. Because of the voltages and currents involved any mistakes will be very noticeable and could be deadly.

If you are not sure of how to make connections to the unit please call Spectrum Digital "BEFORE" applying power to the unit.

Chapter 1

Introduction to the DMC1500

This chapter provides you with a description of the DMC1500 for use with the F240, F243, and LF2407 DSKs, and the eZdsp™ LF2407 along with the key features and a block diagram of the circuit board.

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1.0 Overview of the DMC1500

The DMC1500 is versatile digital motor controller that allows motor controller designers examine certain characteristics of the TMS320F240, TMS320F243, and TMS320LF2407 Digital Signal Processors (DSPs) to determine if one of these DSPs meets their application requirements. Furthermore, the module is an excellent platform to develop and run motor control software for the TMS320F240, TMS320F243, or TMS320LF2407 processor.

The DMC1500 uses a F240, F243, LF2407 DSP Starter Kit (DSK) or eZdsp™ LF2407 board as the computer engine to run algorithms. The DMC1500 along with a DSK or eZdsp allows full speed verification of F24xx code.

Code development for the DMC can be done in two ways;

- Use the serial interface on the DMC with the symbolic assembler and debugger that comes with the DSK, or JTAG Port on the eZdsp™ LF2407.
- Use the XDS510PP PLUS JTAG emulator from Spectrum Digital, with the compiler/assembler/linker and Code Composer from Texas Instruments.

Note: It is recommended to use the SPI110 Opto Pod during development for safety from high voltages

1.1 Key Features of the DMC1500

The DMC1500 has the following features:

- Compatible with the F240, F243, LF2407 DSKs, or eZdsp LF2407 from Spectrum Digital
- Allows development of algorithms for AC Induction, DC Brushless (-0001), or Switched Reluctance Motors (-0002)
- Rated for Bus voltages of 350VDC
- Rated current is 5 amps continuous and 10 amps peak
- Onboard control power supply (115-230 VAC)
- Onboard bus supply (Bridge + Capacitors + Voltage Doubler)
- Optically isolated digital I/O
- Optically isolated RS-232 port
- Optically isolated CAN interface
- Onboard Power Factor Correction Logic

Chapter 2

Operation of the DMC1500

This chapter provides you with a technical description of the DMC1500 along with the key features, and a description of the connectors.

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2.1 Overview of the DMC1500 with a DSK

The DMC1500 is the power stage of a Digital Motor Controller development system. The computing engine for the DMC1500 is either a F240 DSK (#701023), F243 DSK (#701024), or LF2407 DSK (#701025) from Spectrum Digital. The DMC1500 allows development to be done with AC Induction, DC Brushless, and Switched Reluctance motors. To accommodate these 3 types of motors, the DMC1500 has many jumper options and connections. Please be sure to read this **entire** manual before powering up a motor.

A board outline of the DMC1500 is shown below.

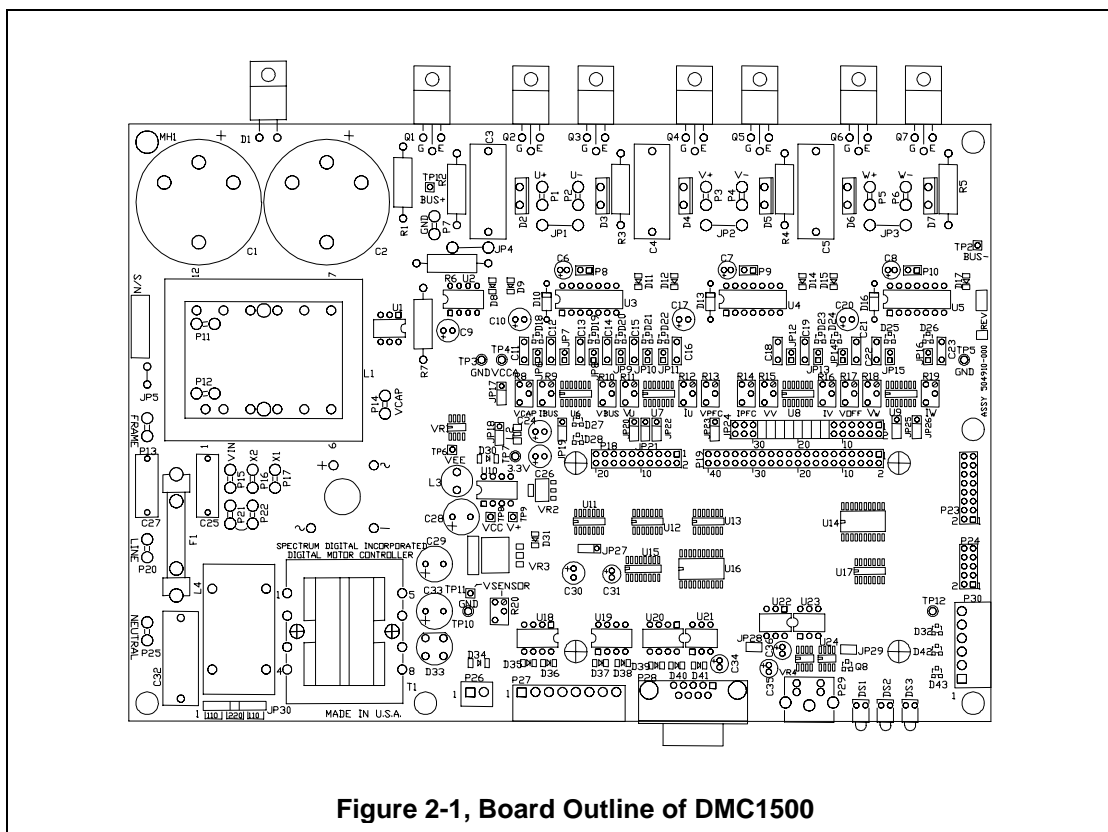


Figure 2-1, Board Outline of DMC1500

The DMC1500 is a stand alone module that is **not** enclosed. It is intended to be used in a development environment only. High voltages are present on the DMC1500 along with components dissipating heat. The user is advised to use extreme caution.



DANGER !

2.2 Installation of the DSK on the Digital Motor Controller

The F240, F243, or LF2407 DSK is the computing engine of the DMC1500 system. The DSK must be installed on the DMC1500 by plugging the DSK into mating connectors. There are two ways to develop and debug algorithms for the DMC1500:

- Use the serial interface on the DMC1500 with the symbolic assembler and debugger that comes with the DSK
- Use the XDS510PP JTAG emulator and SPI110 Opto POD from Spectrum Digital, with the compiler/assembler/linker and Code Composer from Texas Instruments.

Software can be developed using the symbolic assembler and debugger included with the DSK. This allows the engineer to generate algorithms and load them into the RAM memory on the DSK. The DSK communicates to the debugger on the host PC via the serial port on the DMC1500. The serial port on the DMC1500 is optically isolated because the DMC1500 is operating at a floating voltage level.

NOTE:

Do **NOT** use the serial port on the DSK because it is not optically isolated !

Using the XDS510PP JTAG emulator with the SPI110 allows the engineer to debug algorithms with the JTAG interface on the DSK. The SPI110 optically isolates the JTAG interface and is required because the DMC1500 is operating at a floating voltage level.

NOTE:

The SPI110 **MUST** be used with a JTAG emulator !

2.2.1 Installation of the DSK using the Serial Interface on the DMC1500

To install the DSK on the DMC1500 for serial debug, perform the following procedure:

1. Remove all power from the DMC1500
2. Remove all power from the DSK.
3. If installed, unplug the serial cable from the DMC1500
4. Put masking/electrical tape over the DSK serial connector, P4
5. Install connectors on the bottom of the DSK by soldering double row headers into connectors P1 (analog) and P2 (I/O).
6. Configure the on chip UART to use the serial connector on the DMC1500.
7. Plug the DSK on to the DMC1500 by aligning DSK connectors P1 and P2 with DMC1500 connectors P18 and P19 respectively and pushing downward.

2.2.2 Installation of the DSK Using the XDS510PP and SPI110 Opto POD

To install the DSK on the DMC1500 for JTAG debug, perform the following procedure:

1. Remove all power from the DMC1500
2. Remove all power from the DSK.
3. If installed, unplug the serial cable from the DMC1500
4. Install connectors on the bottom of the DSK by soldering double row headers into connectors P1 (analog) and P2 (I/O).
5. Plug the DSK on to the DMC1500 by aligning DSK connectors P1 and P2 with DMC1500 connectors P18 and P19 respectively and pushing downward.
6. Remove power from the SPI110 and attach the SPI110 Opto POD to the JTAG header on the DSK.
7. Remove power from the XDS510PP emulator and attach the JTAG tail to the connector on the top of the XDS510PP.

2.3 Connecting Motors to the Digital Motor Controller

The DMC1500 will support the development of algorithms for a variety of motors. Each type of motor requires a specific type of connection. These connections are discussed in the following sections.

2.3.1 WARNINGS

The DMC1500 is capable of driving high voltage medium current motors. It is designed for bus voltages of up to 350 volts with currents up to 10 amps. There is an onboard diode bridge and capacitor. The bus current can be derived from AC, or DC can be directly driven in. There are many warnings that should be observed when operating with high energy devices.



DANGER !

The user is reminded to remove all power to the unit, motors, and associated electronics when connecting/disconnecting wires or connectors.

Warnings:

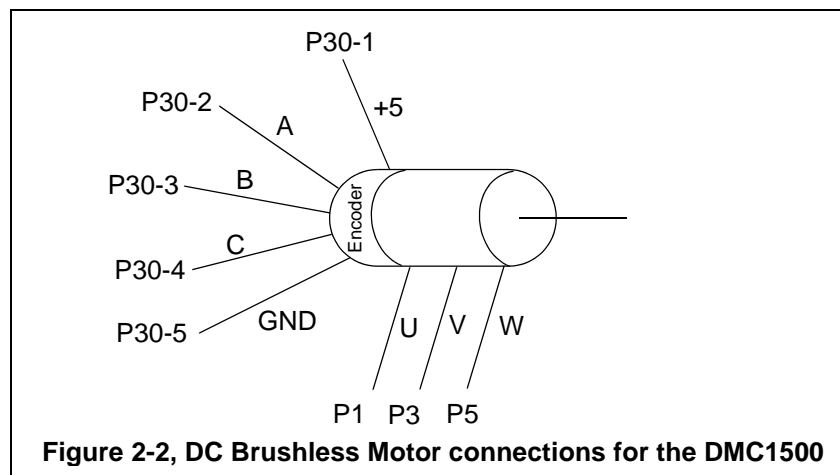
1. Make sure the bus is discharged before operating on or connecting probes to the equipment. There is an LED that indicates the bus is charged. It should not be used to guarantee that the unit is safe to touch. You should verify that the bus is discharged by using a voltmeter across the bus connections.
2. The input power must be fused externally for safe operation. The fuse should be sized to the voltage and current requirements of the load. You must also guarantee that the unit will not be fused above the safe operating range of the inverter module.
3. If the motor is being used for regenerative braking it will source current back into the supply. This will raise the bus voltage. If this is the case then the user must put a voltage regulator across the Bus terminals to absorb this energy. If this is not done then the bus voltage may rise above the maximum voltage and destroy the inverter board.

2.3.2 Connecting a DC Brushless Motor to the DMC1500 (-0001)

To connect a DC brushless motor to the DMC1500 perform the following steps:

1. Remove all power from the DMC1500
2. Attach Phase U from the motor to lug P1.
3. Attach Phase V from the motor to lug P3.
4. Attach Phase W from the motor to lug P5.
5. Attach +5 volts from the motor to connector P30, pin 1.
(+5V is available on P30 pin 6 if external supply is not used)
6. Attach Phase A from the motor to connector P30, pin 2.
7. Attach Phase B from the motor to connector P30, pin 3.
8. Attach Phase C from the motor to connector P30, pin 4.
9. Attach the ground from the motor to connector P30, pin 5.

These connections are shown in the figure below.



The jumper settings for using a DC Brushless motor are shown in the table below.

Table 1: DC Brushless Jumper Settings

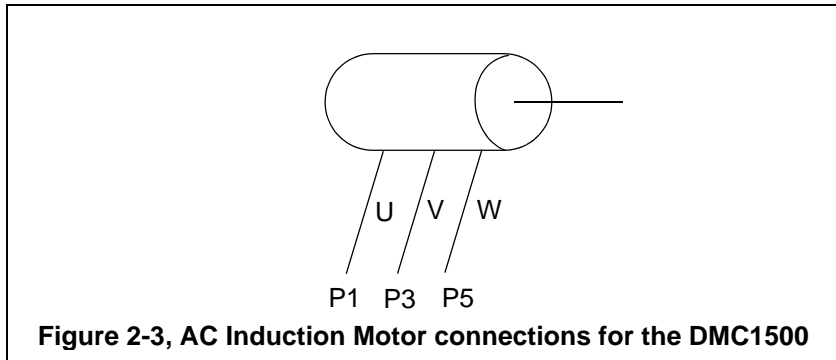
Jumper #	Size	Setting	Function
JP1	1 x 2	In	Phase U Leg Tie
JP2	1 x 2	In	Phase V Leg Tie
JP3	1 x 2	In	Phase W Leg Tie

2.3.3 Connecting an AC Induction Motor to the DMC1500 (-0001)

To connect an AC Induction motor to the DMC1500 perform the following steps:

1. Remove all power from the DMC1500
2. Attach Phase U from the motor to lug P1.
3. Attach Phase V from the motor to lug P3.
4. Attach Phase W from the motor to lug P5.

