DENISON HYDRAULICS
Jupiter Options Card

S20-11716 - Revision E

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DENISON Hydraulics

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1. Closed-Loop Speed Control

The Denison S20-11716 Jupiter Options Card provides the capability of implementing two different electronic control strategies for closed-loop speed control applications. The Jupiter Options Card, together with the appropriate Jupiter Driver Card, can be configured to provide either Feedback or Feed-Forward control. The Feedback control strategy is accomplished by comparing the input speed command with the actual measured speed of the system, producing an error signal that operates the Driver Card. The Feed-Forward control strategy is accomplished by sending the input speed command directly to the Driver Card where it is summed with an error signal to generate a corrected driver signal. The operating characteristics of the control system components will determine which control strategy provides the best overall speed control performance.

The Options Card can accept the output from a wide variety of speed sensor types to provide the measurements of the actual system speed. Set-up instructions are provided in this bulletin for the most common speed sensor types.

1.1. Outputs

SPEED OUT (terminal A20) is a conditioned speed signal that is directly proportional to system speed and can be measured at the RPM test point on the front panel. The ZERO and GAIN potentiometers on the front panel allow the minimum and maximum speed signal to be scaled to ±10 VDC for the maximum system speed.

ERROR OUT (terminal A22) is the difference between the input command signal and the SPEED OUT signal. The ERROR OUT signal represents the amount of correction required and is connected to the Major Loop input of the Driver Card.

4 to 20mA OUT (terminal C14) and the 4 to 20mA RET (terminal C16) is a speed signal that can be sent to a process controller or computer. The 4mA and the 20mA potentiometers on the front panel are used to set the minimum and maximum speeds.

METER OUT (terminal C18) is used to drive a speed meter. The METER potentiometer, on the front panel, is used to scale the meter to read in units of RPM. The METER OUT signal is scaled to operate a 0-199 μA current meter. Denison recommends meter DHC #746-10017.

1.2. Speed Sensor Types

The Options Card will accept the output from a variety of speed sensor types such as **Encoders**, **D.C. Tachometers**, **Conditioned Output Magnetic Proximity Pickups**, **Current,** and **Voltage** signals.

2. Selecting the type of Speed Sensor

2.1. Quadrature Encoder

The Options Card supports dual channel, single channel, differential and single-ended quadrature encoder inputs. If direction sensing is not necessary, a single channel (non-quadrature) encoder may be used to generate either a positive or negative voltage proportional to rotation. For a positive voltage, connect the encoder to channel A and leave the channel B unconnected. For a negative voltage, connect the encoder to channel A and connect channel B to signal ground. The table below lists recommended differential, dual channel, quadrature encoders.

Model	Pulses per Revolution	Maximum Speed
BEI #H20DB-600	600	2,000 RPM
BEI #H35B-2500	2,500	480 RPM
BEI #H35B-10000	10,000	120 RPM

2.2. Conditioned Output Magnetic Proximity Pickup

The conditioned pulse output from a magnetic proximity pickup may be used for measuring speed. Direction sensing is not possible with this type of sensor.

2.3. D.C. Tachometer

The output from a current loop or voltage source D.C. tachometer generator can be used as a speed sensor.

2.4. Current or Voltage Output Speed Sensor

A speed sensor with an output current range of 4 to 20mA or an output voltage range of ±10VDC can also be used.

3. Setup Instructions when using a Quadrature Encoder Speed Sensor

The relationship between encoder pulses per revolution and maximum system shaft speed to the analog output voltage (±10 VDC) is given below.

Calculate encoder output frequency, F_{OUT}.

$$F_{OUT} = \frac{\text{Shaft Revolutions}}{\text{Minute}} \times \frac{\text{1 minute}}{\text{60 seconds}} \times \frac{\text{Encoder counts}}{\text{Revolution}}$$

Select the multiplier, X1/2, X1, X2, X4, from the table on page 9 that will yield the frequency that is closest to, but not greater than, 1KHz or 10KHz. Set the DIP switches for the proper input range according to the table below.

Encoder Input Range		
O = OPEN = OFF C = CLOSED = ON	**SW1**	**SW2**
Switch Position	**1**	**5**
1,000 Hz Full Scale	**C**	**O**
10,000 Hz Full Scale	**O**	**C**

Calculate the multiplied frequency, $F_{MULTIPLY}$

$F_{MULTIPLY} = F_{OUT}$ X Multiplier.

Example 1:

Maximum shaft speed = 85 RPM

Encoder resolution = 600 pulses per revolution.

Calculate encoder output frequency, F_{OUT}, at maximum shaft speed.

$$F_{OUT} = \frac{\text{85 revolutions}}{\text{minute}} \times \frac{\text{1 minute}}{\text{60 seconds}} \times \frac{\text{600 pulses}}{\text{revolution}}$$

F_{OUT} = 850 pulses/second

Select the **X1** multiplier and the **1 kHz** input range.

The X1 multiplier was selected because 850 X 1/2 = 425 Hz and 425 Hz is not as close to 1 kHz as 850 is to 1 kHz. Both 850 X 2 = 1,700 Hz and 850 X 4 = 3,400 Hz are not as close to 10 kHz as 850 Hz is to 1 kHz, percentage wise. Set DIP switch **SW1-1** to the CLOSED position and **SW2-5** to the OPEN position for 1 kHz range.

With a maximum input of 850 Hz, the analog voltage signal representing speed must be set to 10 V because the **COMMAND** signal from the **DRIVER** card is 10 volts at maximum speed. A known frequency must be used to properly set the **SPEED GAIN** potentiometer on the front panel. The 1kHz calibration source will provide a known input frequency, however, observing GRAPH 1 will show that 1kHz will yield a speed signal above 10 V. Multiplying the 1kHz calibration source by 1/2 will produce a calibration frequency of 500 Hz as shown in GRAPH 2.

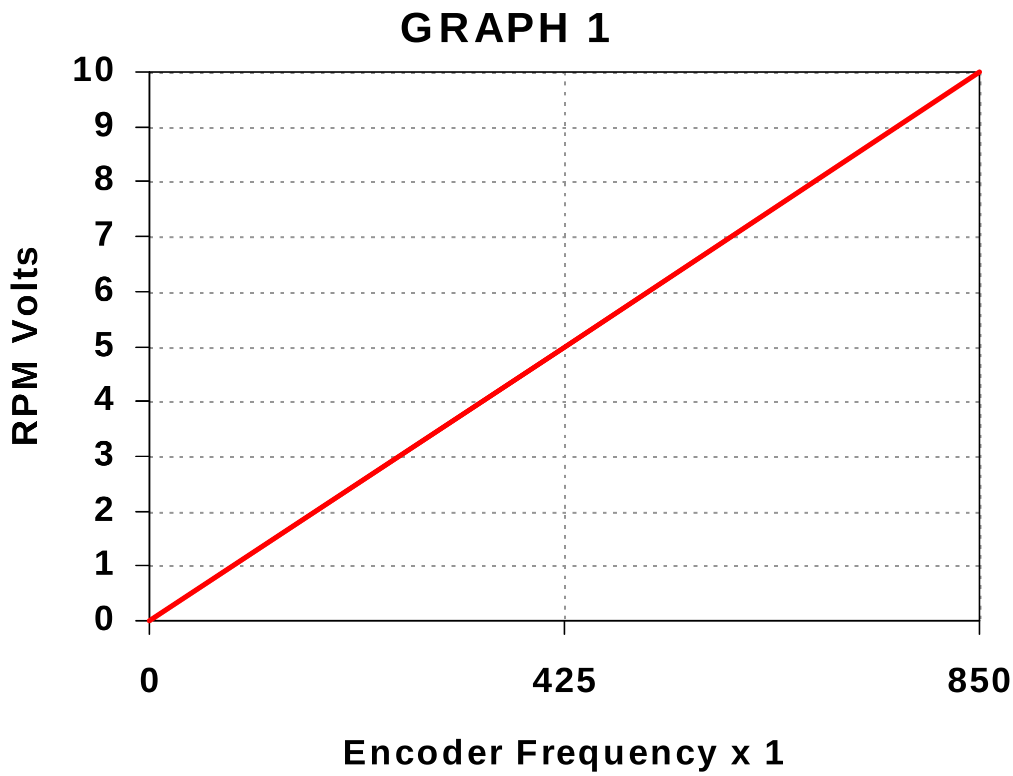
Set DIP switch **SW2-7** CLOSED, **SW2-8** OPEN, **SW2-9** OPEN, and **SW2-10** OPEN for X1/2.

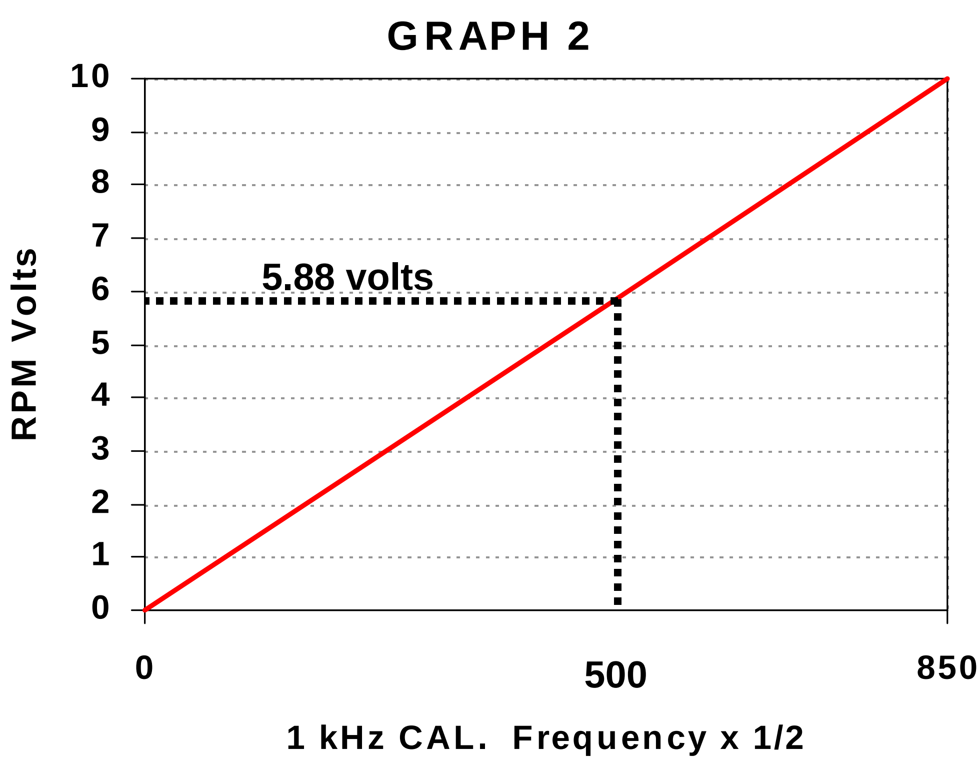
Calculating the calibration voltage $V_{CALIBRATE}$ to be measured at the RPM test point.

$$V_{CALIBRATE} = \frac{10 \text{ volts } X \text{ } 500 \text{ Hz}}{850 \text{ Hz}} = 5.88$$

Adjust the **SPEED GAIN** potentiometer to 5.88 V measured at the speed test point, as shown in GRAPH 2

NOTE: Observe **MAGNITUDE** only and disregard **POLARITY** when in the calibration mode.


GRAPH 1
RPM Volts
10
9
8
7
6
5
4
3
2
1
0
0
425
850
Encoder Frequency x 1


GRAPH 2
RPM Volts
10
9
8
7
6
5
4
3
2
1
0
5.88 volts
0
500
850
1 kHz CAL. Frequency x 1/2

Quadrature Encoder Multiplier Switch Settings				
O = OPEN = OFF C = CLOSED = ON	SW2			
switch number	7	8	9	10
0.5 X Frequency	C	O	O	O
1 X Frequency	O	C	O	O
2 X Frequency (2 channel Quadrature Encoder only)	O	O	C	O
2 X Frequency (1 channel Quadrature Encoder only)	O	O	O	C
4 X Frequency (2 channel Quadrature Encoder only)	O	O	O	C

Quadrature Encoder Input Type	
O = OPEN = OFF C = CLOSED = ON	SW2
Switch number	2
TTL	C
Differential	O

Quadrature Encoder Input Range		
O = OPEN = OFF C = CLOSED = ON	SW1	SW2
switch number	1	5
1,000 Hz Full Scale	C	O
10,000 Hz Full Scale	O	C

Magnetic Proximity Pickup (or Encoder) and D.C. Tachomoter Feedback Type		
O = OPEN = OFF C = CLOSED = ON	SW1	
switch number	3	4
Conditioned Magnetic Proximity Pickup (or Encoder)	C	O
D.C. Tachometer	O	C

3.1. Controller Calibration

The on-board calibrator can be used to set the speed zero and gain. Connect a volt meter to the front panel RPM test point and OPEN SW2 #1 to turn OFF the RUN MODE. Adjust the ZERO potentiometer on the front panel to read 0 V. CLOSE SW2 #4 to apply the 1,000 Hz calibration signal or CLOSE SW2 #3 to apply the 10,000 Hz calibration signal. Adjust the GAIN potentiometer on the front panel to read 10 V.

3.2. Proportional (P) or Proportional plus Integral (PI) Mode Setup:

Figure 12 shows the wiring diagram of the Options Card, Driver Card, and Power Supply for closed-loop speed control in P or PI mode. Potentiometer R58 is embedded on the card and must be adjusted fully CW when in the PI mode. The proportional mode is always active, however, the output amplitude is controlled by the P GAIN potentiometer on the front panel.

The breakpoint feature automatically reduces P GAIN when the error exceeds an adjustable breakpoint threshold, measured on TH3. R67 is embedded on the card and adjusts the breakpoint threshold. To disable the breakpoint feature rotate R67 fully CW.

For the PI mode, OPEN SW3 #4 to turn the integrator ON or apply a voltage of 5 to 15 VDC to pin C4 (integrator reset) to turn the integrator OFF. The I GAIN potentiometer on the front panel adjusts the rate that the integrator will change its output for an error signal.

WARNING

When in PI mode, the integrator reset, pin C4, must be activated (+5 to +15 VDC) prior to starting the hydraulic system.

The integrator zero adjustment potentiometer R4 is factory set and no adjustments are required.

