PWR-82520X

3-PHASE DC MOTOR TORQUE CONTROLLER

DESCRIPTION

The PWR-82520X is a high performance current regulating torque loop controller. It is designed to accurately regulate the current in the motor windings of 3-phase brushless DC and brush DC motors.

The PWR-82520X is a completely self-contained motor controller that converts an analog input command signal into motor current and uses the signals from Hall-effect sensors in the motor to commutate the current in the motor windings. The motor current is internally sensed and processed into an analog signal. The current signal is summed together with the command signal to produce an error signal that controls the pulse width modulation (PWM) duty cycle of the output, thus controlling the motor current. The PWR-82520X can be tuned by using an external Proportional/Integral (PI) regulator network in conjunction with the internal error amplifier.

APPLICATIONS

Packaged in either a small DIP-style or flat-pack hybrid package, the PWR-82520X is ideal for applications with limited printed circuit board area.

PWR-82520X is ideal for applications requiring current regulation and/or holding torque at zero input command. System applications that can use the PWR-82520X are: pumps, actuators, antenna position, environmental control and reaction/momentum wheel systems using brushless and brush motors.

FEATURES

- ***Self-Contained 3-Phase Motor Controller***
- ***Operates as Current or Voltage Controller***
- ***1, 3 and 10 Amp Output Current***
- ***1.5% Linearity***
- ***3% Current Regulating Accuracy***
- ***User-Programmable Compensation***
- ***10 KHz - 100 KHz PWM Frequency***
- ***Complementary Four-Quadrant Operation***
- ***Holding Torque through Zero Current***
- ***Cycle-by-Cycle Current Limit***
- ***Optional Radiation Tolerance to 100Krads***

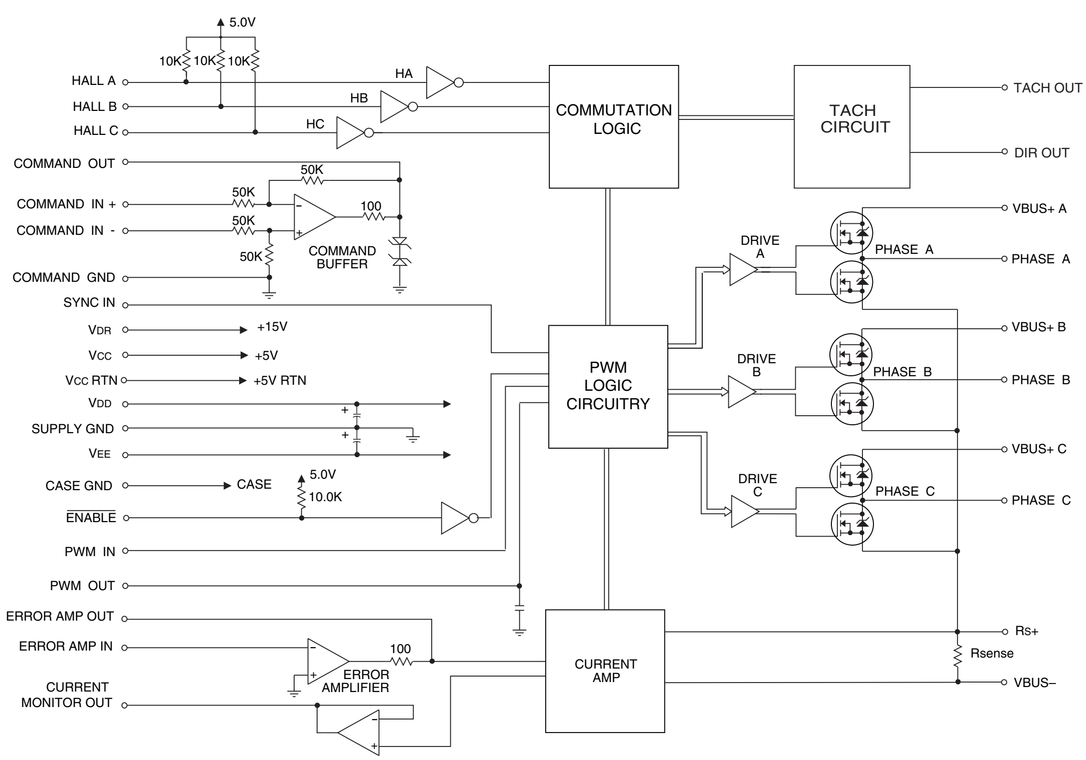


FIGURE 1. PWR-82520X BLOCK DIAGRAM

TABLE 1. PWR-82520X ABSOLUTE MAXIMUM RATINGS (Tc = +25°C unless otherwise specified)			
PARAMETER	**SYMBOL**	**VALUE**	**UNITS**
BUS VOLTAGE	VBUS+	100.0	Vdc
+15V SUPPLY	V_{DR}	+16.5	Vdc
+5V TO +15V	V_{DD}	+16.5	Vdc
+5V SUPPLY	V_{CC}	+5.5	Vdc
-5V TO -15V	V_{EE}	-16.5	Vdc
VBUS- TO GND Voltage Differential	V_{GNDDIF}	V_{DD} +1.0	Vdc
CONTINUOUS OUTPUT CURRENT	I_{OC}		
PWR-82520X1		1.5	A
PWR-82520X3		4.0	A
PWR-82520X10		14	A
COMMAND INPUT +	Command input +	±5.0	Vdc
COMMAND INPUT -	Command input -	±5.0	Vdc
LOGIC INPUTS	$\overline{ENABLE}$, SYNC, HA, HB,HC	7.0	Vdc

TABLE 2. PWR-82520X SPECIFICATIONS (Unless otherwise specified, VBUS = 28Vdc, V_{DR} = +15V, V_{CC} = +5V, V_{DD}=+5V, V_{EE}=-5V, Tc = 25°C, L_L = 500 µH)						
PARAMETER	**SYMBOL**	**TEST CONDITIONS**	**MIN**	**TYP**	**MAX**	**UNITS**
OUTPUT (PWR-82520X1)						
Output Current Continuous	I_{OC}			1		A
Output Current Pulsed	I_{OP}	t = 50µsec			3	A
Current Limit	I_{CL}			1.5		A
Current Offset*	I_{OFFSET}	V_{CMD} = 0V	-20		+20	mA
Output On-Resistance	R_{ON}	+25°C			0.60	Ω
		+85°C			0.90	Ω
Output Conductor Resistance	R_C	+85°C			0.06	Ω
Diode Forward Voltage Drop	V_F	I_D = 1A			1.5	V
OUTPUT (PWR-82520X3)						
Output Current Continuous	I_{OC}			3		A
Output Current Pulsed	I_{OP}	t = 50µsec			8	A
Current Limit	I_{CL}			4		A
Current Offset*	I_{OFFSET}	V_{CMD} = 0V	-20		+20	mA
Output On-Resistance	R_{ON}	+25°C			0.18	Ω
		+85°C			0.27	Ω
Output Conductor Resistance	R_C	+85°C			0.06	Ω
Diode Forward Voltage Drop	V_F	I_D = 1A			1.8	V
OUTPUT (PWR-82520X10)						
Output Current Continuous	I_{OC}			10		A
Output Current Pulsed	I_{OP}	t = 50µsec			20	A
Current Limit	I_{CL}		12.0	14.0	15.4	A
Current Offset*	I_{OFFSET}	V_{CMD} = 0V	-100	0	+100	mA
Output On-Resistance	R_{ON}	+25°C			0.055	Ω
		+85°C			0.075	Ω
Output Conductor Resistance	R_C	+85°C			0.060	Ω
Diode Forward Voltage Drop	V_F	I_D = 10A			1.9	V
COMMAND IN+/- Differential Input	V_{CMD}		-4		+4	Vdc
COMMAND OUT Internal Voltage Clamp	V_{CLAMP}		-5		+5	Vdc