These connections are shown in the figure below.



The jumper settings for using a AC Induction motor are shown in the table below.

Table 2: AC Induction Jumper Settings

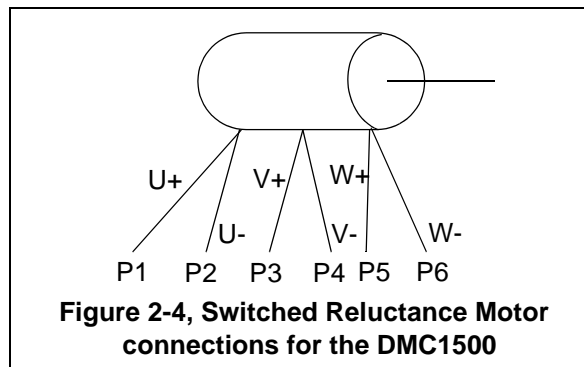
Jumper #	Size	Setting	Function
JP1	1 x 2	In	Phase U Leg Tie
JP2	1 x 2	In	Phase V Leg Tie
JP3	1 x 2	In	Phase W Leg Tie

2.3.4 Connecting a Switched Reluctance Motor to the DMC1500 (-0002)

To connect a Switched Reluctance motor to the DMC1500 perform the following steps:

1. Remove all power from the DMC1500
2. Attach Phase U+ from the motor to lug P1.
3. Attach Phase U- from the motor to lug P2.
4. Attach Phase V+ from the motor to lug P3.
5. Attach Phase V- from the motor to lug P4.
6. Attach Phase W+ from the motor to lug P5.
7. Attach Phase W- from the motor to lug P6.

These connections are shown in the figure below.



The jumper settings for using a Switched Reluctance motor are shown in the table below.

Table 3: Switched Reluctance Jumper Settings

Jumper #	Size	Setting	Function
JP1	1 x 2	Cut/Open	Phase U Leg Tie
JP2	1 x 2	Cut/Open	Phase V Leg Tie
JP3	1 x 2	Cut/Open	Phase W Leg Tie

2.4 DMC1500 Connectors

The DMC1500 has 30 connectors. These connectors are used to bring power to the DMC1500, signals to/from the DSK, and power to the motor. These connectors are shown in the table below and discussed in the following sections.

Table 4: DMC1500 Connectors

Connector	# Pins	Function
P1	1	Phase U+
P2	1	Phase U-
P3	1	Phase V+
P4	1	Phase V-
P5	1	Phase W+
P6	1	Phase W-
P7	1	Ground
P8	2	Phase U External Driver Power
P9	2	Phase V External Driver Power
P10	2	Phase W External Driver Power
P11,P12	1	PFC Inductor Terminals
P13	1	Frame Ground
P14	1	Motor Center Tap Connection
P15-P17	1	Motor Power Selection
P18	20	DSK Analog Connector
P19	40	DSK I/O Connector
P20	1	Line Input
P21-P22	1	Motor Power Selection
P23	16	Sensor Expansion
P24	10	SPI Port
P25	1	Neutral Input
P26	2	External 24VDC Power Input
P27	8	Digital I/O (Opto)
P28	9	RS232 (Opto)
P29	4	CAN Interface (Opto)
P30	6	Hall Sensor/ Encoder Inputs

The position of each connector on the DMC1500 is shown in the figure below.

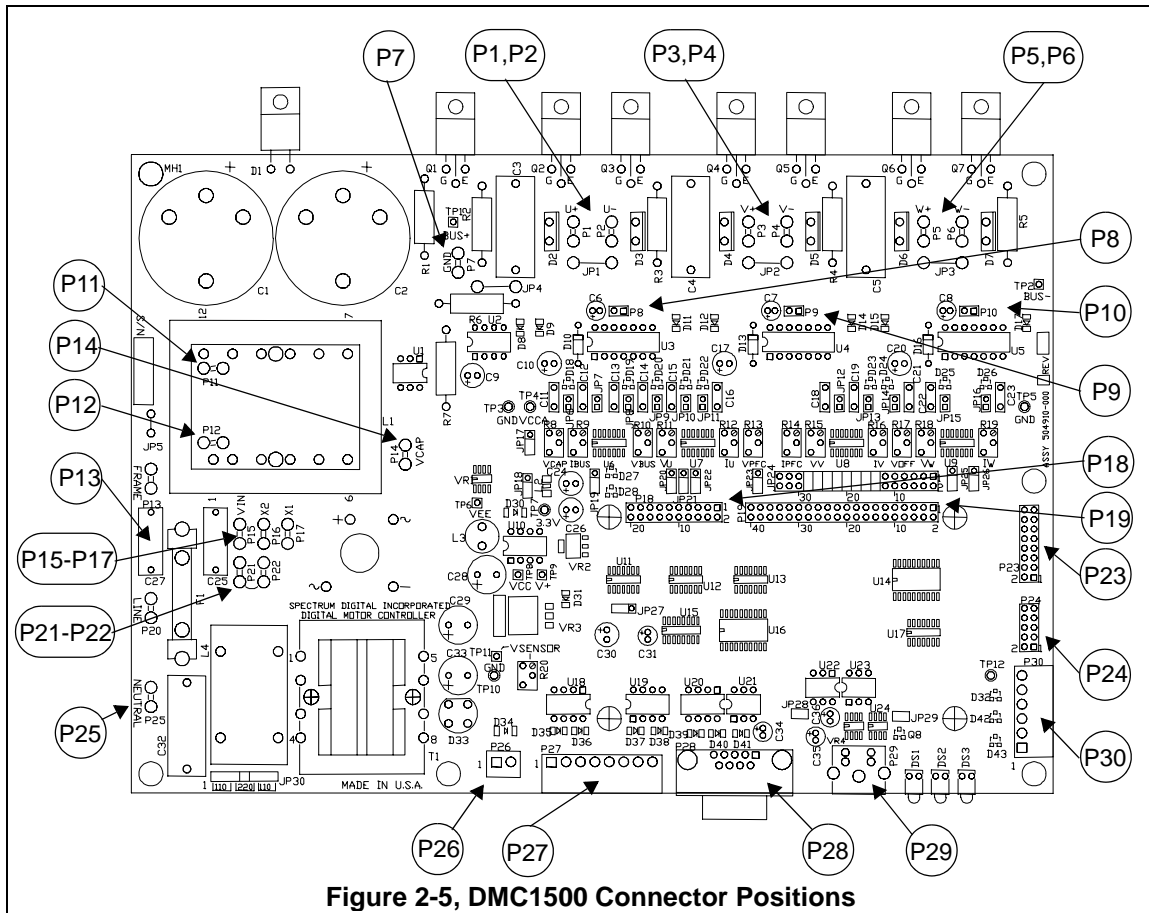


Figure 2-5, DMC1500 Connector Positions

2.4.1 P1-P2, Phase U Hookup

Connectors P1 and P2 are for the Phase U+ and U- signals respectively. These are tab terminals. These lines should be connected directly to your motor. For BLDC and ACI motors connect Phase U to P1. For SR motors connect Phase U between P1 and P2. Make sure JP1 is cut or open for SR motors.

2.4.2 P3-P4, Phase V Hookup

Connectors P3 and P4 are for the Phase V+ and V- signals respectively. These are tab terminals. These lines should be connected directly to your motor. For BLDC and ACI motors connect Phase V to P3. For SR motors connect Phase V between P3 and P4. Make sure JP2 is cut or open for SR motors.

2.4.3 P5-P6, Phase W Hookup

Connectors P5 and P6 are for the Phase W+ and W- signals respectively. These are tab terminals. These lines should be connected directly to your motor. For BLDC and ACI motors connect Phase W to P1. For SR motors connect Phase W between P1 and P2. Make sure JP3 is cut or open for SR motors.

2.4.4 P7, Ground

Connector P7 is for motor ground. This is a male Tab terminal. This line should be connected directly to your motor.

2.4.5 P8, Phase U External Driver Power

The high side driver in U2 is normally powered by the boot strap method. If you want to have continuous gate drive voltage then you can apply 12-15VDC to connectors P8. This voltage supply must be isolated from P9, P10, and from ground. Separate isolated supplies **must** be used for each driver.

2.4.6 P9, Phase V External Driver Power

The high side driver in U3 is normally powered by the boot strap method. If you want to have continuous gate drive voltage then you can apply 12-15VDC to connectors P9. This voltage supply must be isolated from P8, P10, and from ground. Separate isolated supplies **must** be used for each driver.

2.4.7 P10, Phase W External Driver Power

The high side driver in U4 is normally powered by the boot strap method. If you want to have continuous gate drive voltage then you can apply 12-15VDC to connectors P10. This voltage supply must be isolated from P8, P9, and from ground. Separate isolated supplies **must** be used for each driver.

2.4.8 P11-P12, PFC Inductor Terminals

These terminals are not used in standard configurations.

2.4.9 P13, Frame Ground

The terminal should be connected to Earth ground.

2.4.10 P14, Motor Center Tap Connection

The terminal is used for the center tap connection for PSC motors.

2.4.11 P15-P17, P21-22, Motor Power Selection

Connectors P15 and P16 bring in AC power through the AC line filter. Connectors P17 and P18 are the internal power connections. Normally P21 is connected to P22. Connecting P15 to P16 uses the voltage doubler while P15-P17 does not.

WARNING !

Make sure you **do not** exceed the maximum DC bus when using the voltage doubler, i.e. **don't** use the doubler with 220 VAC input.

It is also possible to connect input power to P16-P22 through another source such as a Variac or isolation transformer. Remember to place a fuse in the high side power.

2.4.12 P18, DSK Analog Connector

Connector P18 provides the analog signal interface to the DSK which plugs onto the DMC1500. The signals on this connector are defined in the table below:

Table 5: P18, DSK Analog Connector

Pin #	Signal	Pin #	Signal
1	Gnd	2	Ad0
3	Gnd	4	Ad1
5	Gnd	6	Ad2
7	Gnd	8	Ad3
9	Gnd	10	Ad4
11	Gnd	12	Ad5
13	Gnd	14	Ad6
15	Gnd	16	Ad7
17	Gnd	18	NC
19	Gnd	20	NC

NC = Not Connected

2.4.13 P19, DSK I/O Connector

Connector P19 mates with connector P2 on the DSKs. The signals present on P2 of the DSK are present on P19.

Table 6: P19, DSK I/O Connector

Pin #	Signal	Pin #	Signal
1	+5V	2	+5V
3	Tx	4	Rx
5	In1	6	Cap1
7	Cap2	8	Cap3
9	Pwm1	10	Pwm2
11	Pwm3	12	Pwm4
13	Pwm5	14	Pwm6
15	Strobe-	16	Pwm7
17	Enable-	18	Led-
19	Gnd	20	Gnd
21	Opt1	22	In2
23	SpiSiMo	24	SpiSoMi
25	SpiClk	26	SpiSte
27	CanTx	28	CanRx
29	Out1	30	Out2
31	Reserved	32	Reserved
33	Reserved	34	Reserved
35	Reserved	36	Reserved
37	OverCurrent-	38	Reserved
39	Gnd	40	Gnd

2.4.14 P20, Line Input

Connector P20 is a Tab terminal which attached to the line side from an AC power source (110-220 VAC).

2.4.15 P23, Sensor Expansion

Connector P23 is a 2 x 8 double row header which allows the user to expand their phase current sensors or Hall effect current sensors. The signals on connector P23 are shown in the table below.

Table 7: P23, Sensor Expansion

Pin #	Signal	Pin #	Signal
1	+5V	2	+5V
3	GND	4	Option1
5	GND	6	Option2
7	GND	8	Option3
9	GND	10	Option4
11	GND	12	Option5
13	GND	14	Option6
15	GND	16	GND

Jumper JP24 allows the user to connect these option pins to the analog input channels.

2.4.16 P24, SPI Port

Connector P24 is a 2 x 5 double row header which brings out the four SPI signals from the DSK and Vcc. This allows the user to easily have access to the signals. The SPI signals and their pin positions are shown in the table below.

Table 8: P24, SPI Port

Pin #	Signal	Pin #	Signal
1	Gnd	2	+5V
3	Gnd	4	SpiSiMo
5	Gnd	6	SpiSoMi
7	Gnd	8	SpiClk
9	Gnd	10	SpiSte

2.4.17 P25, Neutral Input

Connector P25 is a Tab terminal which attached to the neutral side from an AC power source (110-220 VAC).

2.4.18 P26, External 24VDC Power Input

An external power supply can be connected to this input to supply control power. This supply must be isolated and capable of sustaining the maximum bus voltage.

2.4.19 P27, Digital I/O (Optically Coupled)

Connector P27 is an 8 pin connector that provides two input and two outputs. The inputs and outputs are optically coupled with NEC PS2501 series devices. The outputs are capable of sourcing and sinking 20Ma. The inputs are setup with 750 Ohm .25 WATT series resistors. You can drive these inputs with 5-12Vdc. These are general purpose I/O signals which are controlled by the DSP. The signals present on this connector and their pin number are shown in the table below:

Table 9: P27, Digital I/O (Optically Coupled)

Pin #	Signal
1	Out2-
2	Out2+
3	Out1-
4	Out1+
5	In1+
6	In1-
7	INT2+
8	INT2-

2.4.20 P28, RS-232 (Optically Coupled)

Connector P28 is a DB9 female connector. This connector can be used to debug algorithms through if the DSK debugger is used, or it can be used as general purpose serial communication. The signals present on P28 are optically coupled.