When using the controller in PI mode, the integrator can become saturated. This will cause the error signal to remain at either the minimum or maximum possible level causing unexpected control performance. A safety network (window comparator) monitors the error signal level and will reset the integrator if the amplitude exceeds a preset limit set by potentiometer R22. R22 is embedded on the card and its setting can be monitored at TH2. Apply a voltage of +5 to 15 VDC to C6 to turn the window comparator OFF. Leave C6 unconnected to turn the window comparator ON.

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3.3. Initial settings of the P GAIN and I GAIN potentiometers:

Proper tuning of the PI control is essential for smooth, responsive, stable, non-oscillating control of speed. The ***Reaction Curve Method*** is a technique that can be used to calculate the initial values of P GAIN (K_p) and I GAIN (K_i) by measuring the natural response of the system.

Turn the power off to the hydraulic system and to the Options and Driver Cards. Remove the wire on terminal A22 of the Options Card and remove the jumper from terminal 16 to terminal 9 on the Driver Card power supply. This puts the Driver Card in an open-loop mode. Turn the Ramps OFF on the Driver Card and rotate R67 (breakpoint adjustment) on the Options Card fully CW to eliminate its effect. Turn the power on to the Options Card and the Driver Card. Set the toggle switch on the Driver Card to LOCAL and set the COMMAND potentiometer to "0". Turn the hydraulic system on.

Using a strip chart recorder, measure the COMMAND signal (terminal A18) and the Speed signal (terminal A20) of the Options card.

Adjust the COMMAND pot for a nominal mid-range speed, press the STEP COMMAND button on the Driver Card letting the system go to zero speed. Release the STEP COMMAND button and observe the system response on the strip chart recorder. Note these features about the reactions.

A) The slope S (RPM/minute) of the speed verses time graph from the strip chart recorder.
B) The delay time L (minutes). This is the time between the change in the speed COMMAND signal and the initial change in the actual speed.
C) The final value of the speed K (RPM), after it stops changing.

$$K_p = \frac{1.2}{SLK}$$

$$K_i = \frac{0.5K_p}{L}$$

Measure the values of S, L, and K using the strip chart recorder and adjust the front panel P GAIN (K_p) and I GAIN (K_i) to the values calculated using the above equations. Several tuning iterations will probably be required to obtain acceptable system response characteristics.

3.4. Input Command Feed-Forward Setup:

Figure 11 shows the wiring diagram of the Options Card, Driver Card, and the Power Supply in a closed-loop speed control system operating in the Input Command Feed-Forward control mode.

Command Feed-Forward is a control strategy that feeds the command signal of the Driver Card directly to the output driver using the Driver Card ZERO and GAIN potentiometers to set the desired speeds while the PI section of the Options Card compensates for any error or non-linearity in the system. The compensator level potentiometer R58 embedded on the error board is used to adjust the amount of compensator influence in a command feed-forward configuration and is used to adjust the amount of error correction that the PI section will contribute.

Follow the Driver Card setup instructions for open-loop control, setting the ZERO and GAIN potentiometers as required. Then adjust potentiometer R58 to correct for the maximum load or error that the system will experience.

3.5. 4 to 20mA Speed Output

Connect a volt meter to the 20 mA front panel test point.

Step 1: Set the speed to zero to obtain an RPM test point reading of 0.0 volts. Adjust the 4 mA potentiometer until 0.4 volts are read on the meter.

Step 2: Set the speed to obtain an RPM test point reading of 10 volts. Adjust the 20 mA potentiometer for 2.0 volts.

Step 3: Repeat steps 1 and 2 until 0.4 volts and 2.0 volts are measured at RPM test point settings of 0.0 volts and 10 volts respectively.

3.6. Speed Meter Output

Use a DC current meter whose range is not greater than ±10 mA and not less than ±10 μA. Set the speed to obtain an RPM test point reading of 10 volts. Adjust the METER potentiometer on the front panel to read the desired speed units.

4. Setup Instructions when using Conditioned Output Magnetic Proximity Speed Pickup

AIRPAX #70087-3040-047 is the recommended magnetic pickup. The wiring diagram, Figure 14, shows the magnetic pickup as a **TTL** open collector device. CLOSE **SW2-2** for TTL input type.

The relationship between the output frequency (Hz) of the magnetic proximity pickup and the number of pulses per revolution is as follows.

$$\text{Magnetic Pickup Frequency} = \frac{\text{(number of pulses per revolution X maximum RPM)}}{60}$$

Select the multiplier, X1/2, X1, X2 from the table below that will yield the frequency that is the closest percentage, but not greater than 1kHz or 10 kHz. Set the DIP switches for the proper input range according to the table below.

Conditioned Magnetic Proximity Pickup Multiplier Switch Settings				
O = OPEN = OFF **C = CLOSED = ON**	SW2			
Switch number	7	8	9	10
0.5 X Frequency	C	O	O	O
1 X Frequency	O	C	O	O
2 X Frequency	O	O	O	C

Conditioned Magnetic Proximity Pickup Input Type	
O = OPEN = OFF **C = CLOSED = ON**	SW2
switch number	2
TTL	C
Differential	O

Conditioned Magnetic Proximity Pickup Input Range		
O = OPEN = OFF **C = CLOSED = ON**	SW1	SW2
switch number	1	5
1,000 Hz Full Scale	C	O
10,000 Hz Full Scale	O	C

CALIBRATE / RUN MODE			
O = OPEN = OFF **C = CLOSED = ON**	SW2		
Switch number	1	3	4
Run	C	O	O
1,000 Hz Calibration	O	O	C
10,000 Hz Calibration	O	C	O
Observe **MAGNITUDE** only disregard **POLARITY**			

4.1. Controller Calibration

The on-board calibrator can be used to set the zero and gain. Connect a volt meter to the front panel RPM test point and OPEN SW2 #1 to turn the RUN MODE OFF. Adjust the ZERO potentiometer on the front panel to read 0 V. CLOSE SW2 #3 for 1,000 Hz calibration or CLOSE SW2 #4 for 10,000 Hz calibration. Adjust the GAIN potentiometer on the front panel to read 10 V.

4.2. Proportional (P) or Proportional Integral (PI) Mode Setup:

Figure 11 shows the wiring diagram of the Options Card, Driver Card, and the Power Supply for closed-loop speed control in P or PI mode. Potentiometer R58 is embedded on the card and must be adjusted fully CW when in the PI mode.

The proportional mode is always active, however, the output amplitude is controlled by the P GAIN potentiometer on the front panel.

The breakpoint feature automatically reduces P GAIN when the error exceeds an adjustable breakpoint threshold, measured at TH3. R67 is embedded on the card and adjusts the breakpoint threshold. To disable the breakpoint feature rotate R67 fully CW.

For PI mode, OPEN SW3 #4 to turn the integrator ON or apply a voltage of 5 to 15 VDC to pin C4 (integrator reset) to turn the integrator OFF. The I GAIN potentiometer on the front panel adjusts the rate that the integrator will change its output for an error signal.

WARNING

When in PI mode, the integrator reset, pin C4, must be activated (+5 to +15 VDC) prior to starting the hydraulic system.

The integrator zero adjustment potentiometer R4 is factory set and no adjustments are required.

When using the controller in PI mode, the integrator can become saturated. This will cause the error signal to remain at either the minimum or maximum possible level causing unexpected control performance. A safety network (window comparator) monitors the error signal level and will reset the integrator if the amplitude exceeds the preset limit set by potentiometer R22. R22 is embedded on the card and its setting can be monitored at TH2. Apply a voltage of +5 to 15 VDC to C6 to turn the window comparator OFF. Leave C6 unconnected to turn the window comparator ON.

4.3. Initial settings of the P GAIN and I GAIN potentiometers:

Proper tuning of the PI control is essential for smooth, responsive, stable, non-oscillating control of speed. The ***Reaction Curve Method*** is a technique that can be used to calculate the initial values of P GAIN (K_p) and I GAIN (K_i) by measuring the natural response of the system.

Turn the power off to the hydraulic system and to the Options and Driver Cards. Remove the wire on terminal A22 of the Options Card and remove the jumper from terminal 16 to terminal 9 on the Driver Card power supply. This puts the Driver Card in an open-loop mode. Turn the Ramps OFF on the Driver Card and rotate R67 (breakpoint adjustment) on the Options Card fully CW to eliminate its effect. Turn the power on to the Options Card and the Driver Card. Set the toggle switch on the Driver Card to LOCAL and set the COMMAND potentiometer to "0". Turn the hydraulic system on.

Using a strip chart recorder, measure the COMMAND signal (terminal A18) and the Speed signal (terminal A20) of the Options card.

Adjust the COMMAND pot for a nominal mid-range speed, press the STEP COMMAND button on the Driver Card letting the system go to zero speed. Release the STEP COMMAND button and observe the system response on the strip chart recorder. Note these features about the reactions.

A) The slope S (RPM/minute) of the speed verses time graph from the strip chart recorder.
B) The delay time L (minutes). This is the time between the change in the speed COMMAND signal and the initial change in the actual speed.
C) The final value of the speed K (RPM), after it stops changing.

$$K_p = \frac{1.2}{SLK}$$

$$K_i = \frac{0.5K_p}{L}$$

Measure the values of S, L, and K using the strip chart recorder and adjust the front panel P GAIN (K_p) and I GAIN (K_i) to the values calculated using the above equations. Several tuning iterations will probably be required to obtain acceptable system response characteristics.

4.4. Input Command Feed-Forward Setup:

Figure 10 shows the wiring diagram of the Options Card, Driver card, and the Power Supply in a closed-loop speed control system operating in the Input Command Feed-Forward control mode.

Command Feed-Forward is a control strategy that feeds the command signal of the Driver Card directly to the output driver using the Driver Card ZERO and GAIN potentiometers to set the desired speeds while the PI section of the Options Card compensates for any error or non-linearity in the system. The compensator level potentiometer, R58 embedded on the error board is used to adjust the amount of compensator influence in a command feed-forward configuration and is used to adjust the amount of error correction the PI section will contribute.

Follow the Driver Card setup instructions for open-loop control, setting the ZERO and GAIN potentiometers as required. Then adjust potentiometer R58 to correct for the maximum load or error that the system will experience.

4.5. 4 to 20mA Speed Output

Connect a volt meter to the 20 mA front panel test point.

Step 1: Set the speed to zero to obtain an RPM test point reading of 0.0 volts. Adjust the 4 mA potentiometer until 0.4 volts are read on the meter.

Step 2: Set the speed to obtain an RPM test point reading of 10 volts. Adjust the 20 mA potentiometer for 2.0 volts.

Step 3: Repeat steps 1 and 2 until 0.4 volts and 2.0 volts are measured at RPM test point settings of 0.0 volts and 10 volts respectively.

4.6. Speed Meter Output

Use a DC current meter whose range is not greater than ±10 mA and not less than ±10 μA. Set the speed to obtain an RPM test point reading of 10 volts. Adjust the METER potentiometer on the front panel to read the desired speed units.

5. Set-up Instructions when using a D.C. Tachometer Speed Sensor

A D.C. tachometer produces a DC voltage proportional to shaft speed. Below is a list of recommended D.C. tachometers.

Model	Output	Max Speed @ 10 V Output
HDC #780-70003	7V/1000 RPM	1400 RPM
HDC #780-70001	12V/1000 RPM	800 RPM
HDC #780-70002	45V/1000 RPM	200 RPM

The following example shows how to calculate the RPM CAL using the +15V power supply as a calibration source. Assume a system maximum speed of 1500 RPM using DC tachometer HDC #780-70001. A speed of 1500 RPM will produce a 10V signal at the RPM test point on the front panel.

$$\text{RPM CAL VOLTAGE} = \frac{10V}{1500\ RPM} \times \frac{1000\ RPM}{12V} \times 15V = 8.33V$$

Adjust the GAIN potentiometer to obtain 8.33 VDC at the RPM test point.

NOTE: Disconnect both wires of the DC tachometer before connecting a calibration voltage to the Options Card and connect both the (+) and (-) wires of the calibration voltage to the card.

Magnetic Proximity Pickup (or Encoder) and DC Tachometer Speed Sensor Type		
O = OPEN = OFF **C = CLOSED = ON**	SW1	
Switch number	3	4
Conditioned Output Magnetic Proximity Pickup (or Encoder)	C	O
DC Tachometer	O	C

D.C. Tachometer Speed Sensor Type	
O = OPEN = OFF **C = CLOSED = ON**	SW2
Switch number	6
Voltage Output Tachometer	O
Current Loop Tachometer	C

5.1. Controller Calibration

Connect a volt meter to the RPM front panel test point and adjust the ZERO potentiometer to read 0V. Follow the procedure described in paragraph 5 above to calculate and adjust the calibration voltage for the D.C. tachometer speed sensor.

5.2. Proportional (P) or Proportional Integral (PI) Mode Setup:

Figure 11 shows the wiring diagram of the Options Card, Driver Card, and the Power Supply for closed-loop speed control in P or PI mode. Potentiometer R58 is embedded on the card and must be adjusted fully CW when in the PI mode.

The proportional mode is always active, however, the output amplitude is controlled by the P GAIN potentiometer on the front panel.

The breakpoint feature automatically reduces P GAIN when the error exceeds an adjustable breakpoint threshold, measured at TH3. R67 is embedded on the card and adjusts the breakpoint threshold. To disable the breakpoint feature rotate R67 fully CW.

For PI mode, OPEN SW3 #4 to turn the integrator ON or apply a voltage of 5 to 15 VDC to pin C4 (integrator reset) to turn the integrator OFF. The I GAIN potentiometer on the front panel adjusts the rate that the integrator will change its output for an error signal.

WARNING

When in PI mode, the integrator reset, pin C4, must be activated (+5 to +15 VDC) prior to starting the hydraulic system.

The integrator zero adjustment potentiometer R4 is factory set and no adjustments are required.

When using the controller in PI mode, the integrator can become saturated. This will cause the error signal to remain at either the minimum or maximum possible level causing unexpected control performance. A safety network (window comparator) monitors the error signal level and will reset the integrator if the amplitude exceeds the preset limit set by potentiometer R22. R22 is embedded on the card and its setting can be monitored at TH2. Apply a voltage of +5 to 15 VDC to C6 to turn the window comparator OFF. Leave C6 unconnected to turn the window comparator ON.