TABLE 2. PWR-82520X SPECIFICATIONS (CONT) (Unless otherwise specified, VBUS = 28Vdc, V_{DR} = +15V, V_{CC} = +5V, V_{DD}=+5V, V_{EE}=-5V, T_C = 25°C, L_L = 500 µH)						
PARAMETER	**SYMBOL**	**TEST CONDITIONS**	**MIN**	**TYP**	**MAX**	**UNITS**
CUR. MONITOR AMP (X1)						
Current Monitor Gain				4		V/A
Current Monitor Offset		I_{OC} = 0A	-10		+10	mVdc
Output Current			-10		+10	mA
Output Resistance	R_{OUT}				1	Ω
CUR. MONITOR AMP (X3)						
Current Monitor Gain				1.33		V/A
Current Monitor Offset		I_{OC} = 0A	-10		+10	mVdc
Output Current			-10		+10	mA
Output Resistance	R_{OUT}				1	Ω
CUR. MONITOR AMP (X10)						
Current Monitor Gain				0.40		V/A
Current Monitor Offset		I_{OC} = 0A	-10		+10	mVdc
Output Current			-10		+10	mA
Output Resistance	R_{OUT}				1	Ω
CURRENT COMMAND*						
Transconductance Ratio	G					
PWR-82520X1			0.24	0.25	0.26	A/V
PWR-82520X3			0.73	0.75	0.77	A/V
PWR-82520X10			2.40	2.50	2.60	A/V
Non-Linearity			-1.5		+1.5	% FSR
VBUS+ SUPPLY						
Nominal Operating Voltage	V_{NOM}		18	28	70	Vdc
+15V SUPPLY						
Voltage	V_{DR}		+13.5	+15.0	+16.5	Vdc
Current	I_{DR}	$\overline{ENABLE}$ = low		11	15	mA
Current	I_{DR}	$\overline{ENABLE}$ = high		0		mA
+5V SUPPLY						
Voltage	V_{CC}		+4.5	+5.0	+5.5	Vdc
Current	I_{CC}			13	18	mA
+5V TO +15V SUPPLY						
Voltage	V_{DD}		+4.5		+16.5	Vdc
Current	I_{DD}			49	65	mA
-5V TO -15V SUPPLY						
Voltage	V_{EE}		-16.5		-4.5	Vdc
Current	I_{EE}			49	65	mA
SYNC						
Low					0.8	Vdc
High			2.4			Vdc
Duty Cycle				50		%
SYNC range as % of free-run freq.			0		120	%
PWM IN						
+Peak	V_{P+}		4.8	5.0	5.2	V
-Peak	V_{P-}		-5.2	-5.0	-4.8	V
Frequency	f		10		110	KHz
Linearity	LIN		-2		+2	%
Duty Cycle	D CYCLE		49	50	51	%
PWM OUT						
Free Run Frequency			95	100	105	KHz
HALL SIGNALS						
Logic 0	HA, HB, HC				0.8	Vdc
Logic 1			2.4			Vdc
$\overline{ENABLE}$						
Enabled	$\overline{ENABLE}$				0.8	Vdc
Disabled			2.4			Vdc
TACH OUT/ DIR OUT						
Current draw	I_{OL}				20	mA
ISOLATION						
Case to Ground		500 Vdc HIPOT	10			MΩ

TABLE 2. PWR-82520X SPECIFICATIONS (CONT)
(Unless otherwise specified, VBUS = 28Vdc, V_{DR} = +15V, V_{CC} = +5V, V_{DD}=+5V, V_{EE}=-5V, Tc = 25°C, L_L = 500 µH)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS
PROPAGATION DELAY	Td (on)	From 0.8V on $\overline{ENABLE}$ to 90% of VBUS		40		µs
	Td (off)	From 2.4V on $\overline{ENABLE}$ to 10% of VBUS		20		µs
SWITCHING CHARACTERISTICS (X1)						
Upper Drive		Rise Time =				
Turn-on Rise Time	tr	10% to 90% of VBUS		75		ns
Turn-off Fall Time	tf	Fall Time =		30		ns
Lower Drive		90% to 10% of VBUS				
Turn-on Rise Time	tr	I_O= 1A		50		ns
Turn-off Fall Time	tf			60		ns
SWITCHING CHARACTERISTICS (X3)						
Upper Drive		Rise Time =				
Turn-on Rise Time	tr	10% to 90% of VBUS		150		ns
Turn-off Fall Time	tf	Fall Time =		150		ns
Lower Drive		90% to 10% of VBUS				
Turn-on Rise Time	tr	I_O= 3A		160		ns
Turn-off Fall Time	tf			130		ns
SWITCHING CHARACTERISTICS (X10)						
Upper Drive		Rise Time =				
Turn-on Rise Time	tr	10% to 90% of VBUS		200		ns
Turn-off Fall Time	tf	Fall Time =		200		ns
Lower Drive		90% to 10% of VBUS				
Turn-on Rise Time	tr	I_O= 10A		200		ns
Turn-off Fall Time	tf			200		ns
THERMAL (PWR-82520X1)						
Thermal Resistance						
Junction-Case	θj-c				25	°C/W
Case-Air	θc-a				10	°C/W
Junction Temperature	Tj				+150	°C
Case Operating Temperature	T_C		-55		+125	°C
Case Storage Temperature	T_{CS}				+150	°C
THERMAL (PWR-82520X3)						
Thermal Resistance						
Junction-Case	θj-c				9	°C/W
Case-Air	θc-a				10	°C/W
Junction Temperature	Tj				+150	°C
Case Operating Temperature	Tc		-55		+125	°C
Case Storage Temperature	Tcs				+150	°C
THERMAL (PWR-82520X10)						
Thermal Resistance						
Junction-Case	θj-c				4	°C/W
Case-Air	θc-a				5.5	°C/W
Junction Temperature	Tj				+150	°C
Case Operating Temperature	T_C		-55		+125	°C
Case Storage Temperature	T_{CS}				+150	°C
RADIATION (PWR-82520R Series Only)						
Total dose					100	Krad
Dose Rate					0.5	Rad/Sec
SEU at LET level of					36	$MeV/mg/cm^2$
Latch-up Immune					36	$MeV/mg/cm^2$
WEIGHT						
X1				1.7 (48)		oz (g)
X3				1.7 (48)		oz (g)
X10				2.9 (82)		oz (g)

* When used in configuration shown in FIGURE 13.

INTRODUCTION

The PWR-82520X is a 3-phase high performance current control (torque loop) hybrid, which can provide true four-quadrant control through zero current. Its high Pulse Width Modulation (PWM) switching frequency makes it suitable for operation with low inductance motors. The PWR-82520X hybrid can accept single-ended or differential mode command signals. The current gain can be easily programmed to match the end user system requirements. With the compensation network externally wired, the hybrid can provide optimum control of a wide range of loads.

The PWR-82520X uses single point current sense technology with a non-inductive hybrid sense resistor, which yields a highly linear current output over the wide military temperature range (see FIGURE 8). The output current non-linearity is better than 1.5% and the total error due to all the factors such as offset, initial component accuracy, etc., is maintained well below 3% of the full-scale rated output current.