Power must be supplied by the Device connected to P28. This is done by driving either pin 4 (DTR) or pin 7 (RTS) or both high. This supplies power to the interface. Make sure that DTR or RTS is high or the serial interface will not work. P28 is configured for a straight through cable to a PC.

The pin positions for the P28 connector as viewed from the edge of the DMC1500 are shown below.

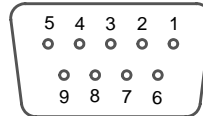


Figure 2-6, P29, DB9 Female Connector

Table 10: P28, RS-232 (Optically Coupled)

Pin #	Signal	DMC1500 Direction
1	N/C	
2	TX	Out
3	RX	In
4	DTR	In(Power)
5	RTN	
6	N/C	
7	RTS	In(Power)
8	N/C	
9	N/C	

2.4.21 P29, CAN Interface (Optically Coupled)

Connector P29 is a 4 pin female mini-DIN connector which provides a CAN interface to the DMC1500. The CAN feature is only available when using the F243 or LF2407 DSK. The TMS320F240 DSP on the F240 DSK does not have a CAN controller.

Because this interface is optically isolated power must be provided by the interface plugged into P29. If JP28 is installed, then a regulated +5 volts must be provided between pins 4 and 3. If JP28 is not installed then unregulated power up to 12 volts can be applied. JP29 is the 120 ohm termination for devices on the end of the CAN bus.

Note: Because of the optocouplers the full bus speed might not be possible. Start with lower baud rates to verify operation.

The signals on this connector and their pin numbers are shown in the table below.

Table 11: P29, CAN Interface (Optically Coupled)

Pin #	Signal Name
1	CAN+
2	CAN-
3	CAN-RTN
4	CAN-Vcc (Power Input)

2.4.22 P30, Hall Sensor/ Encoder Inputs (Non-isolated)

Connector P30 is a 1 x 6 header which supports 3 non-isolated channels. The three channels can either be Hall Effect sensors or a quadrature encoder. The Sensor power on pin 1 can be adjusted from 0-15Vdc by resistor R20.

The signals present on this connector and their pin number are shown in the table below.

Table 12: P30, Hall Sensor/Encoder Inputs

Pin #	Signal
1	Vsensor(0-15Vdc)
2	Capture1(Hall U, Channel A)
3	Capture2(Hall V, Channel B)
4	Capture3(Hall W, Index)
5	Gnd
6	+5V

2.5 Jumpers

The DMC1500 has 30 jumpers. Their designator, size, and function are shown in the table below:

Table 13: DMC1500 Jumpers

Jumper #	Size	Function
JP1	1 x 2	Phase U Leg Tie
JP2	1 x 2	Phase V Leg Tie
JP3	1 x 2	Phase W Leg Tie
JP4	1 x 2	Bus Sense Resistor Disable
JP5	1 x 2	Frame to Ground Tie
JP6	1 x 2	Cap CT Voltage Calibration
JP7	1 x 2	Bus Current Calibration
JP8	1 x 2	PFC Voltage Calibration
JP9	1 x 2	Bus Voltage Calibration
JP10	1 x 2	Phase U Voltage Calibration
JP11	1 x 2	Phase U Current, Offset Enable
JP12	1 x 2	Bus Current Calibration
JP13	1 x 2	Phase V Voltage Calibration
JP14	1 x 2	Phase V Current, Offset Enable
JP15	1 x 2	Phase W Voltage Calibration
JP16	1 x 2	Phase W Current, Offset Enable
JP17	1 x 3	PFC Enable
JP18	1 x 3	Vcca Select (3.3/5.0 Volts)
JP19	1 x 3	V Sense Cap Amplifier
JP20	1 x 3	V Sense Bus Amplifier
JP21	1 x 3	V Sense PFC Amplifier
JP22	1 x 3	V Sense U Amplifier
JP23	1 x 3	V Sense V Amplifier
JP24	2 x 10	A/D Channel Selection
JP25	1 x 3	V Sense W Amplifier
JP26	1 x 3	Opt1
JP27	1 x 3	PWM Watchdog Mode
JP28	1 x 2	CAN Regulator Disable
JP29	1 x 2	CAN Termination Resistor Enable
JP30	1 x 4	110/220 VAC Selection

The position of each jumper on the DMC1500 is shown in the figure below.

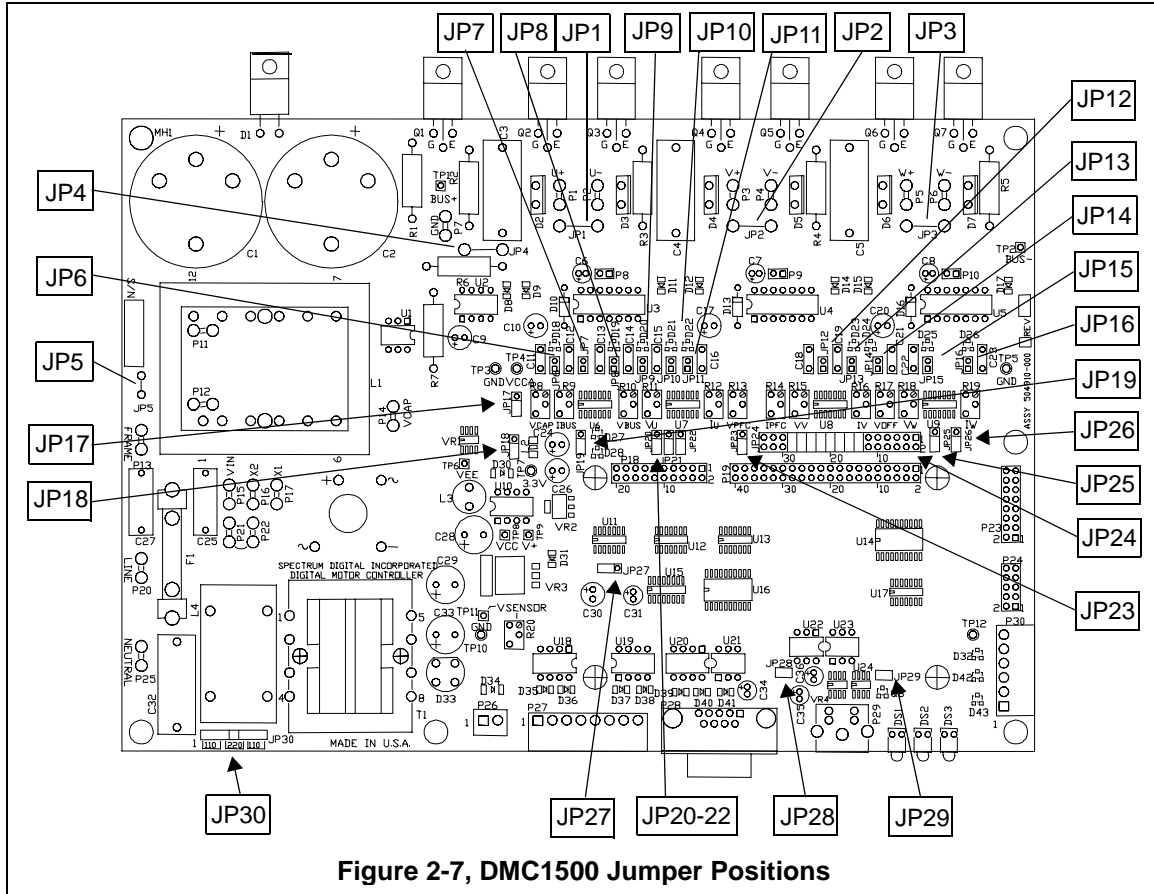


Figure 2-7, DMC1500 Jumper Positions



DANGER !

The user is reminded to remove all power to the unit, motors, and associated electronics when connecting/disconnecting jumpers, wires, or connectors.

2.5.1 JP1, Phase U Leg Tie

Jumper JP1 is used to connect the phase U transistors in a totem-pole configuration. The open position is used for SR motors. The shorted selection is used to drive BLDC and ACI motors. The settings are shown in the table below.

Table 14: JP1, Phase U Leg Tie

Position	Function
Open	SR
Shorted	BLDC, ACI

2.5.2 JP2, Phase V Leg Tie

Jumper JP2 is used to connect the phase V transistors in a totem-pole configuration. The open position is used for SR motors. The shorted selection is used to drive BLDC and ACI motors. The settings are shown in the table below..

Table 15: JP2, Phase V Leg Tie

Position	Function
Open	SR
Shorted	BLDC, ACI

2.5.3 JP3, Phase W Leg Tie

Jumper JP3 is used to connect the phase W transistors in a totem-pole configuration. The open position is used for SR motors. The shorted selection is used to drive BLDC and ACI motors. The settings are shown in the table below..

Table 16: JP3, Phase W Leg Tie

Position	Function
Open	SR
Shorted	BLDC, ACI

2.5.4 JP4, Bus Sense Resistor Disable

Jumper JP4 is used to disable the Bus Sense resistor. In the open position Bus Current Sense is disabled. When the shorted selection is used Phase Current Sense is disabled. The settings are shown in the table below.

Table 17: JP4, Bus Sense Resistor Disable

Position	Function
Open	Bus Current Sense disabled
Shorted	Phase Current Sense disabled

2.5.5 JP5, Frame to Ground Tie

Jumper JP5 is used to connect the DMC1500 chassis to the earth ground. In the open position the DMC1500 is not connected to earth ground. When the shorted selection is used earth ground is connected to the DMC1500 chassis. The setting are shown in the table below.

Table 18: JP5, Frame to Ground Tie

Position	Function
Open	Not grounded
Shorted	DMC1500 chassis to Earth Ground

2.5.6 JP6, Cap CT Voltage Calibration

Jumper JP6 is used to calibrate the V Sense Cap amplifier. When the shorted selection is used the V cap sense amplifier can be calibrated. After calibration, the open position is used for normal operation. The settings are shown in the table below.

Table 19: JP6, Cap CT Voltage Calibration

Position	Function
Open	Normal Mode
Shorted	Calibrate Mode

2.5.7 JP7, Bus Current Calibration

Jumper JP7 is used to calibrate the Bus Current Sense amplifier. When the shorted selection is used the Bus Current sense amplifier can be calibrated. After calibration, the open position is used for normal operation. The settings are shown in the table below.

Table 20: JP7, Bus Current Calibration

Position	Function
Open	Normal Mode
Shorted	Calibrate Mode

2.5.8 JP8, PFC Voltage Calibration

Jumper JP8 is used to calibrate the Power Factor Correction Voltage Sense amplifier. When the shorted selection is used the Power Factor Correction sense amplifier can be calibrated. After calibration, the open position is used for normal operation. The settings are shown in the table below.

Table 21: JP8, PFC Voltage Calibration

Position	Function
Open	Normal Mode
Shorted	Calibrate Mode

2.5.9 JP9, Phase U Bus Voltage Calibration

Jumper JP9 is used to calibrate the Phase U Bus Voltage Sense amplifier. When the shorted selection is used the Bus Voltage sense amplifier can be calibrated. After calibration, the open position is used for normal operation. The settings are shown in the table below.

Table 22: JP9, Bus Voltage Calibration

Position	Function
Open	Normal Mode
Shorted	Calibrate Mode

2.5.10 JP10, Phase U Voltage Calibration

Jumper JP10 is used to calibrate the Phase U Voltage Sense amplifier. When the shorted selection is used the Phase U Voltage sense amplifier can be calibrated. After calibration, the open position is used for normal operation. The settings are shown in the table below.

Table 23: JP10, Phase U Voltage Calibration

Position	Function
Open	Normal Mode
Shorted	Calibrate mode

2.5.11 JP11, Phase U Current, Offset Enable

Jumper JP11 is used to select the sensing of the Bi-polar phase U current. In the open position Uni-polar current is selected for sensing. When the shorted selection is used Bi-polar current is selected. The settings are shown in the table below.

Table 24: JP11, Phase U Current, Offset Enable

Position	Function
Open	Uni-polar Current
Shorted	Bi-polar Current

2.5.12 JP12, Phase V Bus Current Calibration

Jumper JP12 is used to calibrate the Phase V Bus Voltage Sense amplifier. When the shorted selection is used the Bus Voltage sense amplifier can be calibrated. After calibration, the open position is used for normal operation. The settings are shown in the table below.

Table 25: JP12, Bus Current Calibration

Position	Function
Open	Normal Mode
Shorted	Calibrate Mode

2.5.13 P13, Phase V Voltage Calibration

Jumper JP13 is used to calibrate the Phase V Voltage Sense amplifier. When the shorted selection is used the Phase V Voltage sense amplifier can be calibrated. After calibration, the open position is used for normal operation. The settings are shown in the table below.

Table 26: P13, Phase V Voltage Calibration

Position	Function
Open	Normal Mode
Shorted	Calibrate Mode

2.5.14 JP14, Phase V Current, Offset Enable

Jumper JP14 is used to select the sensing of the Bi-polar phase V current. In the open position Uni-polar current is selected for sensing. When the shorted selection is used Bi-polar current is selected. The settings are shown in the table below..