5.3. Initial settings of the P GAIN and I GAIN potentiometers:

Proper tuning of the PI control is essential for smooth, responsive, stable, non-oscillating control of speed. The ***Reaction Curve Method*** is a technique that can be used to calculate the initial values of P GAIN (K_p) and I GAIN (K_i) by measuring the natural response of the system.

Turn the power off to the hydraulic system and to the Options and Driver Cards. Remove the wire on terminal A22 of the Options Card and remove the jumper from terminal 16 to terminal 9 on the Driver Card power supply. This puts the Driver Card in an open-loop mode. Turn the Ramps OFF on the Driver Card and rotate R67 (breakpoint adjustment) on the Options Card fully CW to eliminate its effect. Turn the power on to the Options Card and the Driver Card. Set the toggle switch on the Driver Card to LOCAL and set the COMMAND potentiometer to "0". Turn the hydraulic system on.

Using a strip chart recorder, measure the COMMAND signal (terminal A18) and the Speed signal (terminal A20) of the Options card.

Adjust the COMMAND pot for a nominal mid-range speed, press the STEP COMMAND button on the Driver Card letting the system go to zero speed. Release the STEP COMMAND button and observe the system response on the strip chart recorder. Note these features about the reactions.

A) The slope S (RPM/minute) of the speed verses time graph from the strip chart recorder.
B) The delay time L (minutes). This is the time between the change in the speed COMMAND signal and the initial change in the actual speed.
C) The final value of the speed K (RPM), after it stops changing.

$$K_p = \frac{1.2}{SLK}$$

$$K_i = \frac{0.5K_p}{L}$$

Measure the values of S, L, and K using the strip chart recorder and adjust the front panel P GAIN (K_p) and I GAIN (K_i) to the values calculated using the above equations. Several tuning iterations will probably be required to obtain acceptable system response characteristics.

5.4. Input Command Feed-Forward Setup:

Figure 10 shows the wiring diagram of the Options Card, Driver card, and the Power Supply in a closed-loop speed control system operating in the Input Command Feed-Forward control mode.

Command Feed-Forward is a control strategy that feeds the command signal of the Driver Card directly to the output driver using the Driver Card ZERO and GAIN potentiometers to set the desired speeds while the PI section of the Options Card compensates for any error or non-linearity in the system. The compensator level potentiometer, R58 embedded on the error board is used to adjust the amount of compensator influence in a command feed-forward configuration and is used to adjust the amount of error correction the PI section will contribute.

Follow the Driver Card setup instructions for open-loop control, setting the ZERO and GAIN potentiometers as required. Then adjust potentiometer R58 to correct for the maximum load or error that the system will experience.

5.5. 4 to 20mA Speed Output

Connect a volt meter to the 20 mA front panel test point.

Step 1: Set the speed to zero to obtain an RPM test point reading of 0.0 volts. Adjust the 4 mA potentiometer until 0.4 volts are read on the meter.

Step 2: Set the speed to obtain an RPM test point reading of 10 volts. Adjust the 20 mA potentiometer for 2.0 volts.

Step 3: Repeat steps 1 and 2 until 0.4 volts and 2.0 volts are measured at RPM test point settings of 0.0 volts and 10 volts respectively.

5.6. Speed Meter Output

Use a DC current meter whose range is not greater than ±10 mA and not less than ±10 µA. Set the speed to obtain an RPM test point reading of 10 volts. Adjust the METER potentiometer on the front panel to read the desired speed units.

6. Electric Motor Power Limiting

Electric motor power and electric motor current are directly related. Therefore, it is possible to limit the maximum power consumed by the electric motor by limiting its maximum current. The electric motor current can be measured with a current transformer. Current transformers are rated by the ratio of input current to output current. For example, if a current transformer with a ratio of 125:1 has an input current of 125 A, it will produce an output current of 1 A. The output of the current transformer is supplied to the HP IN (terminal C30) and HP RET (terminal C28) of the Options Card through a 1 Ω resistor which produces a voltage proportional to the electric motor power. The power limiter compares the HP IN signal, measured across a 1 Ω resistor, to the adjustable limit. When the measured HP IN signal exceeds the adjustable limit, the HP LIMITING COMMAND signal (terminal A28) will be reduced, causing the Driver Card to decrease the displacement of the pump. The wiring diagrams of Figures 8, 9, and 10 show how to configure the power limiting feature in the different speed control system configurations.

6.1. Outputs

6.1.1. HP LIMITING COMMAND (terminal A28)

The HP LIMITING COMMAND signal (terminal A28) is the ±10 VDC command signal which is fed back to the driver card for controlling the displacement of the pump.

6.1.2. HP LIMIT ACTIVE (terminal C8)

The HP LIMIT ACTIVE signal (terminal C8) is a transistor open collector output that permits the user to monitor the status of the power limiter. The output (terminal C8) is switched to ground when the HP LIMIT is active. The switching of this output tracks the HP LIMIT LED on the front panel of the Options Card.

6.2. Indicators

6.2.1. Front panel LED

The HP LIMIT indicator is a front panel LED that indicates that the power limiter is active.

6.3. Inputs

6.3.1. Motor current sensing input from the current transformer secondary (terminal C30 and C28)

Input Current Range 0-1 A RMS
Input Impedance 1 Ω

6.4. Power Limit Specifications

Input Current 0 – 1.0 A RMS
Input Impedance 1 Ω
Power Gain Variable
Voltage Output 0 to ±10 VDC

AC Electric Motor Line Current	Current Sensor Ratio	Power Limit Input	HP Test Point
12.5 A to 125 A	125:1	0.1 A to 1.0 A	-0.06 VDC to –1.4 VDC
25.0 A to 250 A	250:1	0.1 A to 1.0 A	-0.06 VDC to –1.4 VDC

Below is a list of recommended current transformers.

Model	Input Current (RMS)	Output Current (RMS)
HDC #D57-00192	12.5 A to 125 A	1.0 A
HDC #D57-00210	25.0 A to 250 A	1.0 A

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6.5. Setting HP Limit

The HP test point on the front panel is used to measure power limit. In order to calculate the power limit, determine the motor's maximum power and full load current and select a current transformer from the above table. An example showing how to calculate the electric motor power limit is shown below.

EXAMPLE: AC MOTOR

Consider an AC motor whose nameplate indicates 150 HP, 440 Volts AC, and 180 A full load current. From the table above select current transformer model HDC #D57-00210, with a 1 A output for an input of 250 A. Calculate the power limit as follows.

$$\text{Power Limit (HP LIMIT)} = \frac{\text{Motor full load current}}{\text{Maximum input of current transformer}}$$

$$\text{Power Limit (HP LIMIT)} = \frac{180}{250} = 0.72\ \text{V}$$

Adjust the Power Limit (HP LIMIT) to -0.72 V

6.6. Setting Power Limit Gain

Set the Power Limit gain to its minimum value by rotating the HP GAIN potentiometer fully CCW. Load the hydraulic system so that the motor power is slightly above the desired maximum power limit. Increase the HP GAIN adjustment until the system is unstable, then decrease the gain until system is stable again. Next, observe the AC voltage at terminal C30, reading the voltage of 0-1 V as a current of 0-1 A. Adjust the HP LIMIT potentiometer until the value at terminal C30 is below motor full load current. Remember the ratio of the current transformer, e.g. 250:1.

7. Appendix

A. Revisions

The Jupiter Options Card has been modified to better facilitate the Power Limiting function. The modified design is REV D. The Jupiter Driver card has also been modified to REV F. Figures 3 thru 7 are the wiring diagrams for the Options Card REV D and REV B Drivers. Figures 8 thru 12 are the wiring diagrams for the Options Card REV D and REV F Drivers.

Consult Denison for configurations not shown.

B. Specifications

Digital Encoder Speed Sensor

Dual channel differential inputs

Square-wave quadrature input *****	±27° ******
Frequency range	100 Hz to 20 kHz
Differential input (logical 1)	+15 VDC to +2.5 VDC
Differential input (logical 0)	-15 VDC to +0.5 VDC

The maximum wire length for differential input using shielded 22 gauge twisted pair wire per channel is 300 meters or 1000 feet. For longer wire lengths, consult Denison.

Maximum differential input	±25 VDC
Maximum common mode voltage	±25 VDC
Input impedance	5 kΩ

***** Positive analog output of encoder speed (fwd led on) requires that channel A leads channel B. Negative output (rev led on) is produced when B leads A. The magnitude of the analog output increases with increasing pulse frequency.

****** The tolerance in the square-wave quadrature input can be as great as ±36° for X1/2, X1, and X2 frequency multipliers, but must not exceed ±27° for the X4 multiplier.

Dual channel TTL inputs:

Same as dual channel differential input except:

TTL input voltage (logical 1)	2.4 VDC to 5.0 VDC
TTL input voltage (logical 0)	0 VDC to +0.7 VDC
Input impedance	10 kΩ pull-up
Absolute maximum input voltage	50 VDC
Over-voltage input protection	zener diode clamps

Single channel differential input

Same as dual channel differential input except use channel A only. Positive analog output of encoder speed (fwd led on) using channel A requires that the channel B input be connected to signal ground. Negative analog output (rev led on) can be obtained by leaving the channel B input open. The magnitude of the analog output increases with increasing pulse frequency.

5 VDC encoder power supply

Switching regulated dc output	5 VDC
Maximum current output	300 mA
Short-circuit fuse protected	500 mA
Ripple	40 mV
Load regulation	5 mV
Input	15 VDC
Efficiency	75%
Switching frequency, full load	60 kHZ

DC tachometer speed sensor

Differential input voltage	7 to 45 V/1000 RPM
Differential input impedance	660 kΩ
Absolute maximum input voltage	300 V

Active magnetic proximity switch feedback

Frequency range	100 Hz to 20 kHz

Differential input

Differential input (logical 1)	+15 - +2.5 VDC
Differential input (logical 0)	-15 - +0.5 VDC
Maximum differential input	±25 VDC
Maximum common mode voltage	±25 VDC
Input impedance	5 kΩ

TTL input:

TTL Input voltage (logical 1)	2.4 - 5.0 VDC
TTL Input voltage (logical 0)	0 - +0.7 VDC
Input impedance	10 kΩ PULL-UP
Absolute maximum input voltage	50 VDC
Over-voltage input protection	zener diode clamps

Auxiliary Speed Signal:

Input voltage	±10 VDC
Input impedance	100 kΩ
Absolute maximum voltage input	150 V

Speed Meter Output:

Meter Output	±10 mA to ±10 μA

4-20mA current loop output *

Current output	4 to 20 mA
Maximum compliance voltage	7.5 VDC
Maximum load impedance	300 Ω
Voltage input range (RPM test point)	0 to 10 VDC
4mA zero adjustment	0 to 15 mA
Absolute maximum output current	28 mA

*** All current loop output adjustments must be preceded by analog voltage output adjustments.**

Proportional error control with command feed-forward control:

Correction of driver output is made proportional to the magnitude of the feedback error with the command input fed forward to the driver output stage.

Proportional gain K_P	0 to 10
Error amplifier gain	1

Proportional and Integral Error Control (PI Control)

Correction of driver output may be made proportional to the magnitude of the feedback error or proportional to the integral of the feedback error or proportional to both in the closed-loop control system. Adjust K_p and K_i for proper mix of PI control.

Error amplifier gain	1

A. Proportional error control

Proportional gain adjustment K_p	0 to 10

B. Integral error control

Integrator gain adjustment K_I	0 to 1 **
Integrator time constant (RC)	70 to 400 ms
Adjustable limits of error	0 TO ±10 VDC *
Remote integrator reset input	
Integrator reset (OFF)	5 to 15 VDC
Integrator ON	open or ground
Window Comparator disable input	
Comparator disabled	5 to 15 VDC
Comparator enabled	open or ground
Integrator on output (2N3904 open-collector)	
Integrator OFF (maximum)	40 VDC
Integrator ON (15mA sink)	0.7 VDC

***** A Window Comparator is used to control the limits of the input error signal to within ±10 VDC. This limit is adjustable thru potentiometer R22 on the card. When the input error exceeds the limit, the integrator is reset, the integrating LED is turned off, and the "integrator on" output goes to a logic high.

****** Integrating action and Window Comparator may be disabled via DIP switch SW3-4.

Power Limiting

Input current	0-1 A (RMS)
Input impedance	1 Ω
Power Gain (HP GAIN)	variable
Command limiting	±10 TO 0 VDC