The Hall sensor interface for current commutation has built-in decoder logic that separates illegal codes and ensures that there is no cross conduction. The Hall sensor inputs are internally pulled up to +5V and they can be driven from open-collector outputs.

The PWM frequency can be programmed externally by adding a capacitor from PWM OUT to PWM GND. In addition, multiple PWR-82520X's can be synchronized by using one device as a master and connecting its PWM OUT pin to the PWM IN of all the other slave devices in a system or by applying a SYNC pulse.

The $\overline{\text{ENABLE}}$ input signal provides quick start and shutdown of the internal PWM. In addition, built-in under voltage fault protection turns off the output in case of improper power supply voltages.

The hybrid features dual current limiting functions. The input command amplifier output is limited to ±5V, limiting the motor current under normal operation. In addition, there is a cycle-by-cycle current limit which kicks in to protect the hybrid as well as the load (see TABLE 2 for limits).

BASIC OPERATION

The PW-82520X utilizes a complimentary four-quadrant drive technique to control current in the load. The complimentary drive has the following advantages over the standard drive:

1. Holding torque in the motor at zero commanded current
2. Linear current control through zero
3. No deadband at zero
4. Reduced power dissipation in the output MOSFETs

The complementary drive design uses a 50% PWM duty cycle for a zero command signal. For a zero input command, a pair of MOSFETs are turned on in the drive, Phase A upper & Phase B lower as shown in FIGURE 2A, to supply current into the load for the first half of the PWM cycle. This is the same mode of operation for the standard four-quadrant drive as shown in FIGURE 3A/B. During the second half of the PWM cycle, a second pair of transistors are turned on, Phase A lower & Phase B upper as shown in FIGURE 2B, for the flyback current and to provide load current in the opposite direction.

This is normally the dead time for standard four-quadrant drive as shown in FIGURE 3B. The result is current flowing in both directions in the motor for each PWM cycle. The advantage this has over standard four-quadrant drive is that at 50% duty cycle,

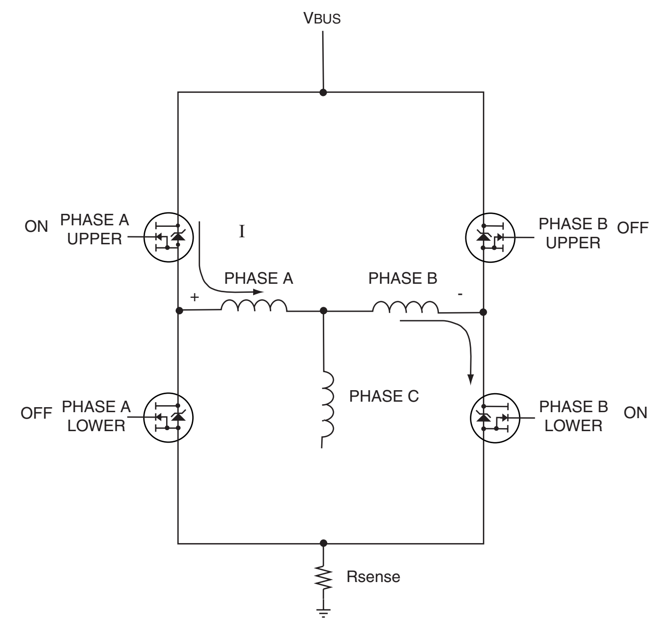


FIGURE 2A. COMPLEMENTARY FOUR-QUADRANT DRIVE FIRST HALF OF PWM CYCLE

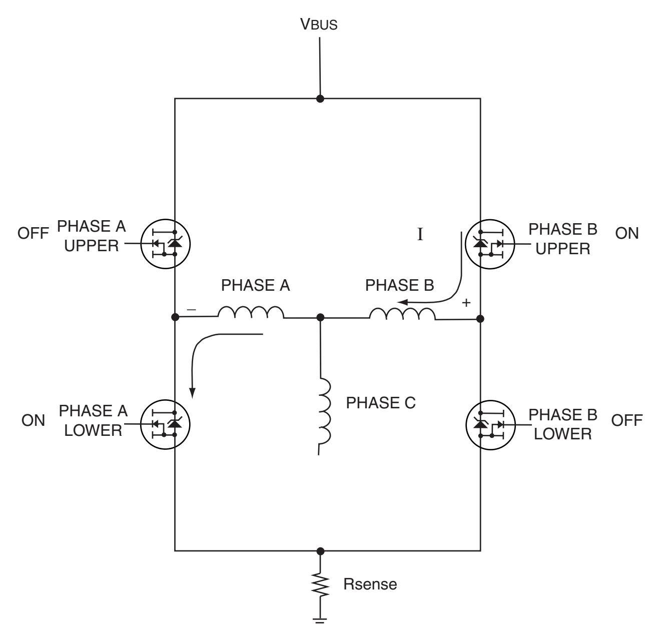


FIGURE 2B. COMPLEMENTARY FOUR-QUADRANT DRIVE SECOND HALF OF PWM CYCLE which corresponds to zero average current in the motor, holding torque is provided. The motor current at 50% duty cycle is simply the magnetizing current of the motor winding.

Using the complimentary four-quadrant technique allows the motor direction to be defined by the duty cycle. Relative to a given switch pair, i.e., Phase A upper and Phase B lower, a duty

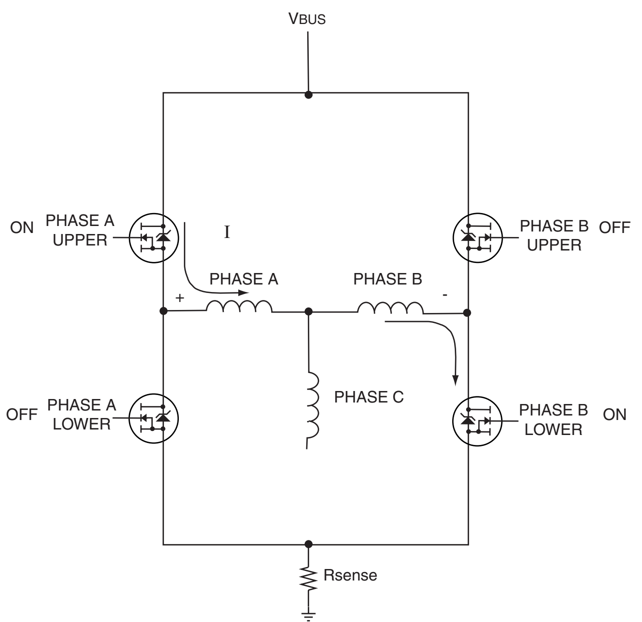


FIGURE 3A. STANDARD FOUR-QUADRANT DRIVE FIRST HALF OF PWM CYCLE

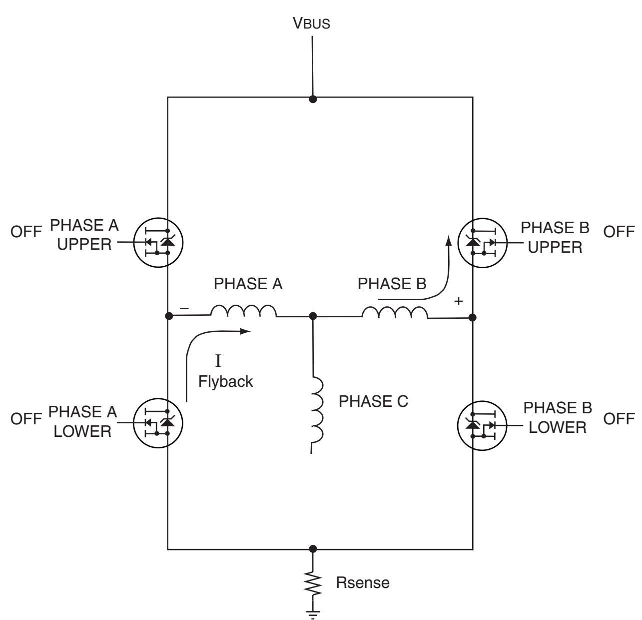


FIGURE 3B. STANDARD FOUR-QUADRANT DRIVE SECOND HALF OF PWM CYCLE

cycle greater than 50% will result in a clockwise rotation whereas a duty cycle less than 50% will result in a counter clockwise rotation. Therefore, with the use of average current mode control, direction can be controlled without the use of a direction bit and the current can be controlled through zero in a very precise and linear fashion.