Table 27: JP14, Phase V Current, Offset Enable

Position	Function
Open	Uni-polar Current
Shorted	Bi-polar Current

2.5.15 JP15, Phase W Voltage Calibration

Jumper JP15 is used to calibrate the Phase W Bus Voltage Sense amplifier. When the shorted selection is used the Bus Voltage sense amplifier can be calibrated. After calibration, the open position is used for normal operation. The settings are shown in the table below.

Table 28: JP15, Phase W Voltage Calibration

Position	Function
Open	Normal Mode
Shorted	Calibrate Mode

2.5.16 JP16, Phase W Current, Offset Enable

Jumper JP16 is used to select the sensing of the bi-polar phase W current. In the open position Uni-polar current is selected for sensing. When the shorted selection is used Bi-polar current is selected. The settings are shown in the table below.

Table 29: JP16, Phase W Current, Offset Enable

Position	Function
Open	Uni-polar Current
Shorted	Bi-polar current

2.5.17 JP17, PFC Enable

Jumper JP17 is used to enable the Power Factor Correction driver. If the 1-2 position is selected the PFC driver is disabled. When the 2-3 selection is used the PFC driver is enabled. The setting are shown in the table below.

Table 30: JP17, PFC Enable

Position	Function
1-2	Disable PFC driver
2-3	Enable PFC driver

2.5.18 JP18, Vcca Select

Jumper JP18 is used to select 3.3 volts or 5.0 volts for analog inputs. If the 1-2 selection is used 3.3 volts is used for analog inputs. The 2-3 selection will allow 5.0 volts to be used. The settings are shown in the table below.

Table 31: JP18, Vcca Select

Position	Function	Processor
1-2	3.3 Volts	TMS320LF2407
2-3	5.0 Volts	TMS320F240/243

2.5.19 JP19, V Sense Cap Amplifier

Jumper JP19 is used to allow the V Sense capacitor input to be amplified or not amplified. The 1-2 position is used to select amplification. When the jumper is in the 2-3 position there will be no amplification. These settings are shown in the table below.

Table 32: JP19, V Sense Cap Amplifier

Position	Function
1-2	Amplified
2-3	Not Amplified

The gain for this amplifier is set by resistor, R8

2.5.20 JP20, V Sense Bus Amplifier

Jumper JP20 is used to allow the V Sense bus input to be amplified or not amplified. The 1-2 position is used to select amplification. When the jumper is in the 2-3 position there will be no amplification. These settings are shown in the table below.

Table 33: JP20, V Sense Bus Amplifier

Position	Function
1-2	Amplified
2-3	Not Amplified

The gain for this amplifier is set by resistor, R10

2.5.21 JP21, V Sense PFC Amplifier

Jumper JP21 is used to allow the V Sense PFC input to be amplified or not amplified. The 1-2 position is used to select amplification. When the jumper is in the 2-3 position there will be no amplification. These settings are shown in the table below.

Table 34: JP21, V Sense PFC Amplifier

Position	Function
1-2	Amplified
2-3	Not Amplified

The gain for this amplifier is set by resistor, R13

2.5.22 JP22, V Sense U Amplifier

Jumper JP22 is used to allow the V Sense U input to be amplified or not amplified. The 1-2 position is used to select amplification. When the jumper is in the 2-3 position there will be no amplification. These settings are shown in the table below.

Table 35: JP22, V Sense U Amplifier

Position	Function
1-2	Amplified
2-3	Not Amplified

The gain for this amplifier is set by resistor, R11

2.5.23 JP23, V Sense V Amplifier

Jumper JP23 is used to allow the V Sense V input to be amplified or not amplified. The 1-2 position is used to select amplification. When the jumper is in the 2-3 position there will be no amplification. These settings are shown in the table below.

Table 36: JP23, V Sense V Amplifier

Position	Function
1-2	Amplified
2-3	Not Amplified

The gain for this amplifier is set by resistor, R15

2.5.24 JP24, A/D Channel Configuration

JP24 allows selecting 8 out of 17 analog signals. The standard configuration is shown in the below.

Table 37: JP24 A/D Channel Configuration

JP18 Position	Signal Selection
1-2	Option 1 to AD0
3-4	Option 2 to AD2
5-6	Option 3 to AD3
7-8	Option 4 to AD4
9-10	Option 5 to AD5
11-12	Option 6 to AD6
13-14	I Sense U to AD0
15-16	I Sense V to AD1
17-18	I Sense U to AD0
19-20	V Sense U to AD3
21-22	V Sense V to AD4
23-24	V Sense W to AD5
25-26	I Sense Bus to AD6
27-28	V Sense Bus to AD7
29-30	I Sense PFC to AD4
31-32	V Sense PFC to AD3
33-34	V Sense Cap to AD5

2.5.25 JP25, V Sense W Amplifier

Jumper JP25 is used to allow the V Sense W input to be amplified or not amplified. The 1-2 position is used to select amplification. When the jumper is in the 2-3 position there will be no amplification. These settings are shown in the table below.

Table 38: JP23, V Sense W Amplifier

Position	Function
1-2	Amplified
2-3	Not Amplified

The gain for this amplifier is set by resistor, R18

2.5.26 JP26, Opt1

Jumper JP26 is a used definable jumper that can be read by reading I/O port XF/IOPC0 pin on the F243 or the XF/IOPC2 on the F240. If the 1-2 position is selected a zero (0) is read. When the 2-3 selection is used a one (1) is read. The setting are shown in the table below.

Table 39: JP26, Opt1

Position	Function
1-2	Read 0
2-3	Read 1

2.5.27 JP27, PWM Watchdog Mode

Jumper JP27 is used to enable the PWM drivers regardless of the watch dog timer. If the 1-2 position is selected the PWM is enabled from I/O. When the 2-3 selection is used the PWM is always enabled. The setting are shown in the table below.

Table 40: JP27, PWM Watchdog Mode

Position	Function
1-2	PWM Enabled From I/O
2-3	PWM Always Enabled

2.5.28 JP28, CAN Regulator Disable

Jumper JP28 is used to select the 5 volt input for the CAN driver. If the open selection is used a value greater than 5 volts can be used as the input for the CAN driver. When the shorted selection is used 5 volts is used as the input. The setting are shown in the table below.

Table 41: JP28, CAN Regulator Disable

Position	Function
Open	Greater than 5 volts
Shorted	5 volts

2.5.29 JP29, CAN Termination Resistor Enable

Jumper JP29 is used to enable the CAN termination resistor. If the open position is selected the use of a CAN termination resistor is disabled. When the shorted selection is used the use of a termination resistor is enabled. The settings are shown in the table below.

Table 42: JP29, CAN Termination Resistor Enable

Position	Termination Resistor
Open	Disabled
Shorted	Enabled

2.5.30 JP30, 110-220 VAC Selection

Jumper JP30 is used to what voltage is being brought in on connectors P24 and P25. If the 1-2, 3-4 position is selected this indicates that 110 VAC is being brought in on P24 and P25. When the 2-3 selection is used it indicates 220 VAC is present on connectors P24 and P25. The settings are shown in the table below.

Table 43: JP30, 110-220 Selection

Position	Function
1-2, 3-4	110 VAC in P24, P25
2-3	220 VAC in P24, P25

2.6 Test Points

The DMC1500 has 12 test points. The user should **not** tie a scope to ground unless an isolation transformer is used for Bus power.



DANGER !

The user is reminded to remove all power to the unit, motors, and associated electronics when connecting/disconnecting probes, jumpers, wires or connectors.

Warning:

1. Remove all input power to the DMC1500 and DSK prior to connecting any probes. LED DS1 should **not** be illuminated.

The table below shows the test points and the signal present on each.

Table 44: DMC1500 Test Points

Test Point #	Signal Name
TP1	Bus+
TP2	Bus-
TP3	Ground
TP4	Vcca
TP5	Ground
TP6	Driver Vee
TP7	3.3 Volts
TP8	Vcc
TP9	Control Power (24VDC)
TP10	Ground
TP11	V Sensor
TP12	Ground

The position of each test point on the DMC1500 is shown in the figure below.

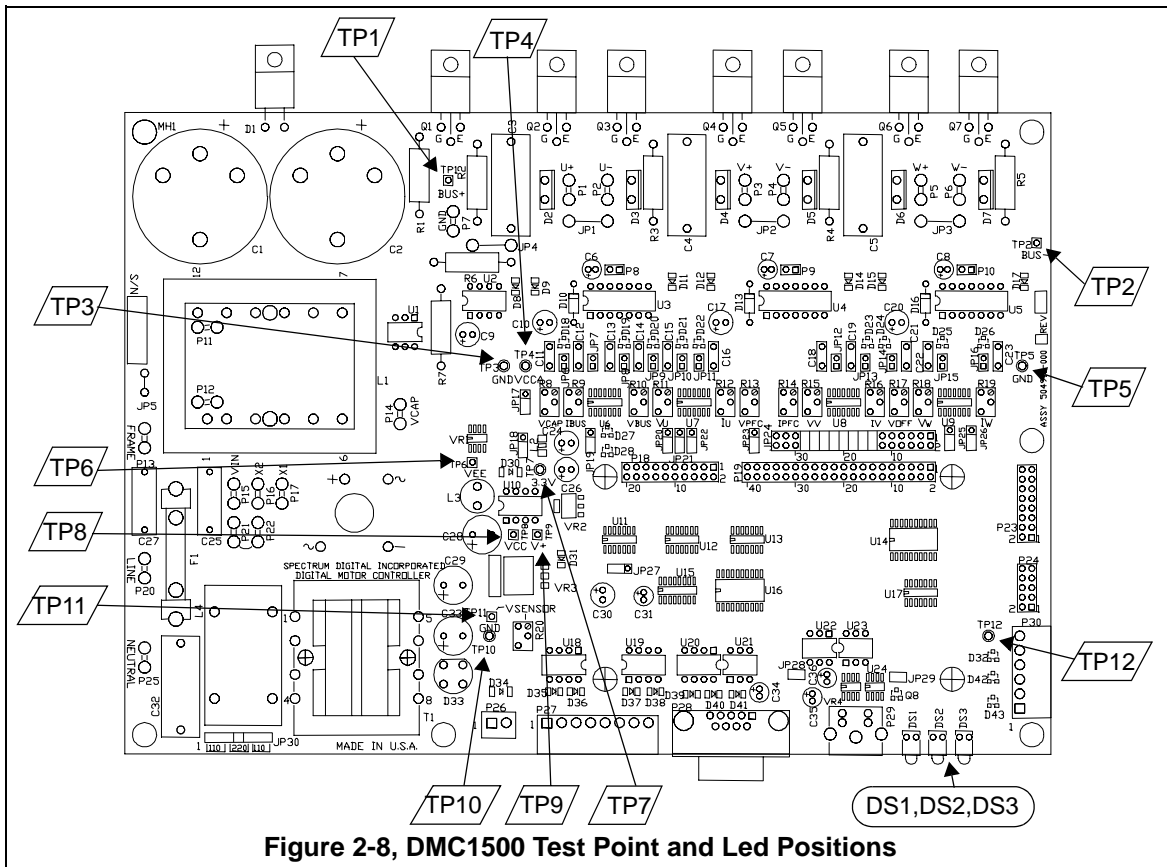


Figure 2-8, DMC1500 Test Point and Led Positions

2.7 Potentiometers

The DMC1500 has 13 potentiometers. The table below shows the potentiometer designator, its function, and range of adjustment:

Table 45: DMC1500 Potentiometers

Potentiometer #	Function	Adjustment Range
R8	Cap CT Voltage Gain	40.5 - 405.5 V
R9	Bus Current Gain	1.5 - 16.6 A
R10	Bus Voltage Gain	40.5 - 405.5 V
R11	Phase U Voltage Gain	40.5 - 405.5 V
R12	Phase U Current Gain	1.1 - 12.5 A
R13	PFC Voltage Gain	40.5 - 405.5 V
R14	PFC Current Gain	1.1 - 12.5 A
R15	Phase V Voltage Gain	40.5 - 405.5 V
R16	Phase V Current Gain	1.1 - 12.5 A
R17	Phase Current Offset	0 - 0.45 V
R18	Phase W Voltage Gain	40.5 - 405.5 V
R19	Phase W Current Gain	1.1 - 12.5 A
R20	Sensor Voltage Trim	0 - 15 V



DANGER !

The user is reminded to use extreme caution when adjusting the potentiometers. It is suggested that you use a non-conducting screw driver.

The position of each potentiometer on the DMC1500 is shown in the figure below.