C. List of Figures

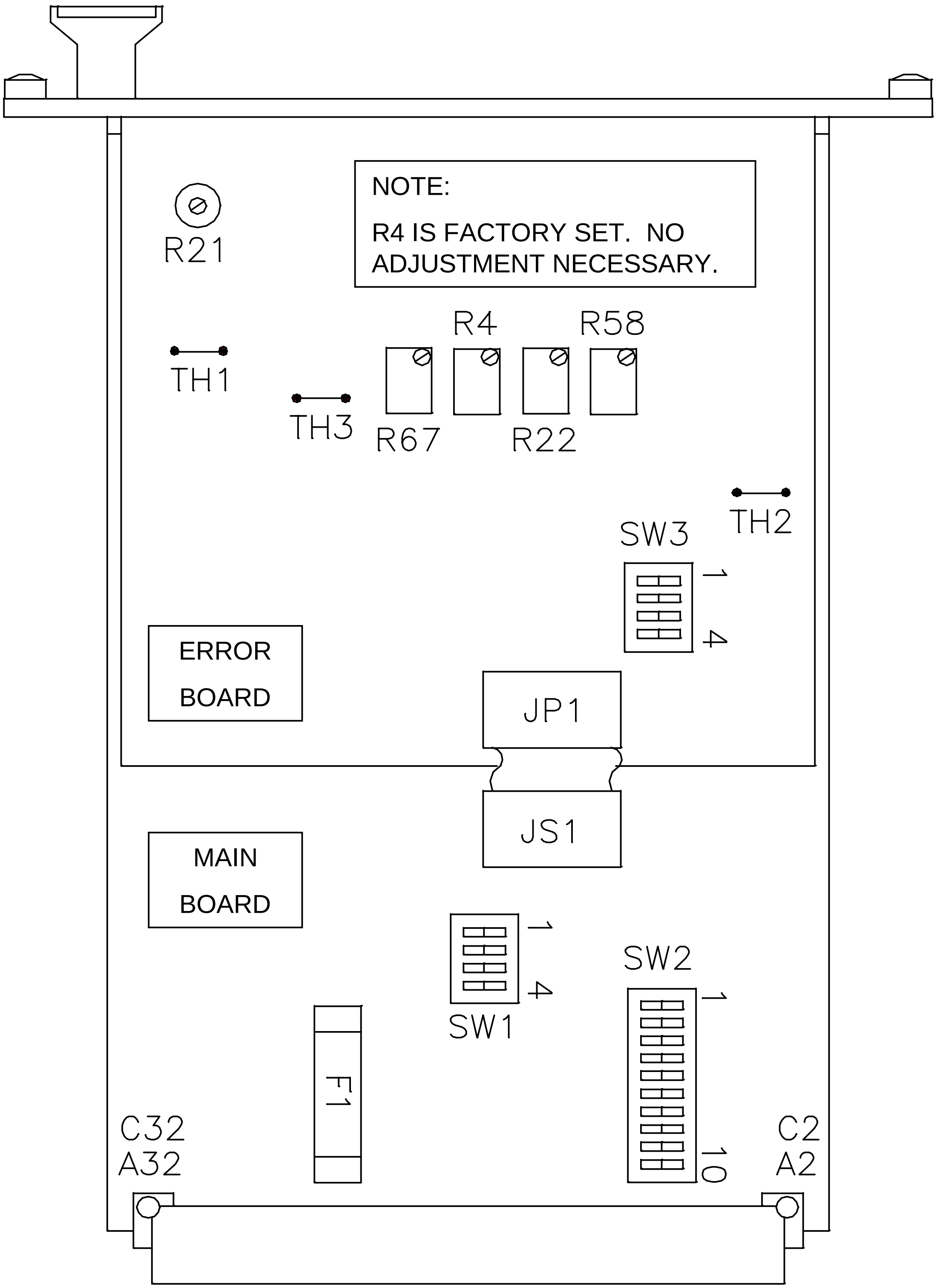

Figure 1

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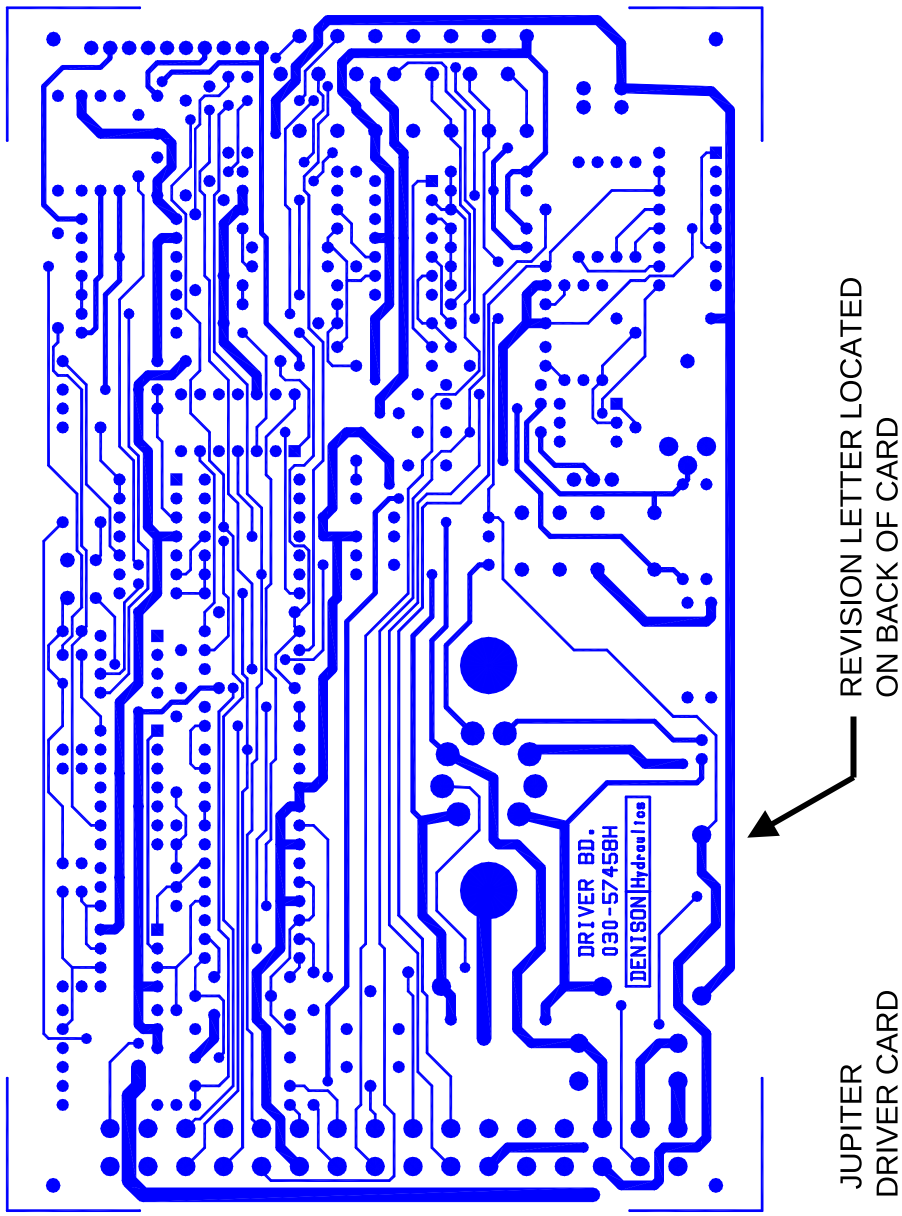

Figure 1. 1

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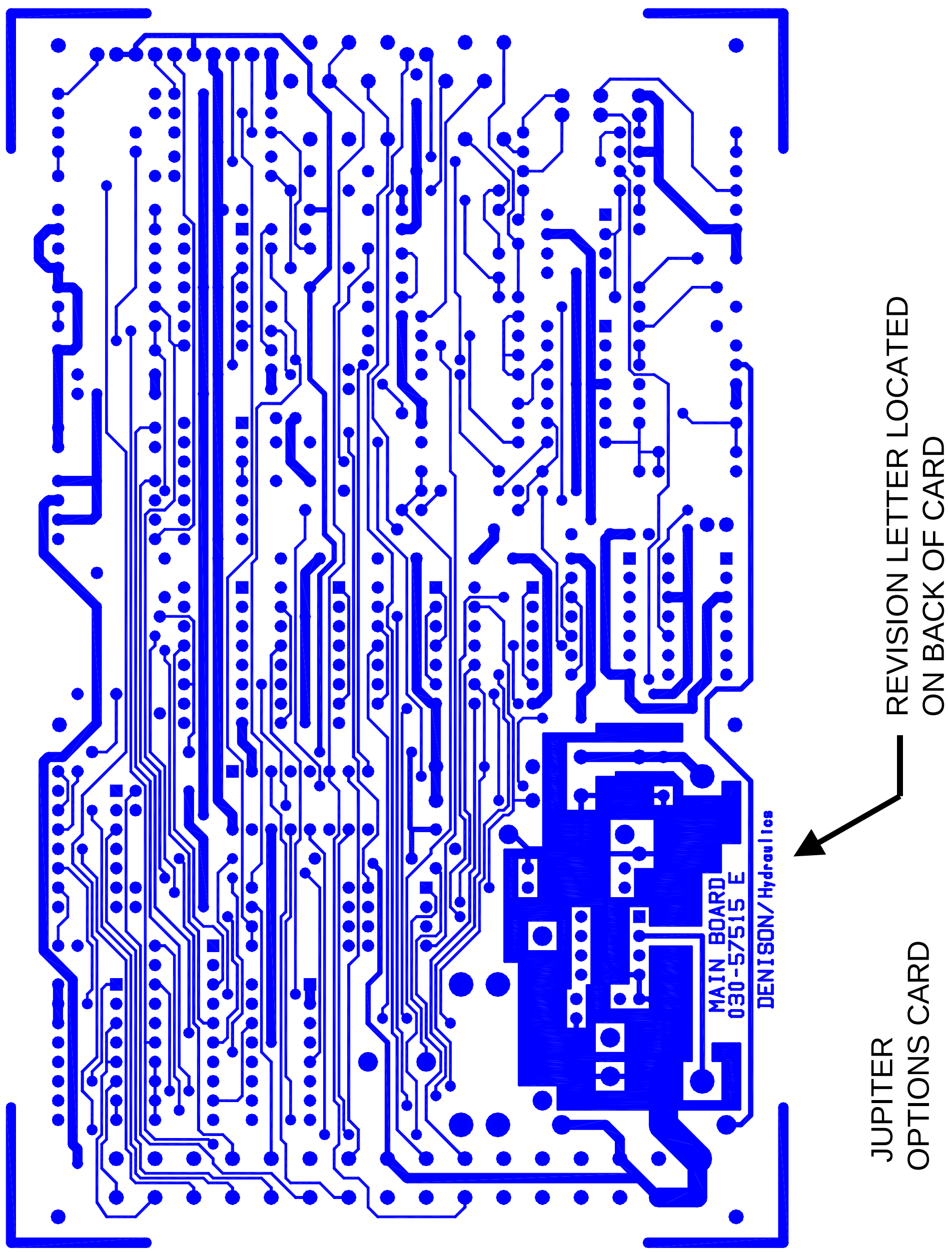

Figure 1. 2

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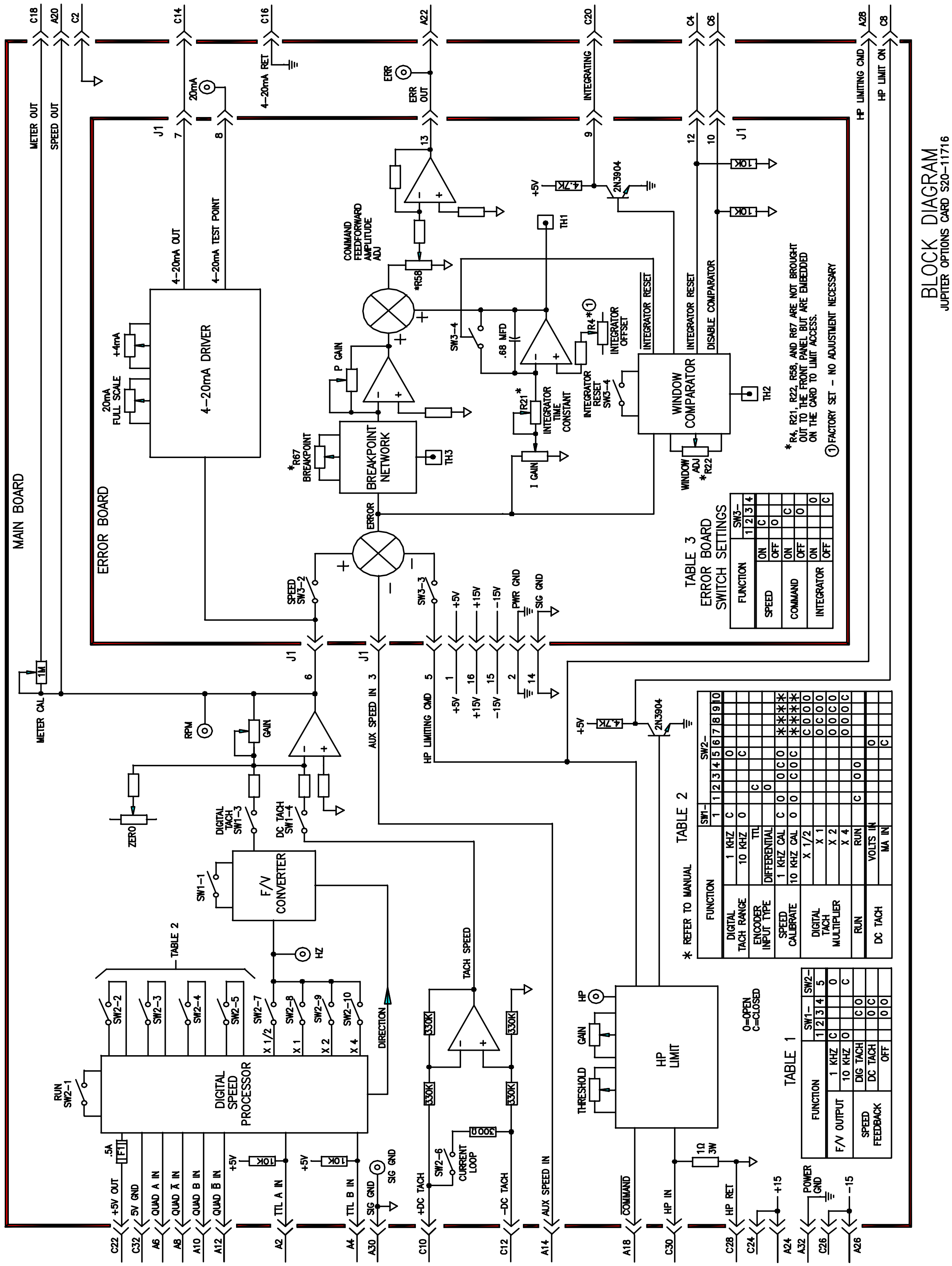
BLOCK DIAGRAM
JUPITER OPTIONS CARD S20-11716
MAIN BOARD
ERROR BOARD
4-20mA DRIVER
DIGITAL SPEED PROCESSOR
F/V CONVERTER
BREAKPOINT NETWORK
WINDOW COMPARATOR
HP LIMIT
TABLE 1
TABLE 2
TABLE 3 ERROR BOARD SWITCH SETTINGS