The PW-82520X contains all the circuitry required to close an average current mode control loop around a complimentary 4-quadrant drive. The PWR-82520X use of average current mode control simplifies the control loop by eliminating the need for slope compensation and eliminating the pole created by the motor inductance. These two effects are normally associated with 50% duty cycle limitations when implementing standard peak current mode control.

FUNCTIONAL AND PIN DESCRIPTIONS

COMMAND IN+, COMMAND IN-

The command amplifier has a differential input that operates from a ±4Vdc full-scale analog current command. The command signal is internally limited to approximately ±5Vdc to prevent the amplifier from saturation. The input impedance of the command amplifier is 10KΩ.

The (PWR-82520X) can be used either as a current or voltage mode controller. When used as a torque controller (current mode), the input command signal is processed through the command buffer, which is internally limited to ±5Vdc. The output of the buffer (command out) is summed with the current monitor output into the error amplifier. External compensation is used on the error amp, so the response time can be adjusted to meet the application.

When used in the voltage mode, the voltage command uses the same differential input terminals to control the voltage applied to the motor. The error amp directly varies the PWM duty cycle of the voltage applied to the motor phase. The transfer function in the voltage mode is 4.7%V/±5% variation of the PWM duty cycle vs. input command. The duty cycle range of the output voltage is limited to approximately 5-95% in both current and voltage modes.

TRANSCONDUCTANCE RATIO AND OFFSET

When the PWR-82520X is used in the current mode, the command inputs (COMMAND IN+ and COMMAND IN-) are designed such that ±4Vdc on either input, with the other input connected to Ground will result in ± full-scale current into the load. The dc current transfer ratio accuracy is ±5% of the rated current including offset and initial component accuracy. The initial output dc current offset with both COMMAND IN+ and COMMAND IN- tied to the Ground will be as shown in TABLE 2 when measured using a load of 0.5mH and 1.0W at ambient room temperature with standard current loop compensation. The winding phase current error shall be within the cumulative limits of the transconductance ratio error and the offset error.

HALL A, B, C SIGNALS

Hall A, B and C (HA, HB, HC) are logic signals from the motor Hall-effect sensors. They use a phasing convention referred to as 120 degree spacing; that is, the output of HA is in phase with motor back EMF voltage VAB, HB is in phase VBC, and HC is in phase with VCA. Logic “1” (or HIGH) is defined by an input greater than 2.4Vdc or an open circuit to the controller; Logic “0”(or LOW) is defined as any Hall voltage input less than 0.8Vdc. Internal to the PWR-82520X are 10K pull-up resistors tied to +5Vdc on each Hall input.

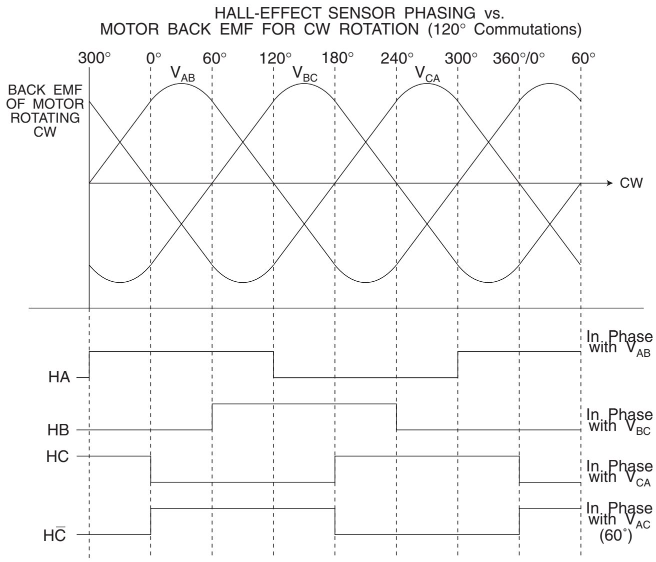


FIGURE 4. HALL PHASING

The PWR-82520X will operate with Hall phasing of 60° or 120° electrical spacing. If 60° commutation is used, then the output of HC must be inverted as shown in FIGURES 4 and 5. In FIGURE 4 the Hall sensor outputs are shown with the corresponding back emf voltage they are in phase with.

Hall Input Signal Conditioning: When the motor is located more than two feet away from the PWR-82520X controller the Hall inputs require noise filtering. It is recommended to use a 1KΩ resistor in series with the Hall signal and a 2000 pF capacitor from the Hall input pin to the Hall supply ground pin as shown in FIGURES 12 and 13.

CURRENT MONITOR OUT

This is a bipolar analog output voltage representative of motor current. The CURRENT MONITOR OUT will have the same scaling as the COMMAND IN input.

COMPENSATION

The PI regulator in the PWR-82520X can be tuned to a specific load for optimum performance. FIGURE 6 shows the standard current loop configuration and tuning components. By adjusting R1, R2 and C1, the amplifier can be tuned. The value of R1, C1 will vary, depending on the loop bandwidth requirement.

$\overline{ENABLE}$

The $\overline{\text{Enable}}$ input enables or disables the internal PWM. In the disable mode, the PWM is shut down and the outputs, Phase A, Phase B and Phase C, are in an "off" state and no voltage is applied to the motor.