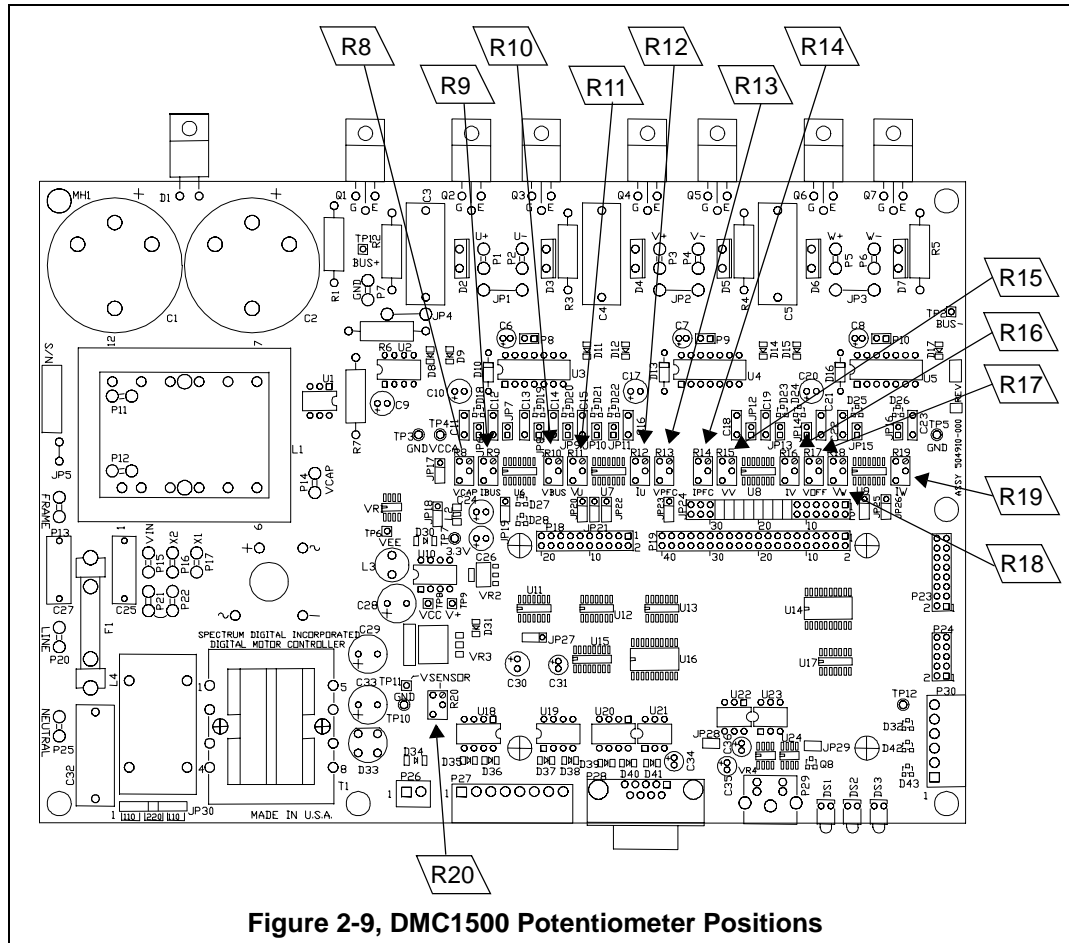


Figure 2-9, DMC1500 Potentiometer Positions

2.8 LEDs

The DMC1500 has 3 light emitting diodes (LEDs). The position of these LEDs are shown in figure 2-x above. Their function and color are shown in the table below.

Table 46: DMC1500 LEDs

Led #	Function
DS1	Power (Green)
DS2	User Programmable (Yellow)
DS3	Drive Enabled (Red)

2.9 Fusing

The DMC1500 has a replacable fuse, F1. This fuse is rated for 6 amps at 250 volts. If this fuse needs to be replaced it must be replace with a fuse with the same rating.



DANGER !

The user is reminded to remove all power to the unit, motors, and associated electronics when connecting/disconnecting wires or connectors.

Warning:

1. Remove all input power to the DMC1500 and DSK prior to connecting any probes. LED DS! should **not** be illuminated.

2.10 Motor Power Input Options

There are several input options. You can bring power in through P20 and P25 which also powers the onboard logic. You can also bring power in through P16 or P17 and P22. There is also a voltage doubled input option. If you use P17 and P22, the Input voltage is rectified and fed to BUS+. If you use P16 and P22, then the input voltage is rectified and doubled and fed to BUS+. This allows you to generate 220 bus voltages from 110 mains.

NOTE !

If applying 220 volts to P20 and P25 make sure that jumper JP30 is set correctly or the control logic will be destroyed.

If 110 VAC is on P20, P25 and JP30 is jumpered pins 1-2 and 3-4 you can have the following configurations:

- A. P20 Line(110)
P15-P17 Bus(110)
P25 Neutral
P21-P22
- B. P20 Line(110)
P15-P16 Bus(220)
P25 Neutral
P21-P22

If 220 VAC is on P20, P25 and JP30 is jumpered pins 2-3 you can have the following configurations:

- A. P20 Line(220)
P15-P17 Bus(220)
P25 Neutral
P21-P22
- B. No Voltage Doubler Option.

If using separate motor power you can have the following configurations:

- A. P17 Line(110)
Bus(110)
P22 Neutral
- B. P16 Line(110)
Bus(220)
P22 Neutral

2.11 Power Factor Correction

The Power Factor Correction Logic consists of Inductor L1, Diode D1 transistor Q1, and driver U2. The PFC supports a boost configuration. Without PFC power caps C1 and C2 charge only when the voltage of the mains is greater than the voltage on the caps. This causes high main current for short periods of time. The PFC logic stores energy in the inductor all through the 60Hz cycle and transfers it to the Caps. The input current is more uniform and matches the input waveform.

Transistor Q1 is turned on which creates a current path from the bridge through the inductor, transistor and back to the mains. The control algorithm then turns the transistor off. The energy in the inductor then travels through diode D1 and charges the caps C1, and C2. The control algorithm uses one pwm channel to drive the transistor and uses input voltage, inductor current, and capacitor voltage to control the PWM duty cycle.

Note: The DMC1500 is specified for half output power rating when using the power factor correction.

2.12 Emulation Logic

The DMC1500 contains an additional watchdog timer that disables the drivers if it is not strobed every 225mS. The software to strobe the watchdog should be placed in an Interrupt Service Routine (ISR) or in the main loop if timeout can be guaranteed. This logic is useful for emulation. If the emulator stops, the commutation will stop and the rotor will lock. Stopping the emulator will also stop the watchdog which will disable the drivers preventing continuous rotor current. There are also two other modes. With jumper JP27 in position 2-3 the watchdog logic is disabled. When jumper JP27 is in position 1-2 then an I/O pin can be used to enable the drivers and disable the watchdog. The watchdog strobe is on T1CMP/IOPB6 of the C242. The Enable signal is on TDIR/IOPB6. Refer to the signal mapping when using the F240, F243, or LF2407 DSK.

Table 47: On Board Watchdog Timer, JP22

JP27	Enable TDIR/IOPB6	Strobe T1CMP/IOPB6	Watchdog Drivers
1-2	Low	Don't Care	Enabled
1-2	High	Don't Care	Disabled
1-2	High	Yes	Enabled
2-3	Don't Care	Don't Care	Enabled
none	Don't Care	Yes	Enabled

2.13 External Driver Power

The high side drivers in U3-U5 are normally powered by the boot strap method. If you want to have continuous gate drive voltage then you can apply 12-15VDC to connectors P8-P10. Each of these three supplies must be isolated from each other and ground.

2.14 Power Stage

The power stage is either configured for ACI/BLDC or SR from the factory. Spectrum Digital does not support making a conversion in the field and this would void the warranty. Both configurations use 20Amp 400V high speed IGBT's. The ACI/BLDC configuration uses jumpers JP1-JP3 to tie the high side transistor to the low side transistor. The motor phases are then connected to P1,P3,P5. The SR configuration uses six 8 amp steering diodes across the IGBT's. In this configuration the motor phases are connected between the upper and lower transistors.

Table 48: ACI/BLDC Configuration

Pin #	Phase Signal
P1	Phase U
P3	Phase V
P5	Phase W

Table 49: SR Configuration

Pin #	Phase Signal
P1	Phase U+
P2	Phase U-
P3	Phase V+
P4	Phase V-
P5	Phase W+
P6	Phase W-

2.15 Phase Current

The DMC1500 supports reading the phase current in the lower transistor leg. This is the most common configuration. The currents are measured across three .04 ohm resistors. These sense signal are then filtered for a 40Khz cutoff frequency, clamped to the rails and applied to the non inverting input to an opamp. For each input there is also a jumper to apply an offset voltage. This allows unipolar or bipolar current measurements. The gain of each amplifier can be adjusted from 10 to 111. The example below shows how to calibrate the gain and offset for the U channel.

First determine your maximum current. In our example we will allow plus and minus 5 amps. The maximum voltage across the sense resistor would then be:

$$V = I \times R$$

$$V = 5.00 \text{ Amps} \times .04 \text{ Ohms}$$

$$V = .20 \text{ Volts}$$

The next step is to calculate the gain. Because we are measuring a bipolar current, 0 A/D volts corresponds to -5 Amps, 2.5 Volts for 0 Amps, and 5.0 Volts for +5 Amps. This example assumes 5 volts input on the A/D (on the LF2407 the max A/D voltage is 3.3 volts)

$$\text{Gain} = V_{out}/V_{in}$$

$$\text{Gain} = 2.5V/0.20V$$

$$\text{Gain} = 12.5$$

The next step is to adjust the gain for the channels. Install jumpers JP11, JP14, JP16 for bipolar operation. Pick a reference voltage such that it will not be greater than 5 volts when multiplied by the gain. We will pick a reference voltage of .1 which when multiplied by 12.5 meets our criteria. Measure the voltage at JP11 and adjust R17 for 0.1 Volts. Next measure the output voltages at JP24 pin 1 and adjust R12 for 1.25 volts. Repeat this procedure for the remaining two phases. The final step is to adjust the offset voltage. This is done by measuring the output voltage on one of the channels at JP11 and adjusting R17 until the voltage is 2.5 Volts.

Table 50: Phase Current Gain Adjust

Phase	Adjust	Measure on J24
U	R12	Pin 13
V	R16	Pin 15
W	R19	Pin 17

2.16 Phase Voltage

The phase voltages are measured from the top transistor with respect to Bus-. Each phase is divided by a resistive divider consisting of 400K and 4.99k. This gives a division of 81. Each channel also contains a filter with a cutoff frequency of 3.2Khz. The gain of each channel can be adjusted between 1 and 10. In our example we will assume a maximum voltage of 160 volts.

$$\text{Op-amp voltage} = \text{Phase Voltage} / 81$$

$$\text{Op-amp voltage} = 160\text{V} / 81$$

$$\text{Op-amp voltage} = 1.97 \text{ Volts}$$

The next step is to calculate the gain. In our case we want the 1.97 volts to correspond to 5.0 volts to the A/D. The gain would be:

$$\text{Gain} = \text{A/D Volts} / \text{Op-amp Volts}$$

$$\text{Gain} = 5.0 \text{ volts} / 1.97 \text{ Volts}$$

$$\text{Gain} = 2.6$$

To set the gain make sure there is 0 phase volts. To set phase U volts install jumper JP10. Next measure the voltage on JP10 and adjust R17 for .5 volts. This sets a reference voltage we will use to set the gain. The output voltage will be:

$$\text{Vout} = \text{Ref} \times \text{gain}$$

$$\text{Vout} = .5\text{v} \times 2.6$$

$$\text{Vout} = 1.3\text{V}$$

Now measure the voltage on JP24 pin 17 and adjust R11 for 1.3 volts. Repeat this procedure for each of the phases.

Table 51: Phase Current Gain Adjust

Phase	Jumper	Adjust	Measure on JP24
U	JP10	R11	Pin 17
V	JP13	R15	Pin 19
W	JP15	R18	Pin 21

Note: Make sure the jumper is removed after each adjustment

2.17 Bus/PFC Current

The currents are measured across .04 ohm resistors. The Bus current resistor R6 is shunted with a jumper JP4 from the factory. You can either have bus current measurements or phase current measurements but not both at the same time. To enable the bus current measurement cut out jumper JP4. These sense signal are then filtered for a 40Khz cutoff frequency, clamped to the rails and applied to the non inverting input to an opamp. The gain of each amplifier can be adjusted from 10 to 111. The example below shows how to calibrate the gain for the bus current.

First determine your maximum current. In our example we will allow 5 amps. The maximum voltage across the sense resistor would then be:

$$\begin{aligned}
 V &= I \times R \\
 V &= 5.00 \text{ Amps} \times .04 \text{ Ohms} \\
 V &= .20 \text{ Volts}
 \end{aligned}$$

The next step is to calculate the gain.

$$\begin{aligned}
 \text{Gain} &= V_{out}/V_{in} \\
 \text{Gain} &= 5.0V/0.20V \\
 \text{Gain} &= 25
 \end{aligned}$$

The next step to adjust the gain is to install jumper JP7. Pick a reference voltage such that the A/D voltage will not be greater than 5 volts when multiplied by the gain. We will pick a reference voltage of .1 volts which when multiplied by 25 meets our criteria. Measure the voltage at JP7 and adjust R17 for 0.1 Volts. Next measure the output voltages at JP24 pin 25 and adjust R9 for 2.5 Volts.

Table 52: Ibus and IPFC Current Adjust

IAdj	Jumper	Adjust	Measure on JP24
Ibus	JP7	R9	Pin 25
IPFC	JP12	R14	Pin 29

Note: Make sure the jumper is removed after each adjustment

2.18 Bus/PFC/Cap Voltage

The Bus, PFC and Cap center tap voltage are adjusted the same as the phase voltages.