Figure 2

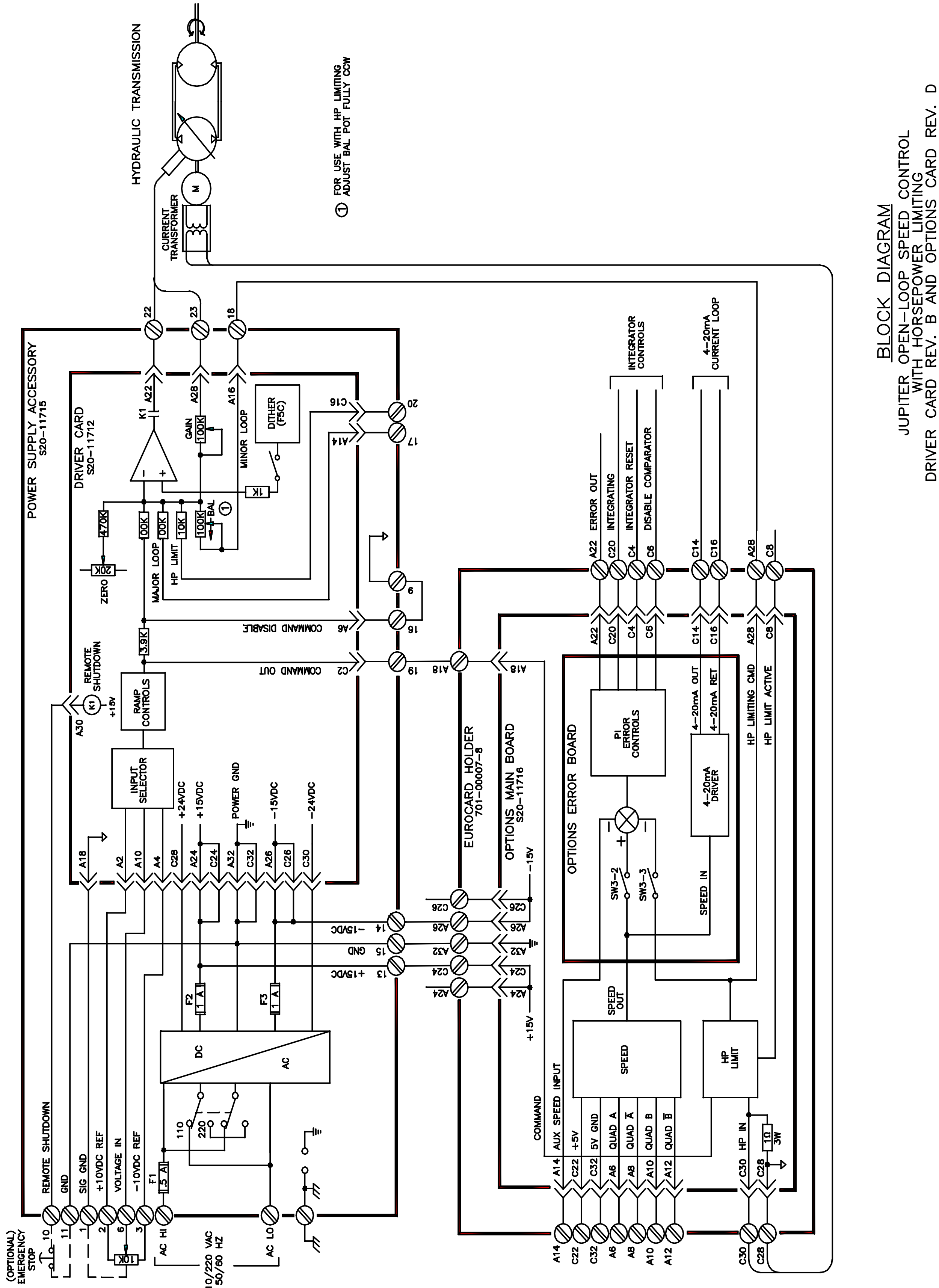
BLOCK DIAGRAM
JUPITER OPEN-LOOP SPEED CONTROL
WITH HORSEPOWER LIMITING
DRIVER CARD REV. B AND OPTIONS CARD REV. D
HYDRAULIC TRANSMISSION
CURRENT TRANSFORMER
① FOR USE WITH HP LIMITING
ADJUST BAL POT FULLY CCW
POWER SUPPLY ACCESSORY
S20-11715
DRIVER CARD
S20-11712
EUROCARD HOLDER
701-00007-8
OPTIONS MAIN BOARD
S20-11716
OPTIONS ERROR BOARD
INPUT SELECTOR
RAMP CONTROLS
PI ERROR CONTROLS
4-20mA DRIVER
SPEED
HP LIMIT
DITHER (F5C)
INTEGRATOR CONTROLS
4-20mA CURRENT LOOP
(OPTIONAL) EMERGENCY STOP
110/220 VAC
50/60 HZ

Figure 3

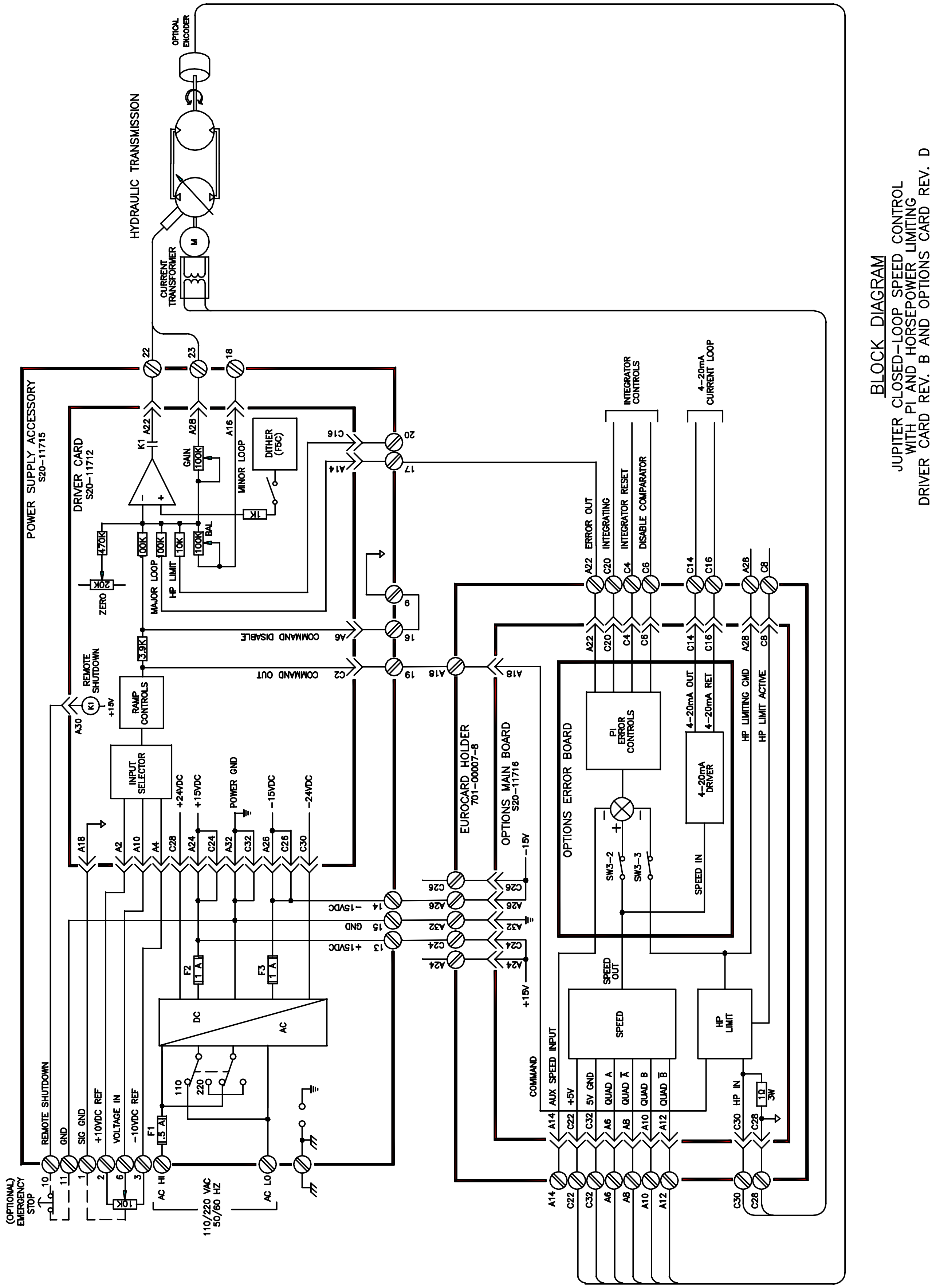

Figure 4

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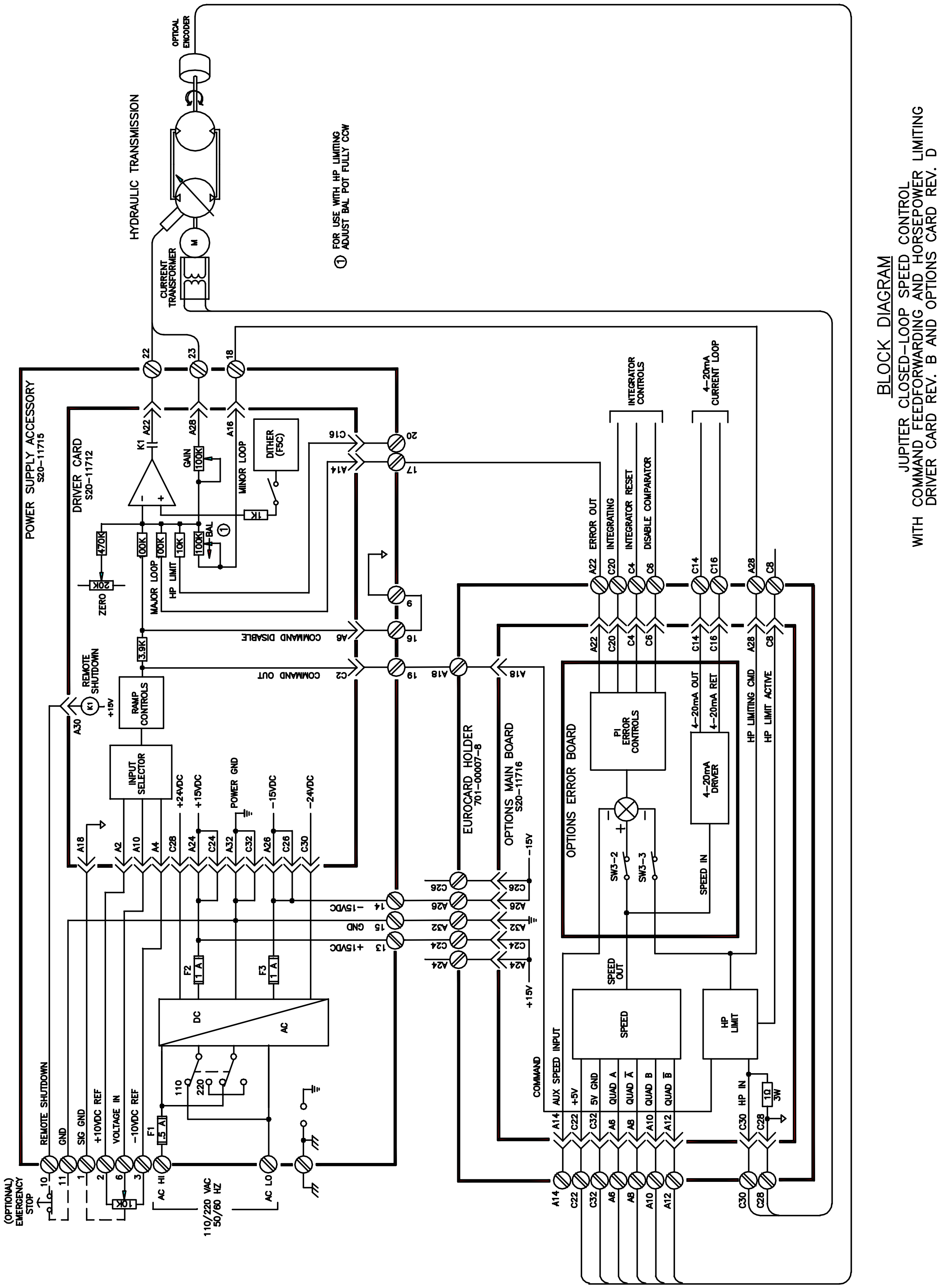

Figure 5

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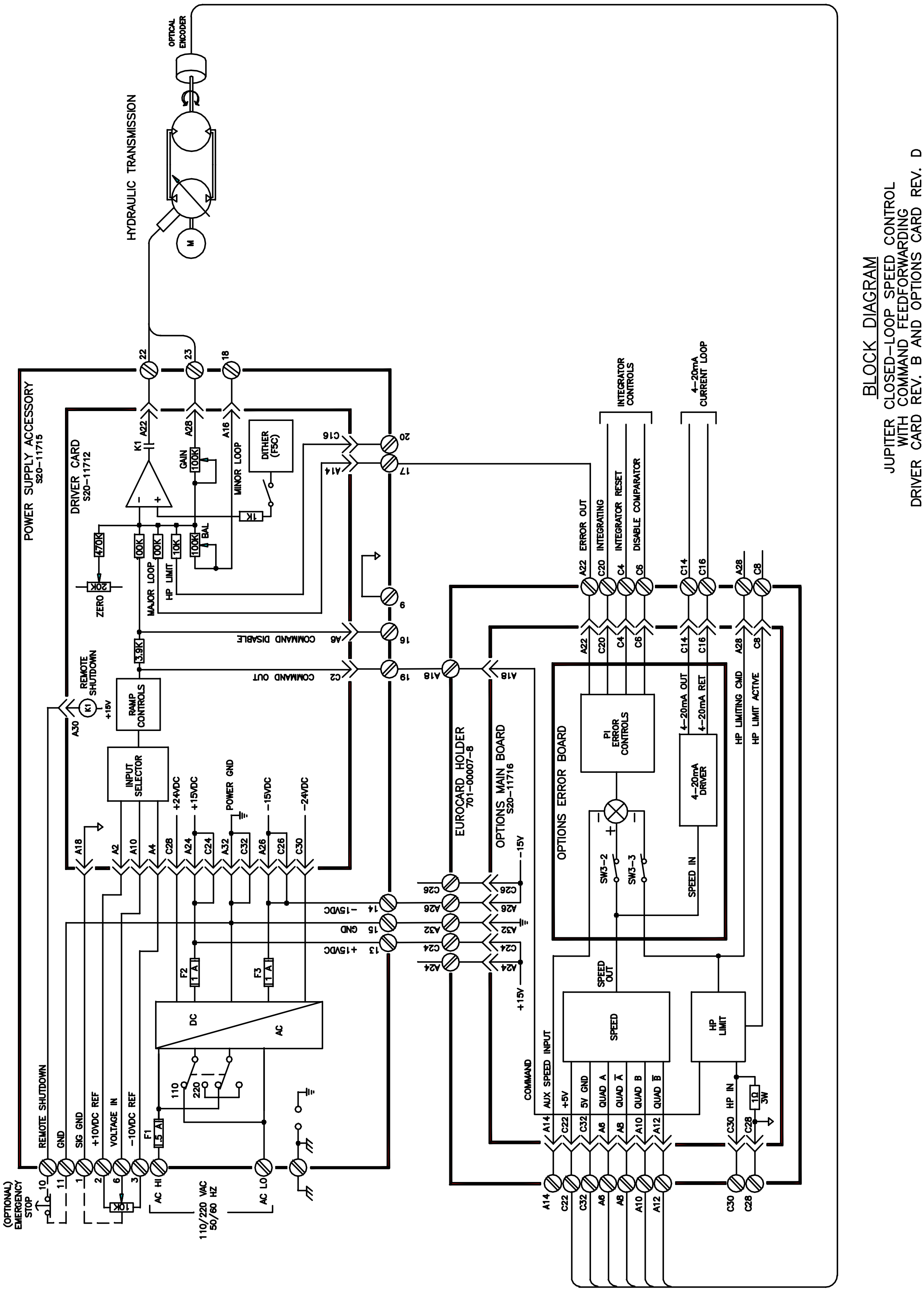