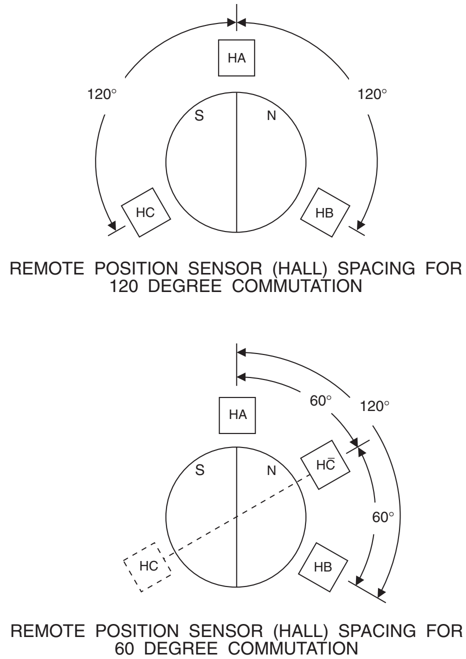


FIGURE 5. HALL SENSOR SPACING

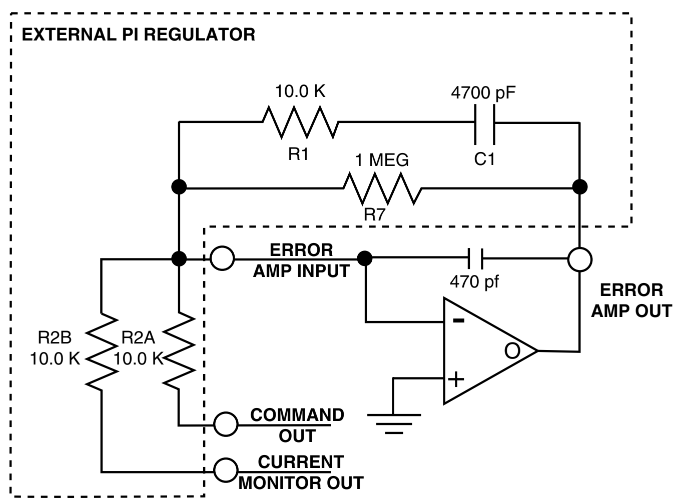


FIGURE 6. STANDARD PI CURRENT LOOP

VBUS+A, VBUS+B, VBUS+C

The VBUS+ supply is the power source for the motor phases. For a 100V-rated device, the normal operating voltage is 28Vdc and may vary from +18 to +70Vdc with respect to VBUS-. The power stage MOSFETS in the hybrid have an absolute maximum VBUS+ supply voltage rating of 100V. The user must supply sufficient external capacitance or circuitry to prevent the bus supply from exceeding the maximum recommended voltages at the hybrid power terminals under any conditions.

The VBUS should be applied at least 50ms after V_{DD} and V_{EE} to allow the internal analog circuitry to stabilize. If this is not possible, the hybrid must be powered up in the "disabled" mode.

VBUS-

This is the high current ground return for VBUS+. This point must be closely connected to SUPPLY GND for proper operation of the current loop.

GROUNDS

SUPPLY GND: SUPPLY GND is the return for the V_{DR}, V_{EE}, V_{DD} supplies. The phase current sensing technique of the PWR-82520X requires that VBUS- and SUPPLY GND be connected together externally (see VBUS- supply).

COMMAND GND: COMMAND GND is used when the command buffer is used single-ended and the COMMAND IN- or COMMAND IN+ is tied to COMMAND GND.

CASE GND: This pin is internally connected to the hybrid case. In some applications the user may want to tie this to Ground for EMI considerations.

SYNC IN

The sync pulse, as shown in FIGURE 7, can be used to synchronize the switching frequency up to 20% faster than the free running frequency of all the slave devices.

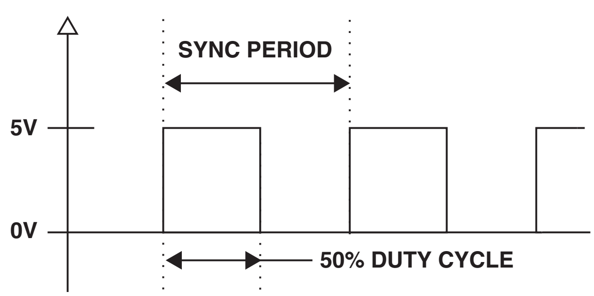


FIGURE 7. SYNC INPUT SIGNAL

V_{DR} (+15V SUPPLY)

This input is used to power the gate driver circuitry for the output MOSFETs. There is no power consumption from V_{DR} when the hybrid is disabled.

V_{CC} (+5V SUPPLY) AND V_{CC} RTN

These inputs are used to power the digital circuitry of the hybrid.

V_{DD} (+5V TO +15V SUPPLY), V_{EE} (-5V TO -15V SUPPLY)

These inputs can vary from ±5V to ±15V as long as they are symmetrical. V_{DD} and V_{EE} are used to power the small signal analog circuitry of the hybrid. Please note that using ±5V supply will reduce approximately 60% of the quiescent power consumption when compared to ±15V operation.

PWM FREQUENCY

The PWM frequency from the PWM OUT pin will free-run at a frequency of 100KHz ± 5KHz. The PWM frequency is user adjustable from 100KHz down to 10KHz through the addition of an external capacitor. The PWM triangle wave generated internally is brought out to the PWM OUT pin. This output, or an external triangle waveform generated by the user, may be connected to PWM IN on the hybrid.

> **WARNING!** The PWR-82520X does not have short circuit protection. Operation into a short or a condition that requires excessive output current will damage the hybrid.

TABLE 3. COMMUTATION TRUTH TABLE

INPUTS					OUTPUTS		
$\overline{\text{ENABLE}}$	DIR**	HA	HB	HC	PHASE A	PHASE B	PHASE C
L	CW	1	0	0	H	L	Z
L	CW	1	1	0	H	Z	L
L	CW	0	1	0	Z	H	L
L	CW	0	1	1	L	H	Z
L	CW	0	0	1	L	Z	H
L	CW	1	0	1	Z	L	H
L	CCW	1	0	1	Z	H	L
L	CCW	0	0	1	H	Z	L
L	CCW	0	1	1	H	L	Z
L	CCW	0	1	0	Z	L	H
L	CCW	1	1	0	L	Z	H
L	CCW	1	0	0	L	H	Z
H	-	-	-	-	Z	Z	Z

NOTES:
1=Logic Voltage >2.4Vdc, 0=Logic voltage < 0.8Vdc
** DIR is based on the convention shown in FIGURE 4.
Actual motor set up might be different.

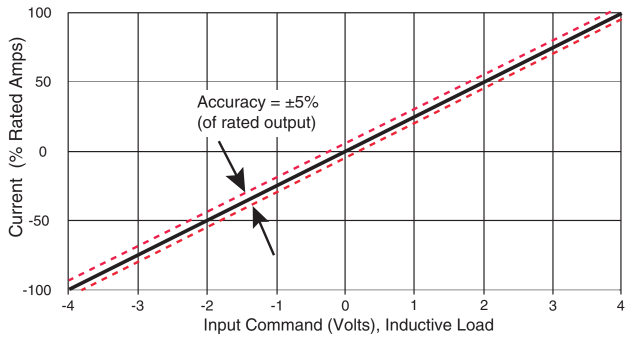


FIGURE 8. ACCURACY CURVE

TABLE 4. HALL INPUTS FOR H-BRIDGE CONTROLLER

INPUTS					OUTPUTS		
$\overline{\text{ENABLE}}$	COMMAND IN	HA	HB	HC	PH A	PH B	PH C
L	Positive	1	1	0	H	Z	L
L	Negative	1	1	0	L	Z	H
H	-	1	1	0	Z	Z	Z

PWM OUT

This is the output of the internally generated PWM triangle waveform. It is normally connected to PWM IN. The frequency of this output may be lowered by connecting an NPO capacitor (Cext) between PWM OUT and COMMAND GND. The PWM frequency is determined by the following formula:

$$\frac{16.5E\text{-}6}{330pF + C_{EXT}pF}$$

PHASE A, B, C

These are the power drive outputs to the motor and switch between VBUS+ Input and VBUS- Input or become high impedance - see TABLE 3.

OUTPUT CURRENT

Output current derating as a function of the hybrid case temperature is provided in FIGURE 9. The hybrid contains internal pulse by pulse current limit circuitry to limit the output current during fault conditions. (See TABLE 2) Current Limit accuracy is +10/-15%.

> **WARNING:** Never apply power to the hybrid without connecting either PWM OUT or an external triangular wave to PWM IN! Failure to do so may result in one or more outputs latching on.