Table 53: Bus, PFC, and Cap Center Tap Voltage Adjust

Vadj	Jumper	Adjust	Measure on JP24
Bus	JP9	R10	Pin 29
PFC	JP8	R13	Pin 31
Cap	JP6	R8	Pin 33

Note: Make sure the jumper is removed after each adjustment.

2.19 Overcurrent Failure

The overcurrent trip logic is made from the bus current resistor R1, resistor R21, and Opto Isolator U1. When the Bus current exceeds the maximum value opto U1 conducts causing a PPINT to the DSK.

Appendix A

DMC1500 Schematics

This appendix contains the schematics for the DMC1500. The schematics were drawn on ORCAD.

REV	DESCRIPTION	DATE	APPROVED

NOTES: UNLESS OTHERWISE SPECIFIED

1. All resistors 5% 125V unless specified
2. Not populated on 1001, DP-17
3. Not populated on -0002, JP1-JP3

DUPT

5A RMS
10A PK

PFC 2.5A 310VDC Out
5A 110VAC In

U6	IBUS	U7	U9
A	SPARE	VBUS	VDEF
B	IPFC	UFC	APVD
C	VCAP	U	V

For Design Rule Check

SPARES

U17A 74HC14

U17B 74HC14

U17C 74HC14

U13C 74HC10B

U11B 74HC00

U11A 74HC00

U6B TLC2274

U8B TLC2274

U15B CEXT

U15A REXT/CEXT

74HC123

U20B PSE501-2

Blank

Sheet2.sch

Sheet3.sch

Sheet4.sch

Sheet5.sch

Sheet6.sch

Sheet7.sch

Sheet8.sch

Sheet9.sch

Sheet10.sch

Sheet11.sch

Sheet12.sch

Sheet13.sch

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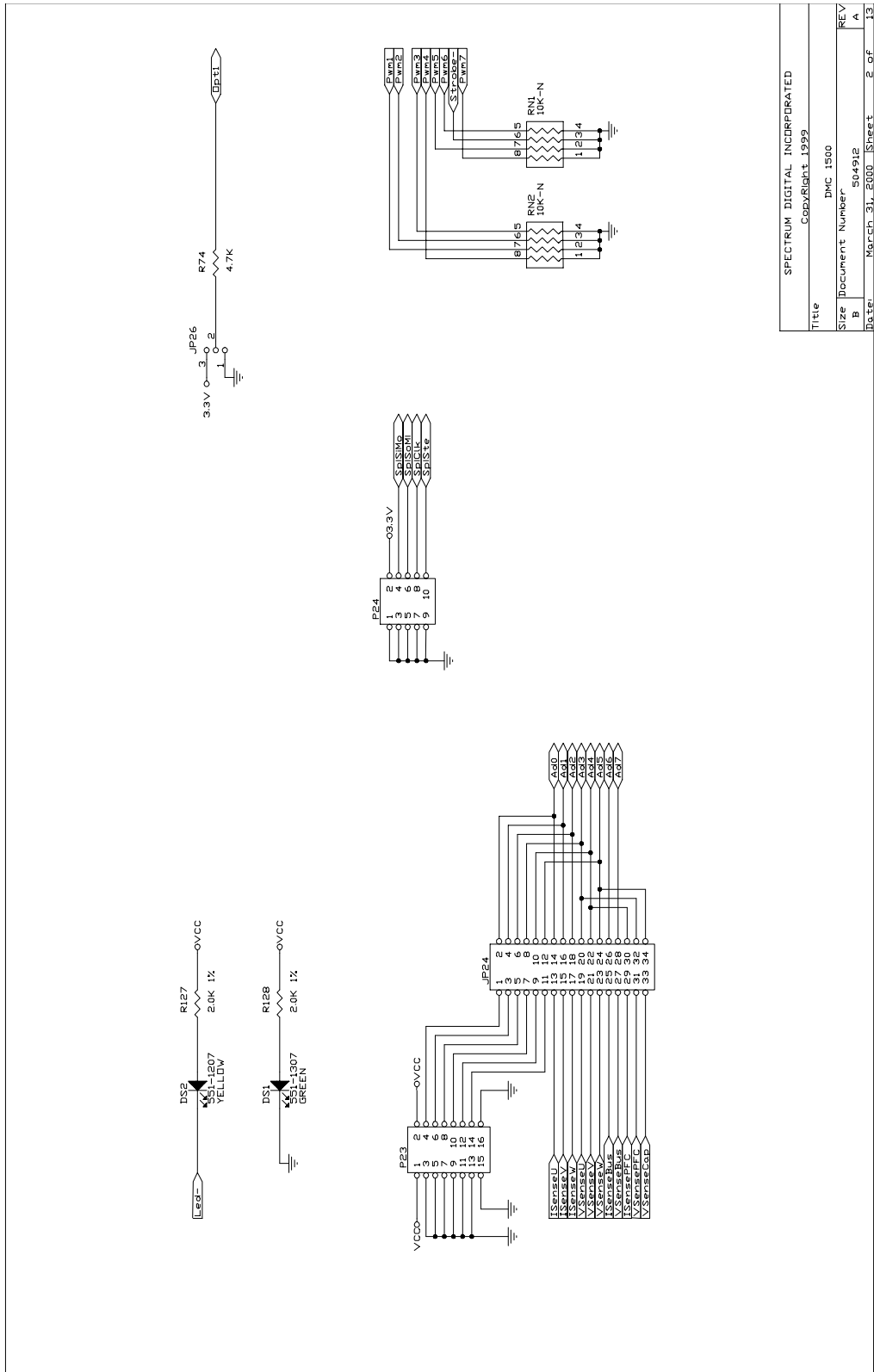
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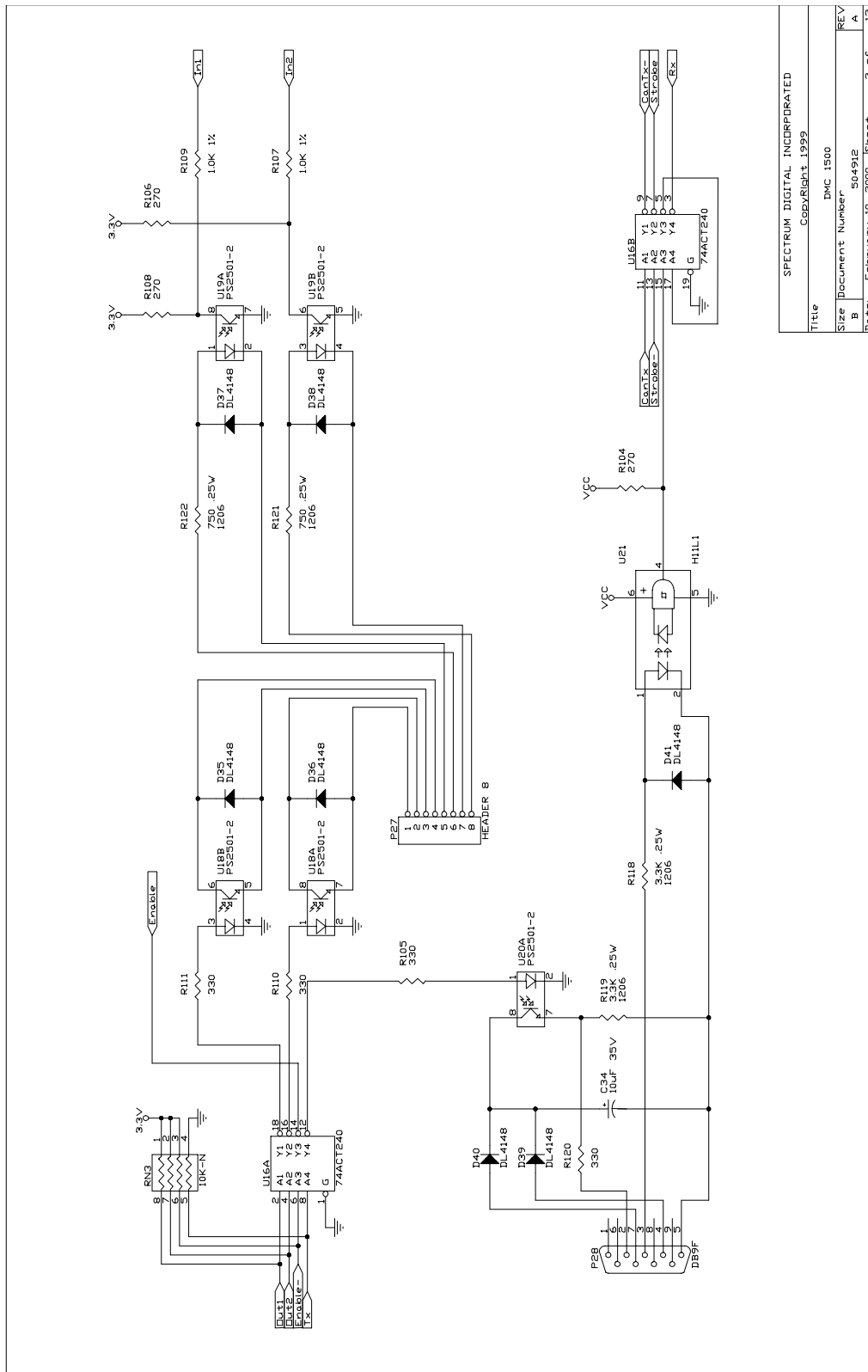
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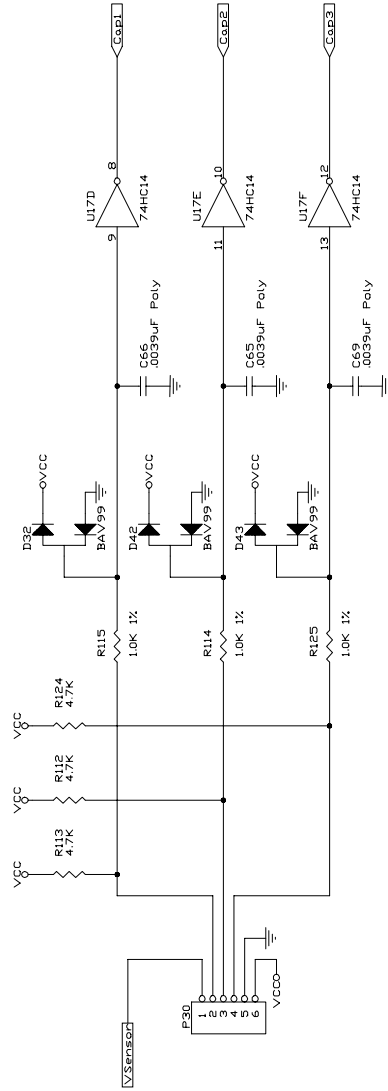
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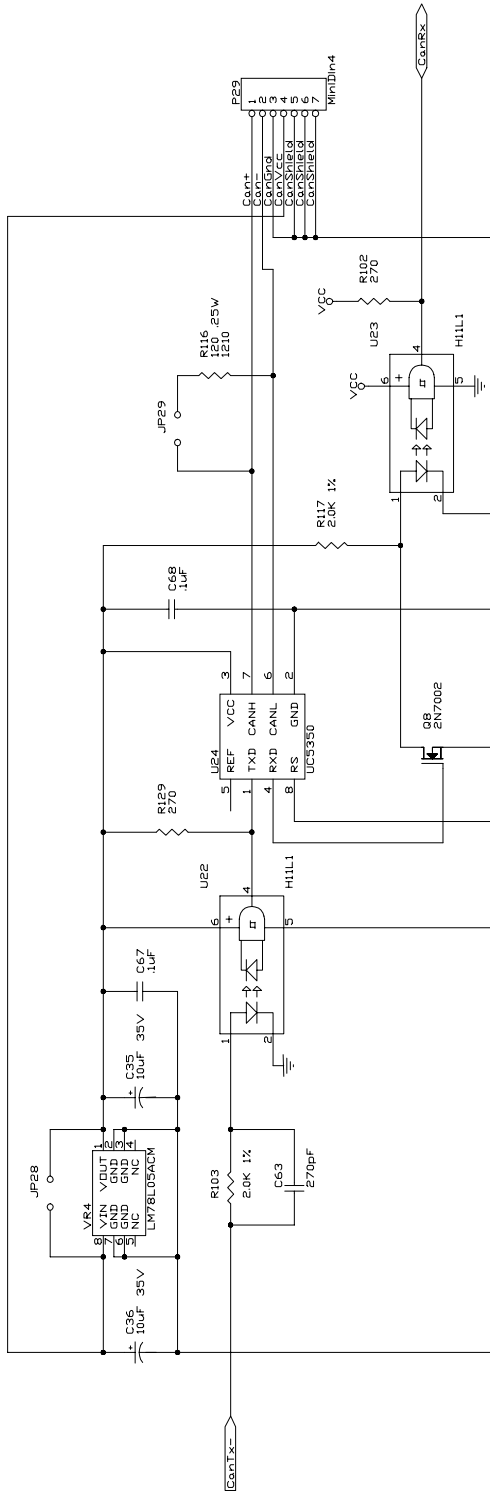
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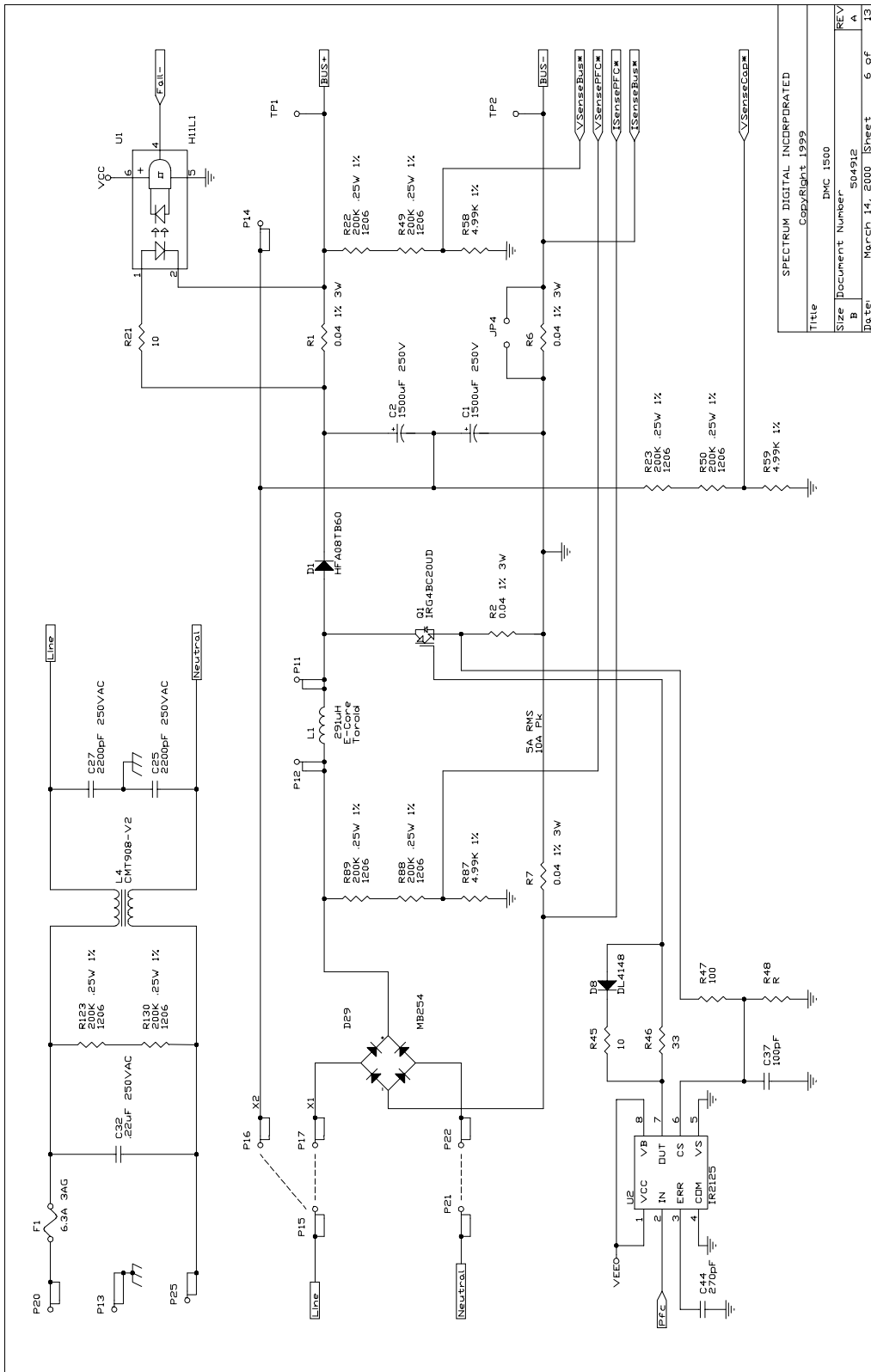
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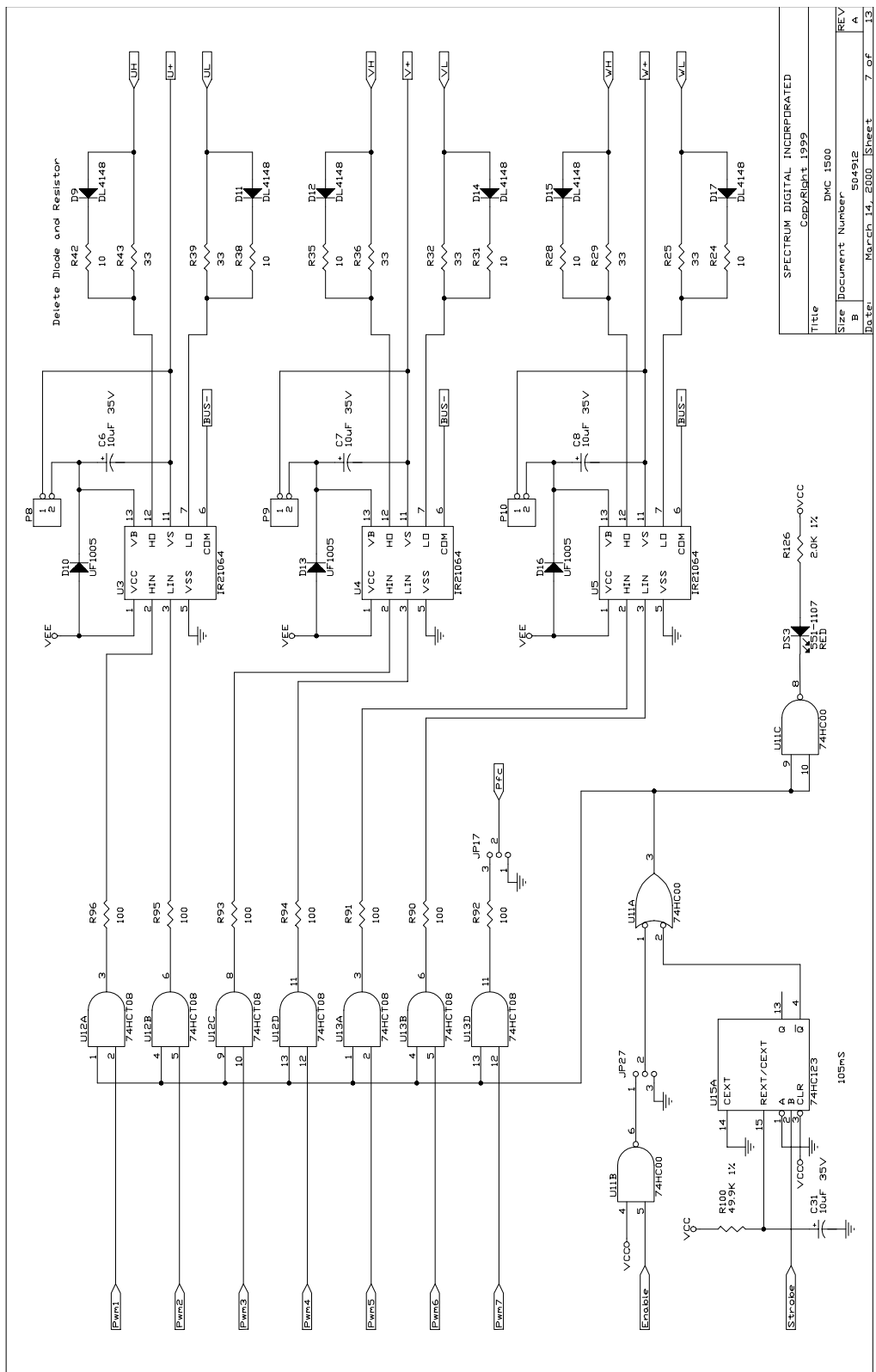
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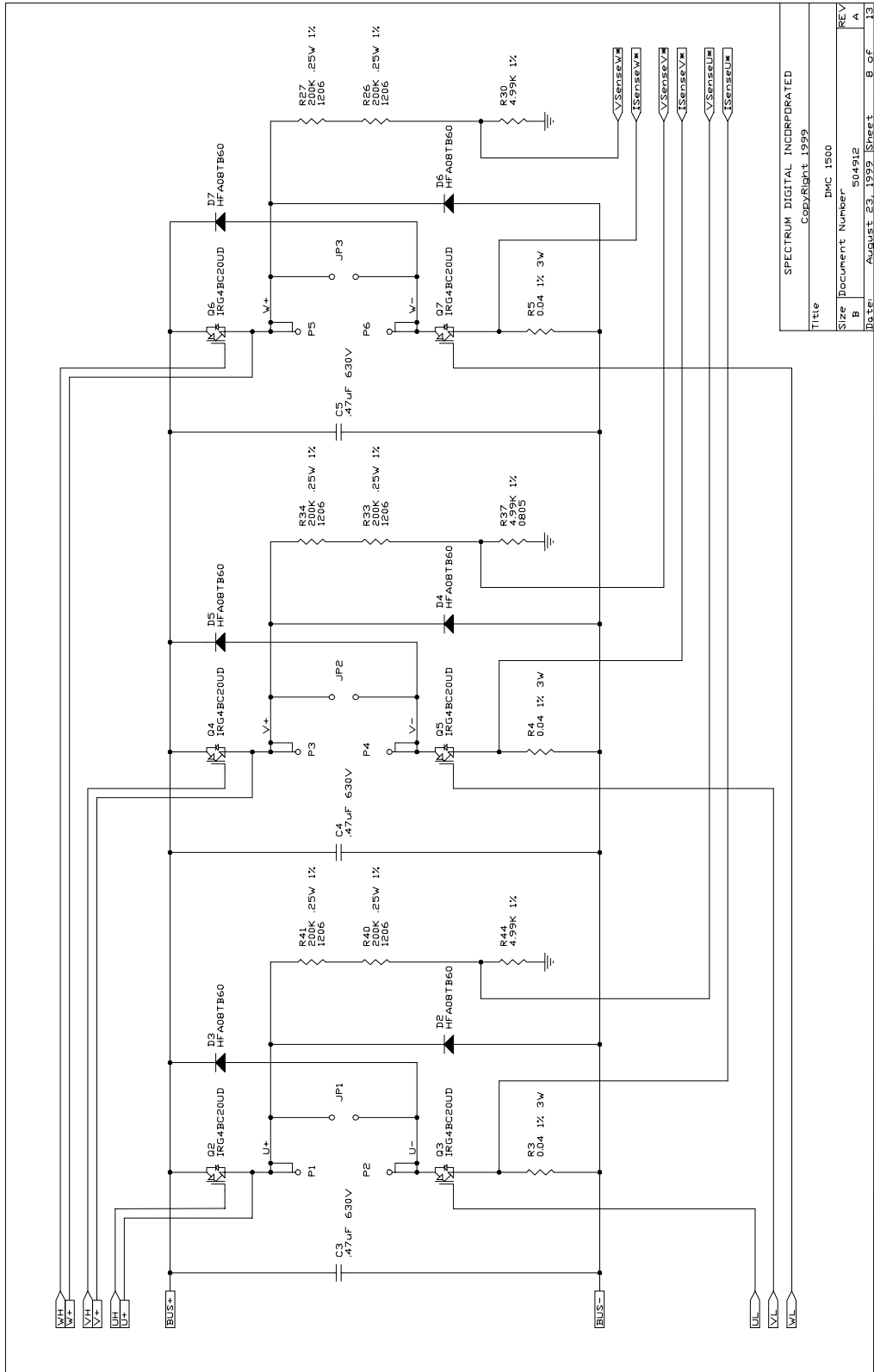