Figure 6

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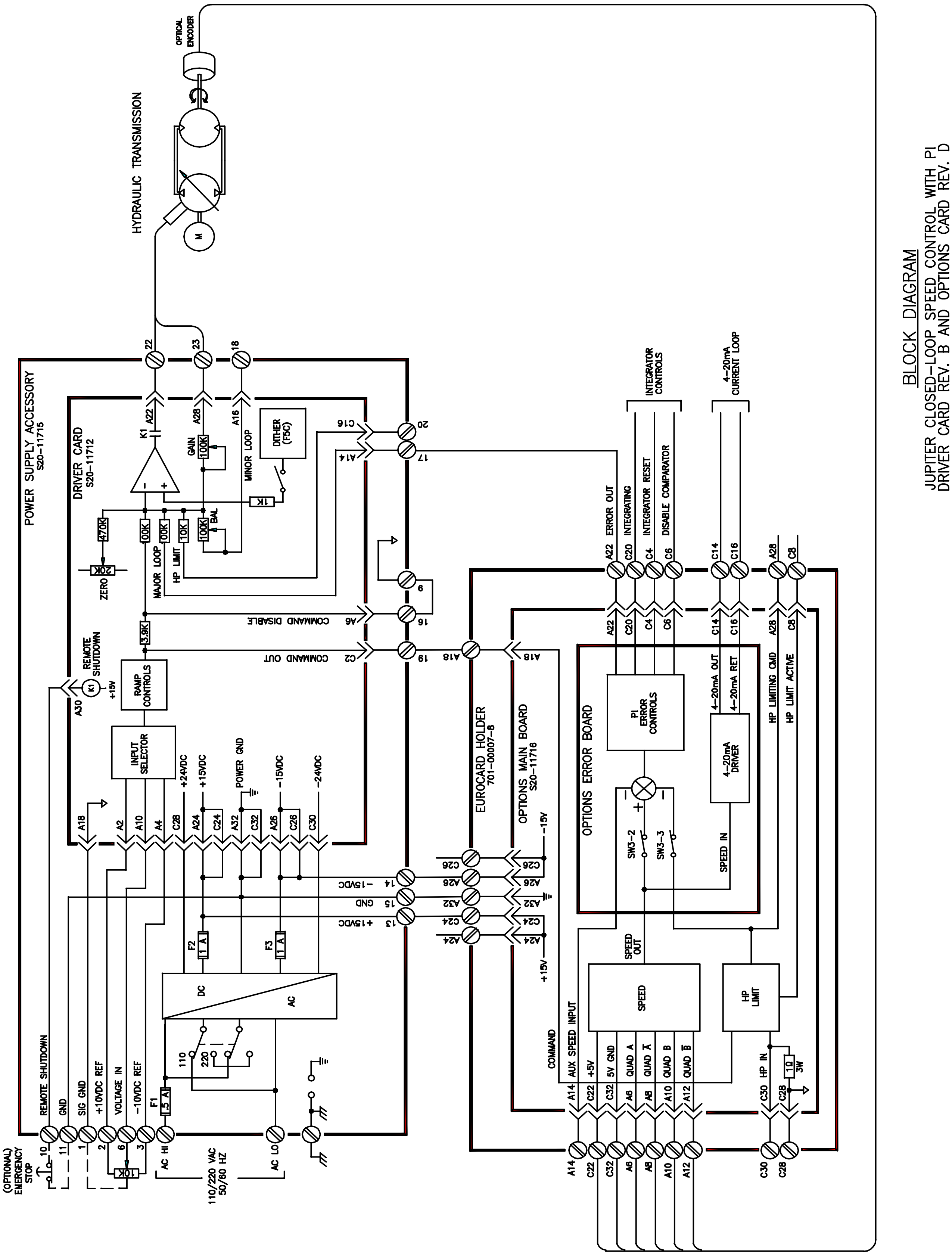

Figure 7

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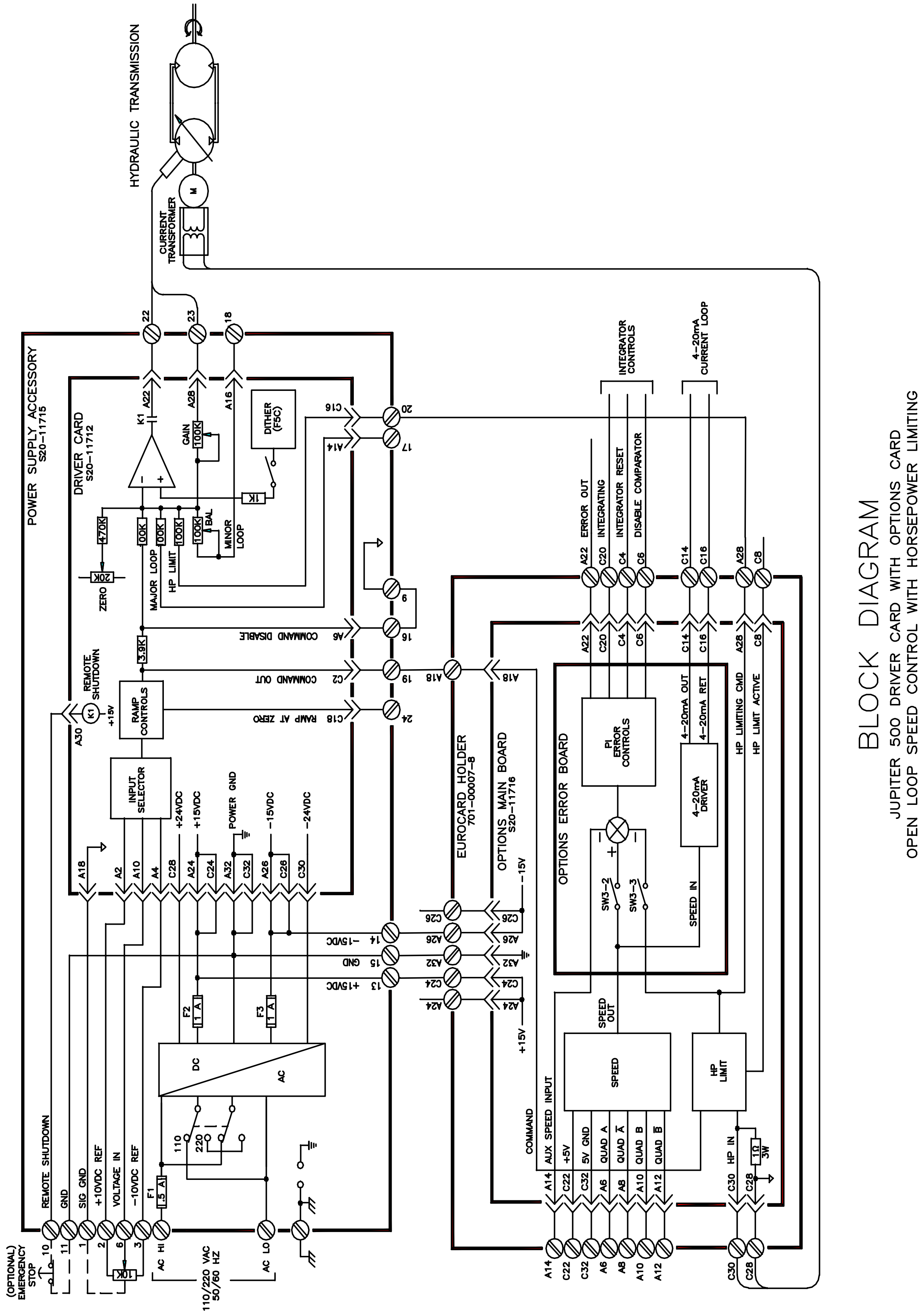
BLOCK DIAGRAM
JUPITER 500 DRIVER CARD WITH OPTIONS CARD
OPEN LOOP SPEED CONTROL WITH HORSEPOWER LIMITING
HYDRAULIC TRANSMISSION
POWER SUPPLY ACCESSORY S20-11715
DRIVER CARD S20-11712
EUROCARD HOLDER 701-00007-8
OPTIONS MAIN BOARD S20-11716
OPTIONS ERROR BOARD
CURRENT TRANSFORMER
INPUT SELECTOR
RAMP CONTROLS
PI ERROR CONTROLS
4-20mA DRIVER
SPEED
HP LIMIT
DITHER (F5C)
110/220 VAC 50/60 HZ
(OPTIONAL) EMERGENCY STOP