TACH OUT

The TACH OUT provides a tachometer signal relative to motor speed which is derived from the three Hall inputs HA, HB, and HC. The tach circuitry combines these three signals into a single pulse train as a 50%-duty-cycle pulse. There are three puls-

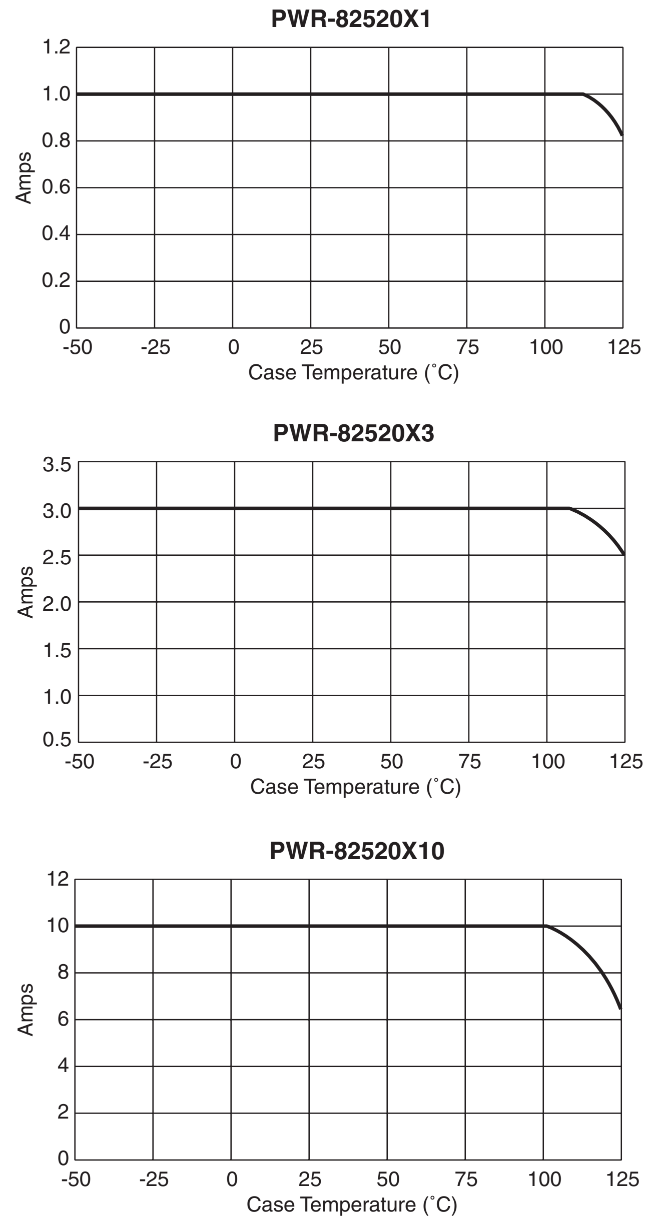


FIGURE 9. OUTPUT CURRENT FOR CONTINUOUS COMMUTATION (ELECTRICAL > 600RPM, VBUS+ = 28V, PWM = 100KHZ)

es that occur every 360 electrical degree. The number of pulses per motor revolution is formulated below:

$$Pr = \frac{P}{2} \times 3 \text{ (e.g., 6 pulses/revolution for a 4 pole motor)}$$

The motor RPM is:

$$RPM = \frac{60}{T \times Pr}$$

where,

P = number of motor pole
Pr = number of pulses per revolution
T = pulse period in seconds

DIR OUT

The DIR OUT indicates the direction the motor is rotating, clockwise (CW) or counterclockwise (CCW).

BRUSH MOTOR OPERATION

The PWR-82520X can also be used as a brush motor controller for current or voltage control in an H-Bridge configuration. The PWR-82520X would be connected as shown in FIGURE 11. All other connections are as shown in either FIGURE 12 or 13 depending on voltage or current mode operation. The Hall inputs are wired per TABLE 4. A positive input command will result in positive current to the motor out of Phase A.

THERMAL OPERATION

It is recommended the PWR-82520X be mounted to a heat sink. This heat sink shall have the capacity to dissipate heat generated by the hybrid at all levels of current output, up to the peak limit, while maintaining the case temperature limit as per FIGURE 9.

RADIATION (PWR-82520R SERIES ONLY)

Total Dose: The hybrid shall operate, as specified in TABLE 2, when subjected to a total dose radiation environment of 100KRad (Si) at a dose rate of 0.5 Rad/sec.

Single Event Upset: The hybrid shall be Single Event Upset (SEU) immune and still meet the requirements of TABLE 2 for a Linear Energy Transfer (LET) level of 36 MeV/mg/cm^2.

Latch-up: The hybrid shall be latch-up immune and still meet the requirement of TABLE 2 for a LET level of 36 MeV/mg/cm^2.

NOTE: 100KRad (Si) total dose of radiation is usually two to three times the operational level of commercial and military satellites. This results in a large cost savings for the end user since Lot Acceptance Tests (LAT) are usually not required.

OPTIONAL FEATURES

External Sensing Resistor: The external sensing points are available for the end users to install an external resistor (non-inductive). The resistance of the resistor is scaled to the applicable current range. Please contact factory for this option.

Flat Package: PWR-82520X1 & -X3 are also offered in a flat package configuration as shown in Figure 15. Please contact factory for price and delivery.

Class S Processing: PWR-82520XX substrate is set up to be screened to military class S level (hybrid class K). Please contact factory for price and delivery.

PSpice modeling: The PSpice mathematical modeling of the PWR-82520XX is also available to support end users in their initial design analysis. Please contact factory for application support.

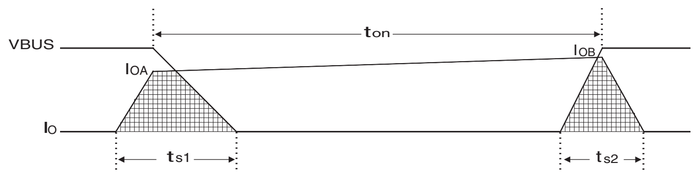


FIGURE 10. OUTPUT CHARACTERISTICS

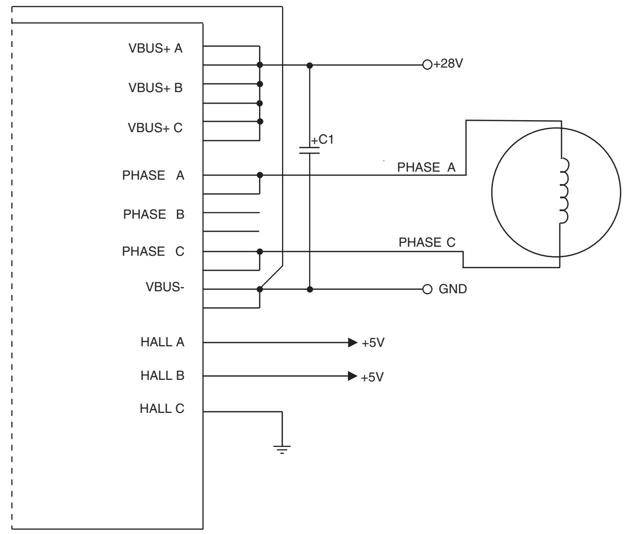


FIGURE 11. BRUSH MOTOR HOOK-UP

PWR-82520X Power Dissipation (see FIGURE 10)

There are two major contributors to power dissipation in the motor driver: conduction losses, and switching losses.