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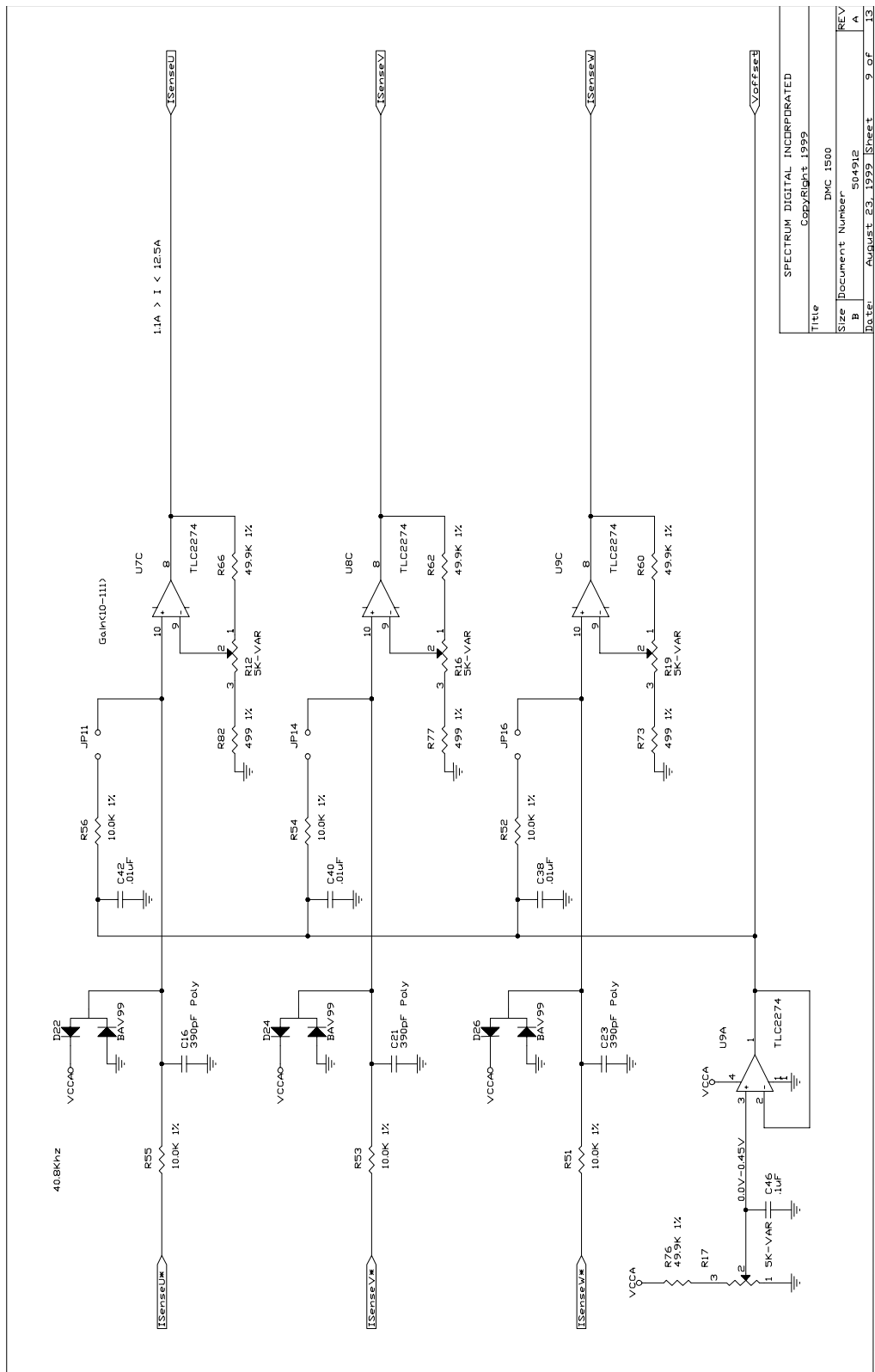