Figure 8

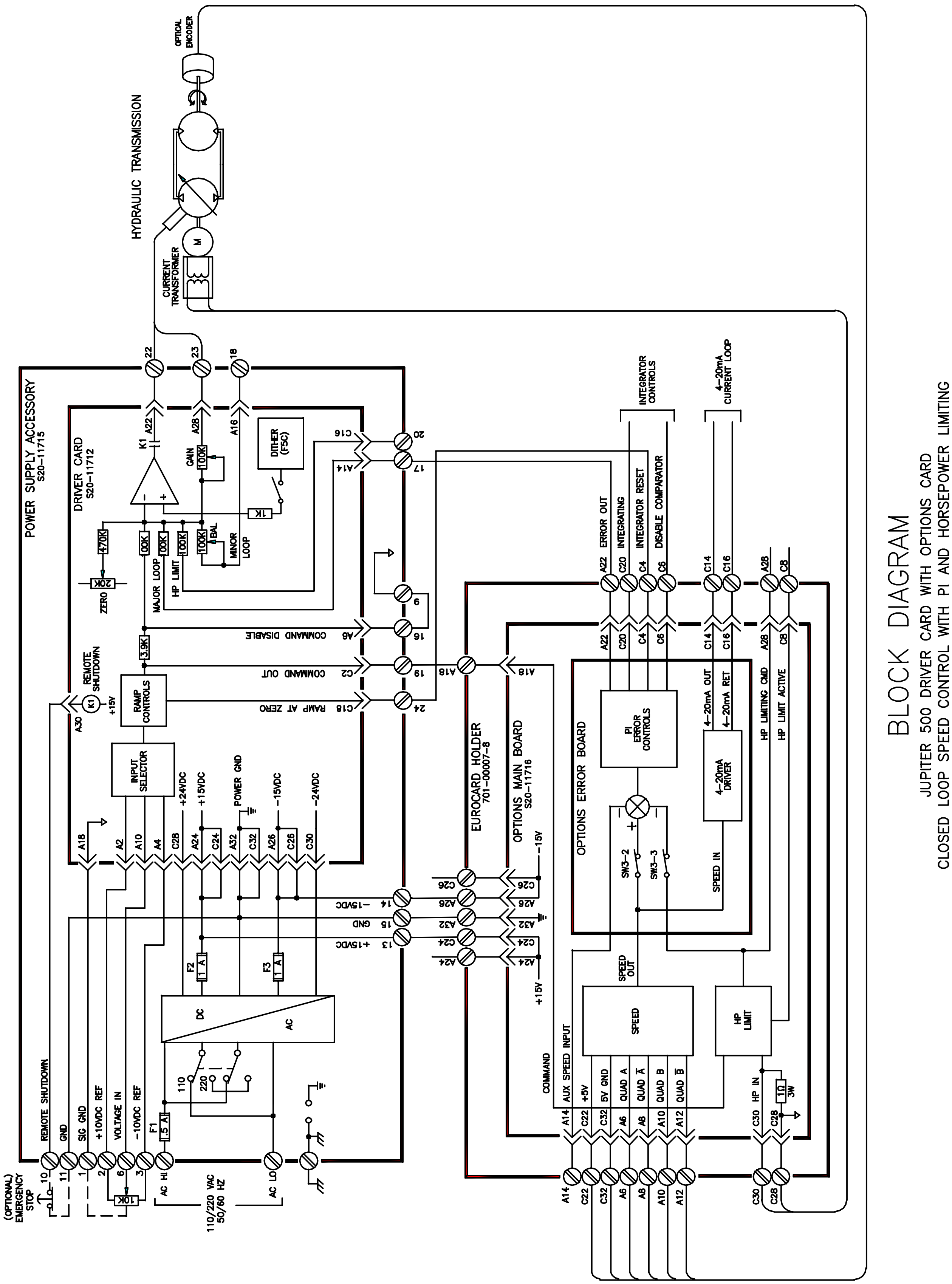

Figure 9

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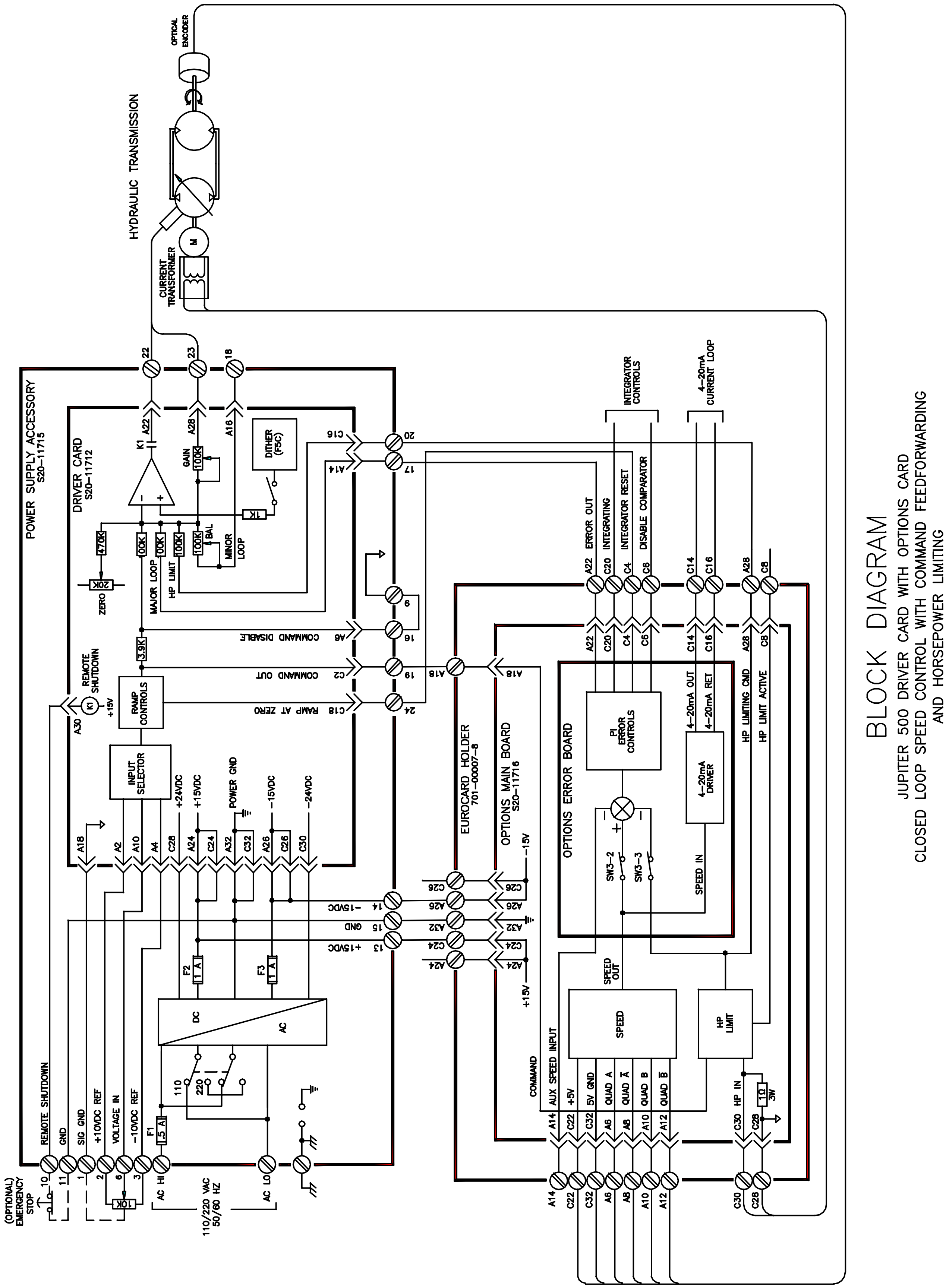

Figure 10

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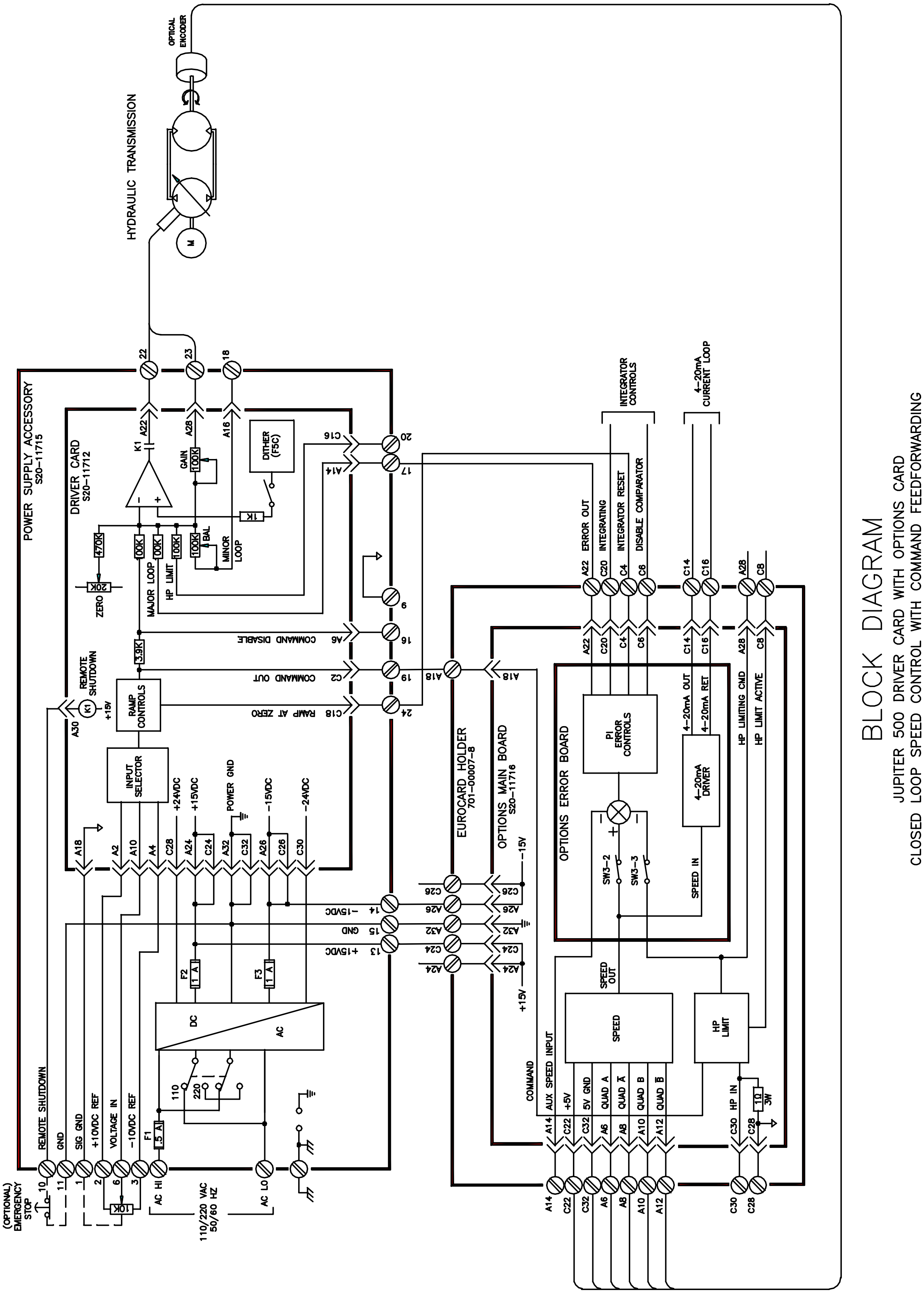

Figure 11

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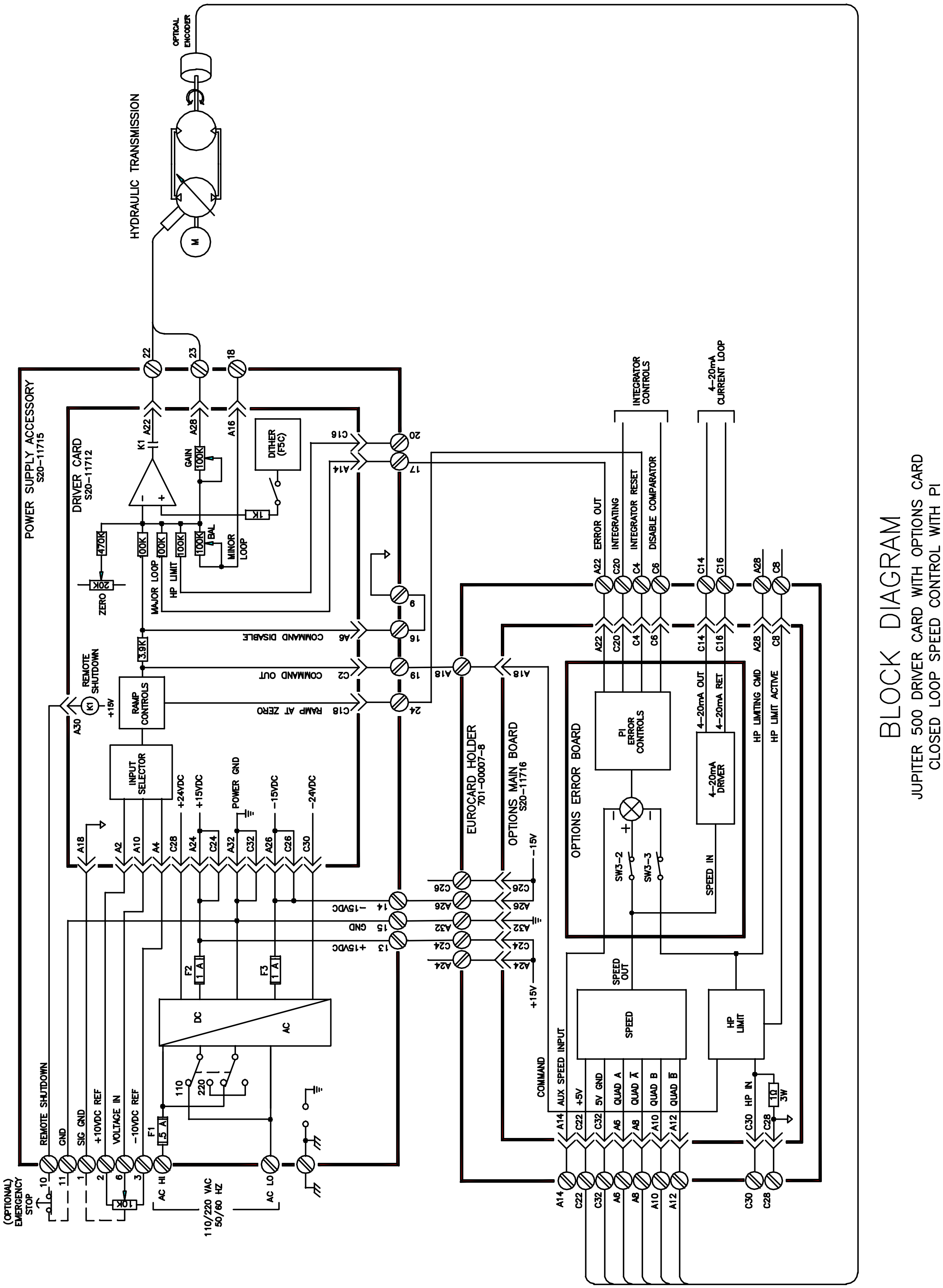
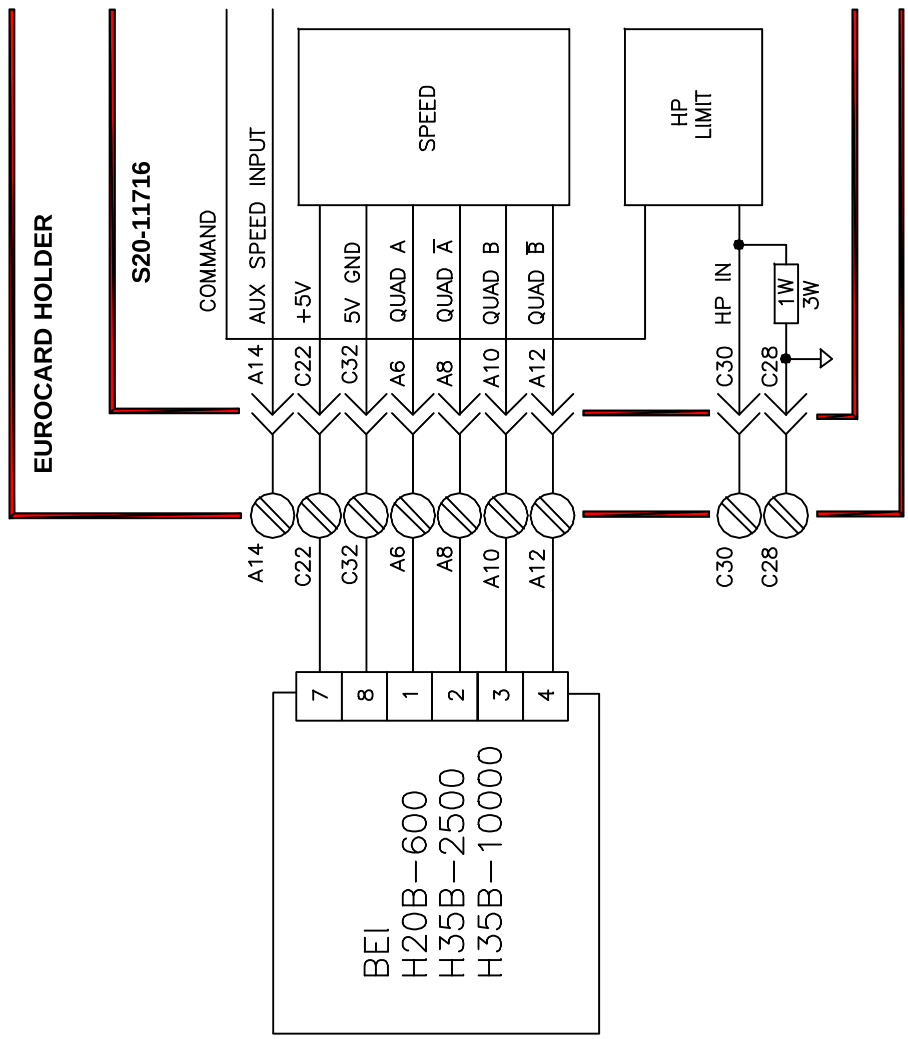
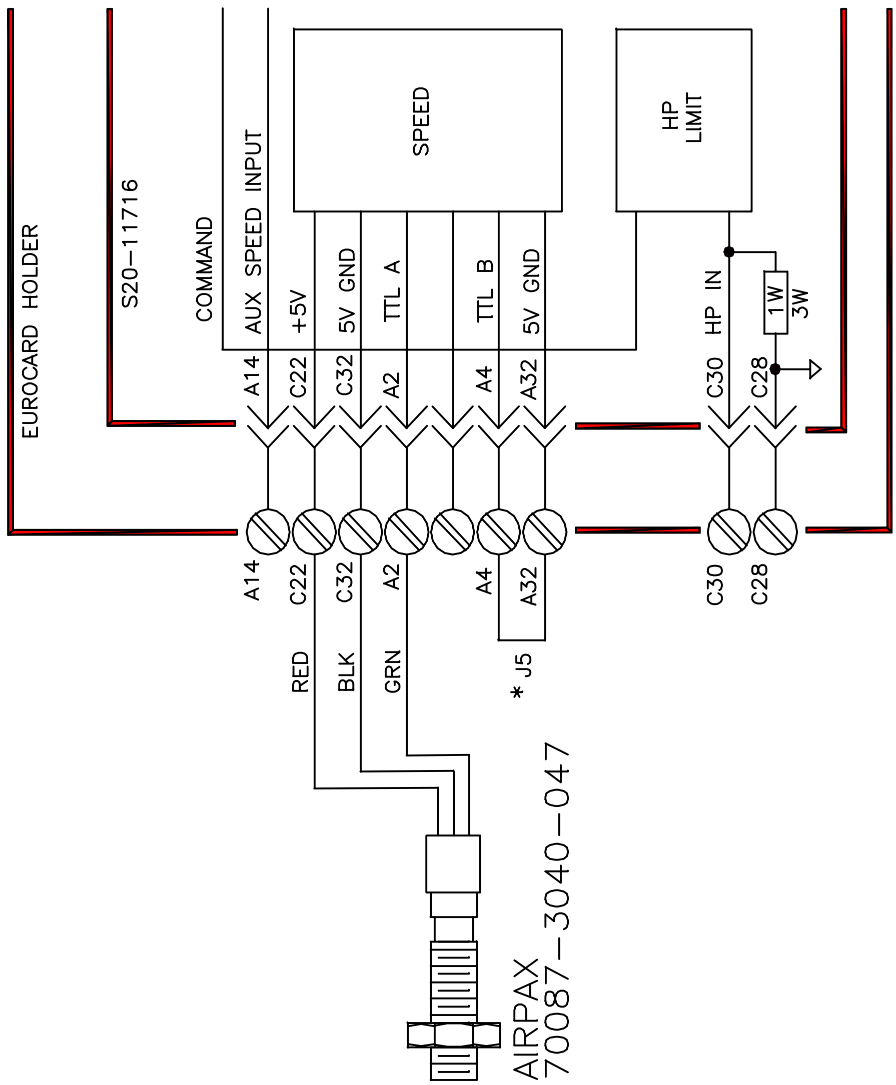