An example calculation is shown below:

VBUS = +28 V (Bus Voltage)

Ioa = 3 A, Iob = 7 A (see FIGURE 10)

ton = 36 µs, T = 40 µs (90% duty cycle) (see FIGURE 10)

Ron = 0.055 W (on-resistance, see TABLE 2)

Rc = 0.133 W (conductor resistance, see TABLE 2)

ts1 = 125 ns, ts2 = 200 ns (see FIGURE 10)

fo = 50 KHz (switching frequency)

1. Transistor Conduction Losses (P_T)

Pt = (Imotor rms)2 x (Ron)

Pt = (4.87)2 x (0.055)

Pt = 1.30 Watts

$$I_{motor\ rms} = \sqrt{\left(I_{OB}I_{OA} + \frac{(I_{OB} - I_{OA})^2}{3}\right)\left(\frac{ton}{T}\right)}$$

$$I_{motor\ rms} = \sqrt{\left(7 * 3 + \frac{(7 - 3)^2}{3}\right)\left(\frac{36}{40}\right)}$$

2. Switching Losses (Ps)

Ps = [VBUS (Ioa (ts1) + Iob (ts2)) fo] / 2

Ps = [28 V (3 A (125 ns) + 7 A (200 ns)) 50 KHz] / 2

Ps = 1.24 Watts

TRANSISTOR POWER DISSIPATION (Pq)

Pq = Pt + Ps

Pq = 1.30 + 1.24 = 2.54 Watts

OUTPUT CONDUCTOR DISSIPATION

Pc = (Imotor rms)2 x (Rc)

Pc = (4.87)2 x (0.133)

Pc = 3.15 Watts

TRANSISTOR POWER DISSIPATION FOR CONTINUOUS COMMUTATION

Pqc = Pq (0.33)

Pqc = (2.54) x (0.33)