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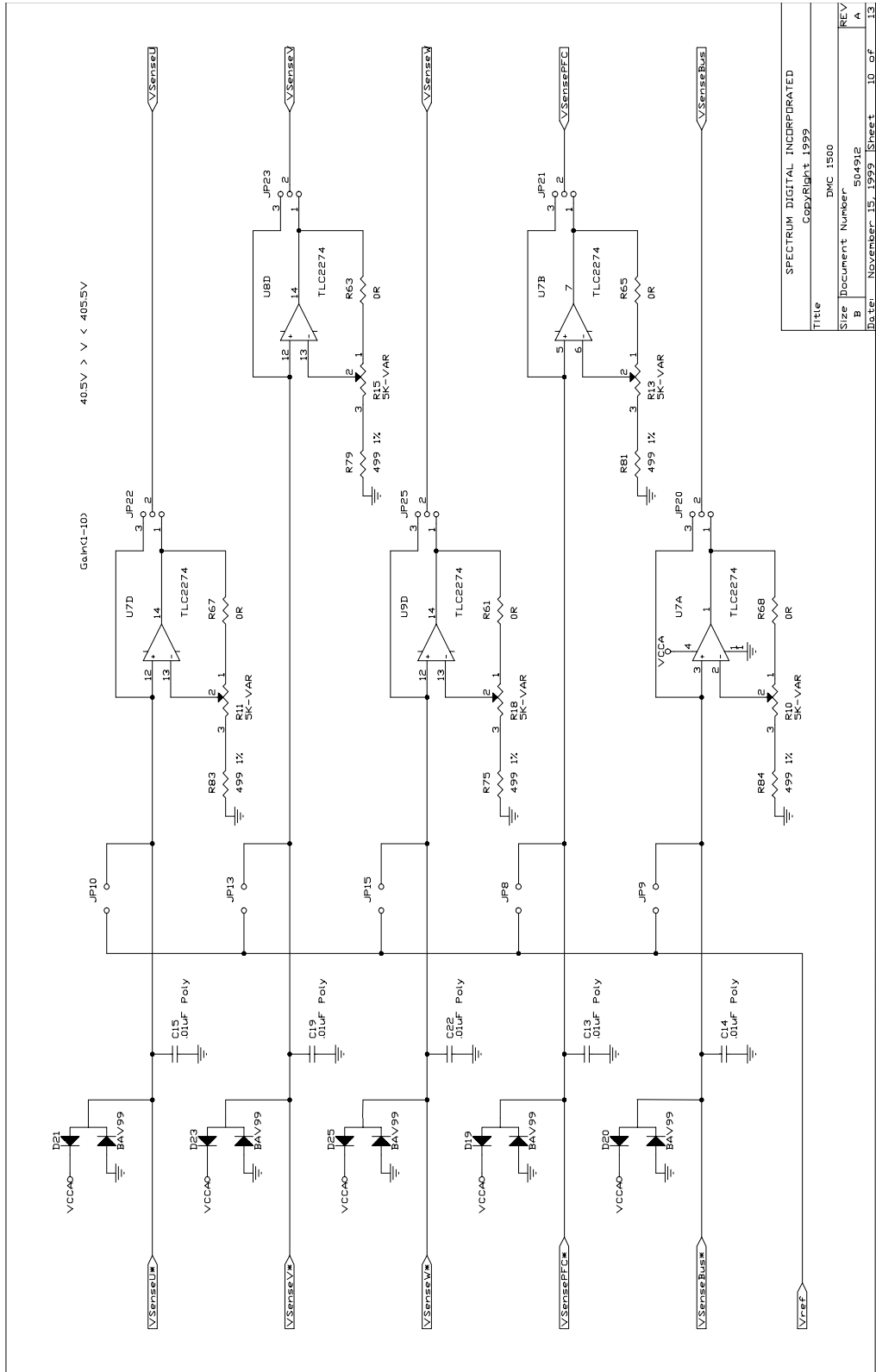




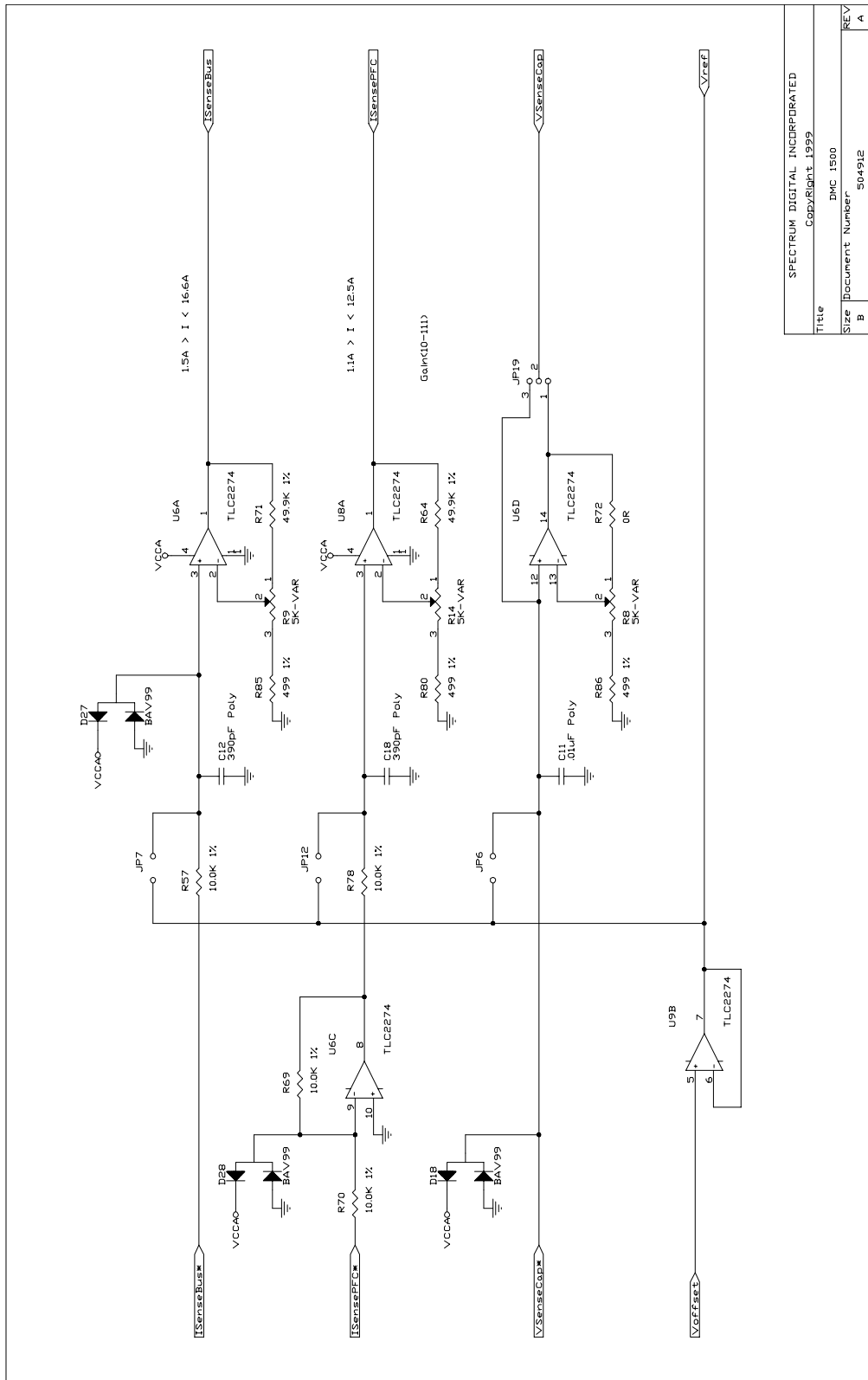
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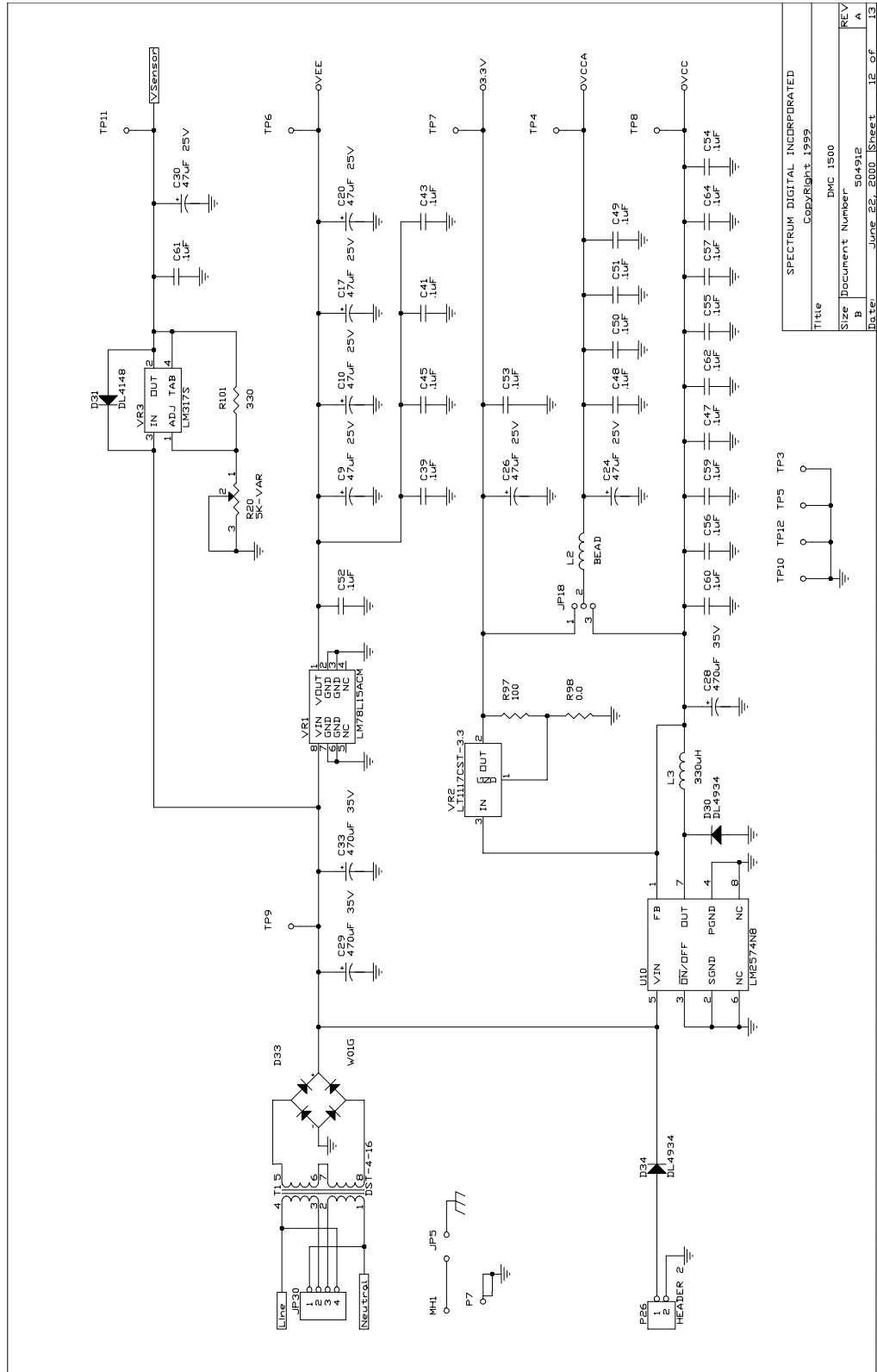
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