BLOCK DIAGRAM
JUPITER 500 DRIVER CARD WITH OPTIONS CARD
CLOSED LOOP SPEED CONTROL WITH PI
HYDRAULIC TRANSMISSION
OPTICAL ENCODER
POWER SUPPLY ACCESSORY
S20-11715
DRIVER CARD
S20-11712
EUROCARD HOLDER
701-00007-8
OPTIONS MAIN BOARD
S20-11716
OPTIONS ERROR BOARD
INTEGRATOR CONTROLS
4-20mA CURRENT LOOP
110/220 VAC
50/60 HZ
(OPTIONAL) EMERGENCY STOP

Figure 12



CCW ROTATION OF ENCODER SHAFT WILL PRODUCE A POSITIVE ANALOG SPEED SIGNAL. REVERSE A6 AND A8 WITH A10 AND A12 FOR NEGATIVE SPEED SIGNAL WITH CCW ROTATION OF ENCODER SHAFT.

Figure 13



* NOTE: INSTALL J5 FOR POSITIVE (+) ANALOG OUTPUT
REMOVE J5 FOR NEGATIVE (-) ANALOG OUTPUT

Figure 14

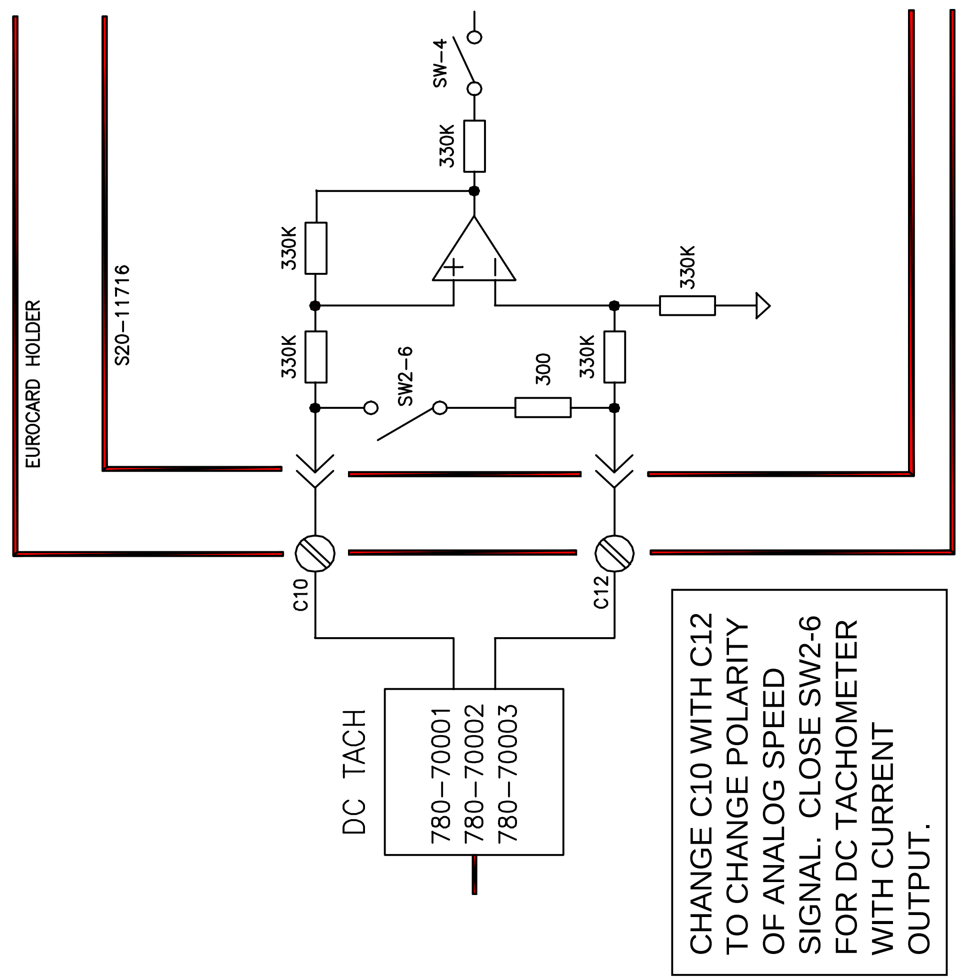

EUROCARD HOLDER
S20-11716
SW-4
330K
330K
330K
SW2-6
300
330K
330K
C10
C12
DC TACH
780-70001
780-70002
780-70003
CHANGE C10 WITH C12 TO CHANGE POLARITY OF ANALOG SPEED SIGNAL. CLOSE SW2-6 FOR DC TACHOMETER WITH CURRENT OUTPUT.

Figure 15

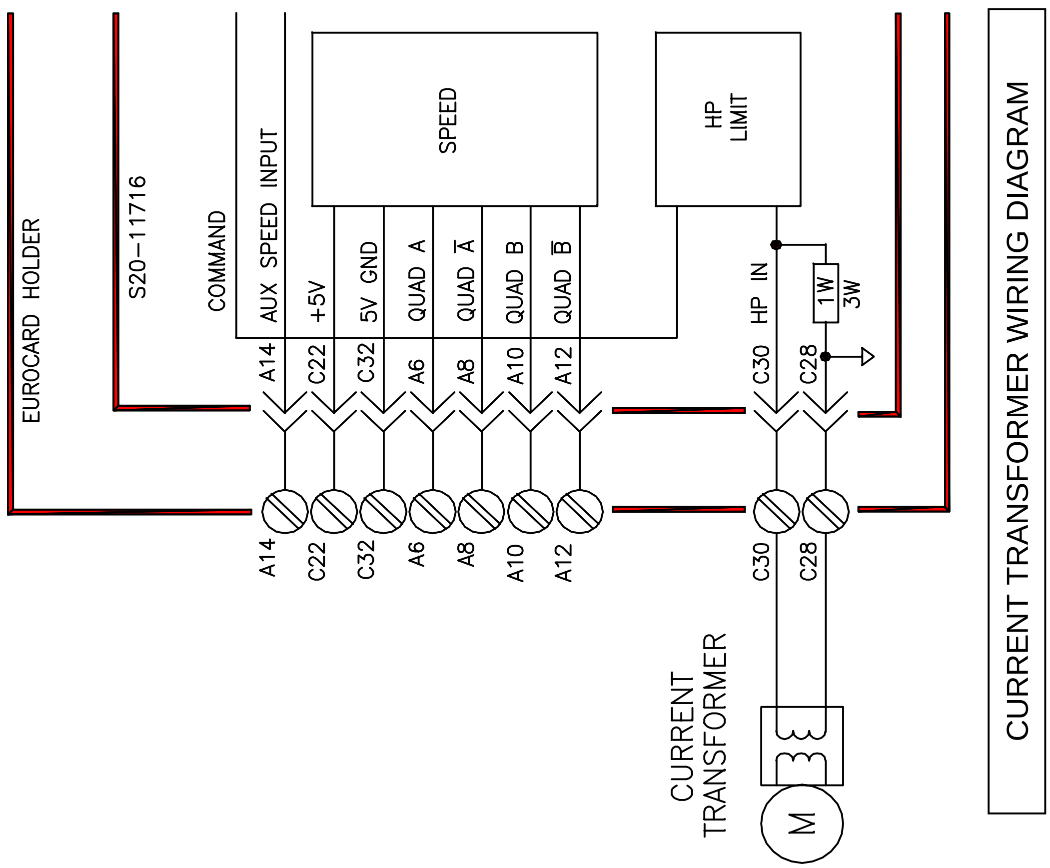

CURRENT TRANSFORMER WIRING DIAGRAM
EUROCARD HOLDER
S20-11716
COMMAND
AUX SPEED INPUT
+5V
5V GND
QUAD A
QUAD Ā
QUAD B
QUAD B̄
SPEED
HP LIMIT
HP IN
1W
3W
A14
C22
C32
A6
A8
A10
A12
C30
C28
CURRENT TRANSFORMER
M

Figure 16

D. Accessories

A. Eurocard Holder — HDC #701-00007-8

Connector	DIN 32D, Internal Connector
Terminals	32 tubular screws with pressure plates

Dimensions:

Holder	130H x 164D x 50.8W mm
Holder with Options Card	128.4H x 216D x 50.8W mm

*************** HOLDER TERMINATIONS *****************

TERMINAL #		TERMINAL #	
A2	TTL CHAN A IN	C2	SIGNAL GND
A4	TTL CHAN B IN	C4	INTEGRATOR RESET
A6	DIFF CHAN A +IN	C6	COMPARATOR DISABLE
A8	DIFF CHAN A -IN	C8	HP LIMIT ACTIVE
A10	DIFF CHAN B +IN	C10	DC TACH +IN
A12	DIFF CHAN B -IN	C12	DC TACH -IN
A14	ALT SPEED COMMAND	C14	4-20 mA OUT
A16		C16	4-20 mA RET
A18	COMMAND INPUT	C18	METER OUT
A20	ANALOG SPEED OUT	C20	INTEGRATOR ACTIVE
A22	ANALOG ERROR OUT	C22	+5 VDC
A24	+15 VDC	C24	+15 VDC
A26	-15 VDC	C26	-15 VDC
A28	HP LIMITING COMMAND	C28	HP LIMIT RET
A30	SIGNAL GND	C30	HP LIMIT IN
A32	PWR GND	C32	PWR GND

B: DIGITAL ENCODERS

Model	Pulses/Revolution	Speed Range
BEI #H20DB-600	600	High
BEI #H35B-2500	2,500	Medium
BEI #H35B-10000	10,000	Low

C. ACTIVE MAGNETIC PICKUPS

AIRPAX #70087-3040-047

Gearing must be selected to maintain pulse frequency within 100 Hz to 20 kHz over the operating speed range.

D. <u>DC TACHOMETERS</u>

HDC #780-70003	7V/1000 RPM
HDC #780-70001	12V/1000 RPM
HDC #780-70002	45V/1000 RPM

E. <u>METERS</u>

Analog with calibrated scale (Specify)
DIGITAL DHC #746-10017.

E: DIP Switch Settings

Conditioned Output Magnetic Proximity Pickup and Encoder Speed Sensor		
O = OPEN = OFF **C = CLOSED = ON**	SW1	
switch number	3	4
Conditioned Magnetic Proximity Pickup or Encoder	C	O
D.C. Tachometer	O	C

Conditioned Output Magnetic Proximity Pickup and Encoder Speed Sensor	
O = OPEN = OFF **C = CLOSED = ON**	SW2
switch number	2
TTL	C
Differential	O

Calibrate / Run Mode			
O = OPEN = OFF **C = CLOSED = ON**	SW2		
switch number	1	3	4
Run	C	O	O
1,000 Hz Calibration	O	O	C
10,000 Hz Calibration	O	C	O

Conditioned Magnetic Pickup and Encoder Multiplier Switch Settings				
O = OPEN = OFF **C = CLOSED = ON**	SW2			
switch number	7	8	9	10
1/2 X Frequency	C	O	O	O
1 X Frequency	O	C	O	O
2 X Frequency (2 channel Encoder only)	O	O	C	O
2 X Frequency (Conditioned Magnetic Pickup only)	O	O	O	C
4 X Frequency (2 channel Encoder only)	O	O	O	C

Conditioned Output Magnetic Proximity Pickup and Encoder Input		
O = OPEN = OFF **C = CLOSED = ON**	SW1	SW2
switch number	1	5
1,000 Hz Full Scale	C	O
10,000 Hz Full Scale	O	C

D.C. Tachometer Input Type		
O = OPEN = OFF	**C = CLOSED = ON**	SW2
	switch number	6
Voltage Output Tachometer		O
Current Loop Tachometer		C

Speed ON or OFF		
O = OPEN = OFF	**C = CLOSED = ON**	SW3
	switch number	2
ON		C
OFF		O

Command Source		
O = OPEN = OFF	**C = CLOSED = ON**	SW3
	switch number	3
Command From Driver Board		C
Auxiliary Command		O

Integrator Reset		
O = OPEN = OFF	**C = CLOSED = ON**	SW3
	switch number	4
Integrator OFF (Reset)		C
Integrator ON		O

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E-mail: literature@denisonhydraulics.com

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DENISON Hydraulics

August 2000

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