Pqc = 0.84 Watts

TOTAL HYBRID POWER DISSIPATION

Ptotal = (Pq + Pc) x 2

Ptotal = (2.54 + 3.15) x 2

Ptotal = 11.38 Watts

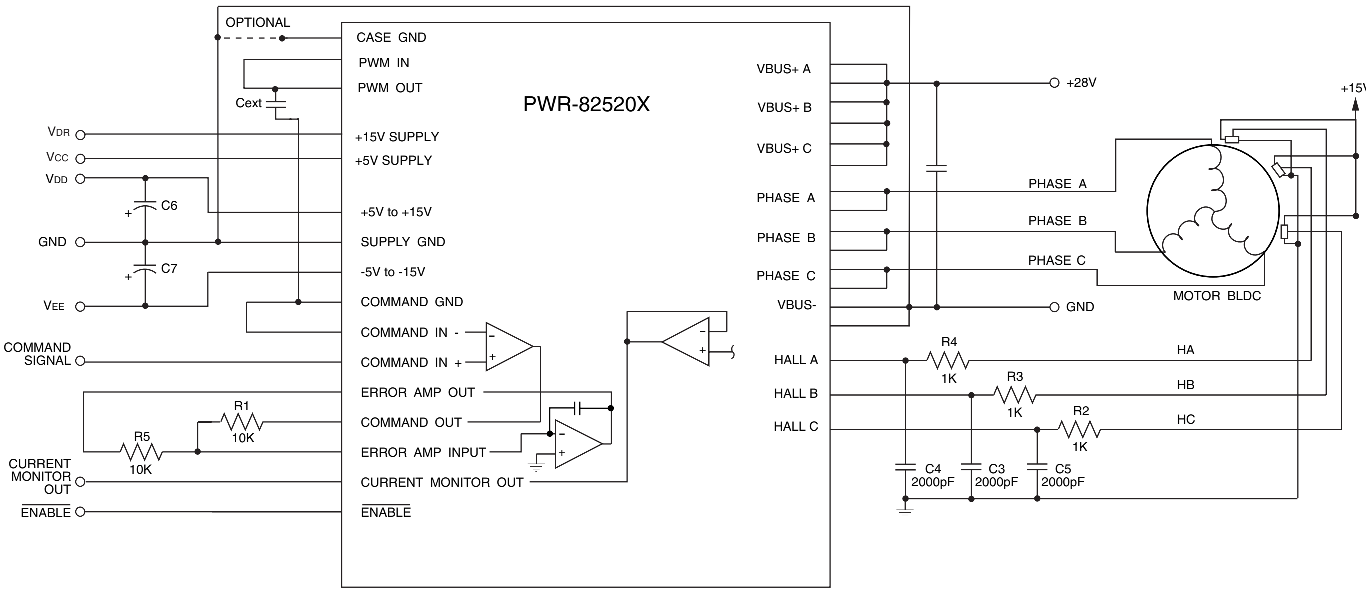


FIGURE 12. VOLTAGE CONTROL HOOK-UP

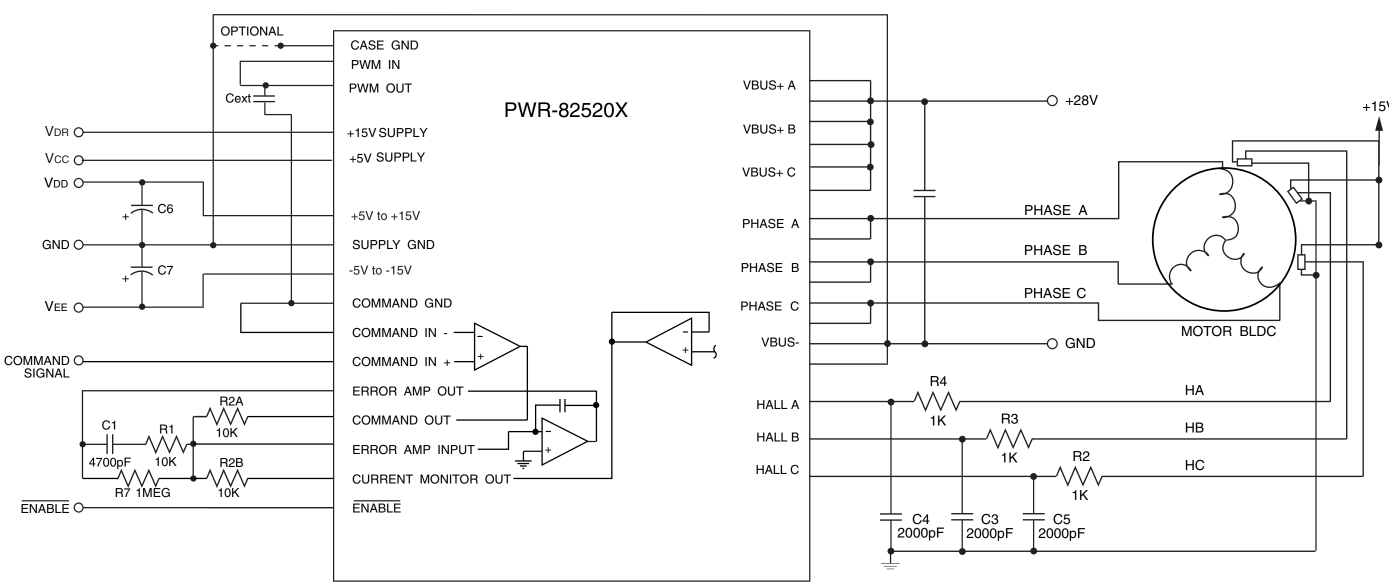


FIGURE 13. TORQUE (CURRENT) CONTROL HOOK-UP

PIN ASSIGNMENTS

TABLE 5A. PIN ASSIGNMENTS X1 & X3

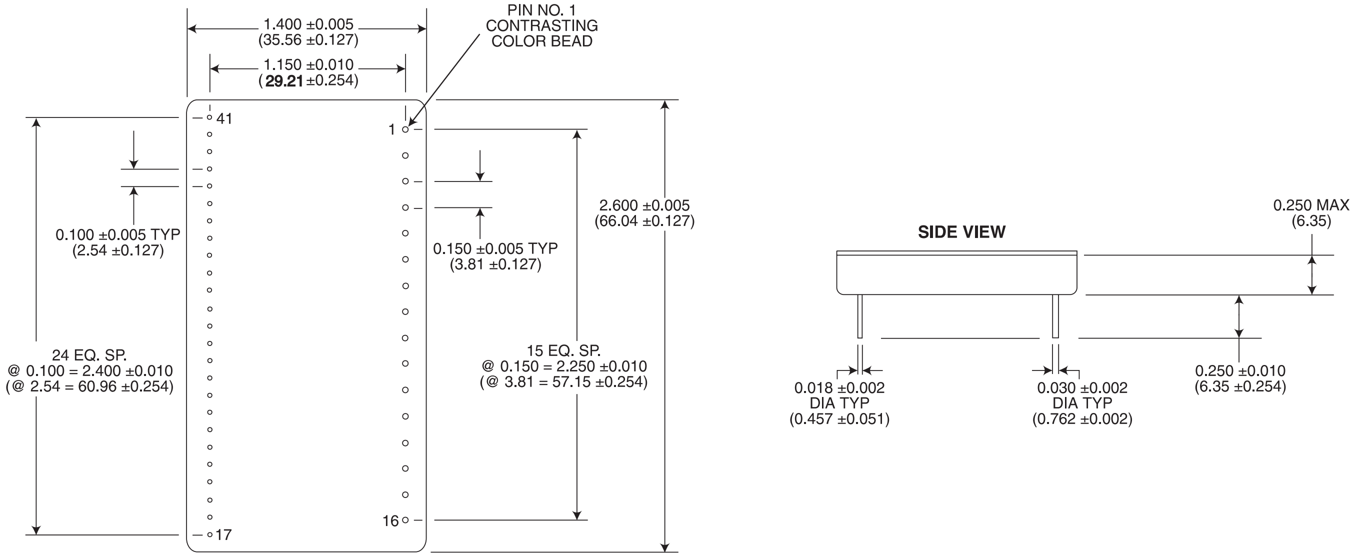
PIN	FUNCTION	PIN	FUNCTION
1	VBUS+ C	41	TACH OUT
2	VBUS+ C	40	DIR OUT
3	PHASE C	39	HALL A
4	PHASE C	38	HALL B
5	VBUS+ B	37	HALL C
6	VBUS+ B	36	$\overline{\text{ENABLE}}$
7	PHASE B	35	V_{CC}
8	PHASE B	34	V_{CC} RTN
9	VBUS-	33	V_{DR}
10	VBUS-	32	SYNC IN
11	R_S+	31	V_{DD}
12	R_S+	30	SUPPLY GND
13	VBUS+ A	29	V_{EE}
14	VBUS+ A	28	N/C
15	PHASE A	27	N/C
16	PHASE A	26	CURRENT MONITOR OUT
		25	ERROR AMP IN
		24	ERROR AMP OUT
		23	COMMAND OUT
		22	COMMAND IN -
		21	COMMAND IN +
		20	COMMAND GND
		19	PWM OUT
		18	PWM IN
		17	CASE GND

* N/C pins have internal connections for factory test purposes.

TABLE 5B. PIN ASSIGNMENTS X10

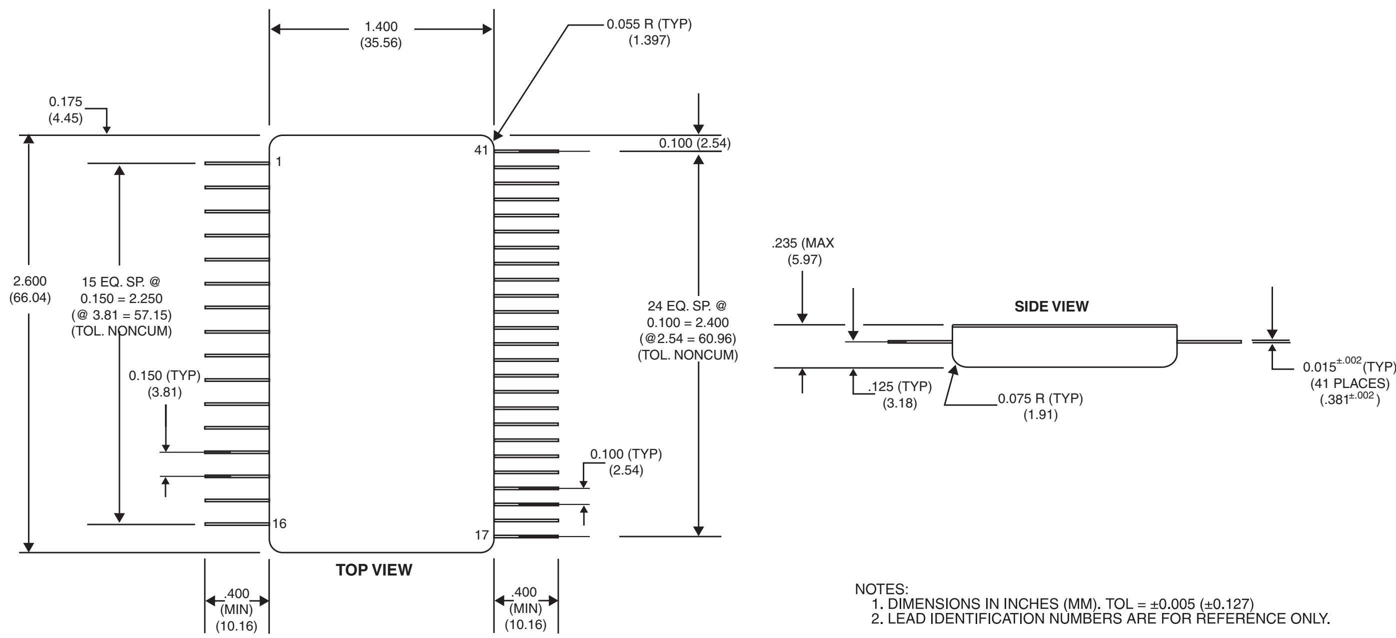
PIN	FUNCTION	PIN	FUNCTION
1	CASE GND	27	VBUS+ C
2	N/C	28	VBUS+ C
3	PWM IN	29	PHASE C
4	PWM OUT	30	PHASE C
5	COMMAND GND	31	VBUS+ B
6	COMMAND IN +	32	VBUS+ B
7	COMMAND IN -	33	PHASE B
8	COMMAND OUT	34	PHASE B
9	ERROR AMP OUT	35	VBUS-
10	ERROR AMP IN	36	VBUS-
11	CURRENT MONITOR OUT	37	R_S+
12	N/C	38	R_S+
13	N/C	39	VBUS+ A
14	V_{EE}	40	VBUS+ A
15	SUPPLY GND	41	PHASE A
16	V_{DD}	42	PHASE A
17	SYNC IN	43	N/C
18	V_{DR}		
19	V_{CC} RTN		
20	V_{CC}		
21	$\overline{\text{ENABLE}}$		
22	HALL C		
23	HALL B		
24	HALL A		
25	DIR OUT		
26	TACH OUT		

* N/C pins have internal connections for factory test purposes.



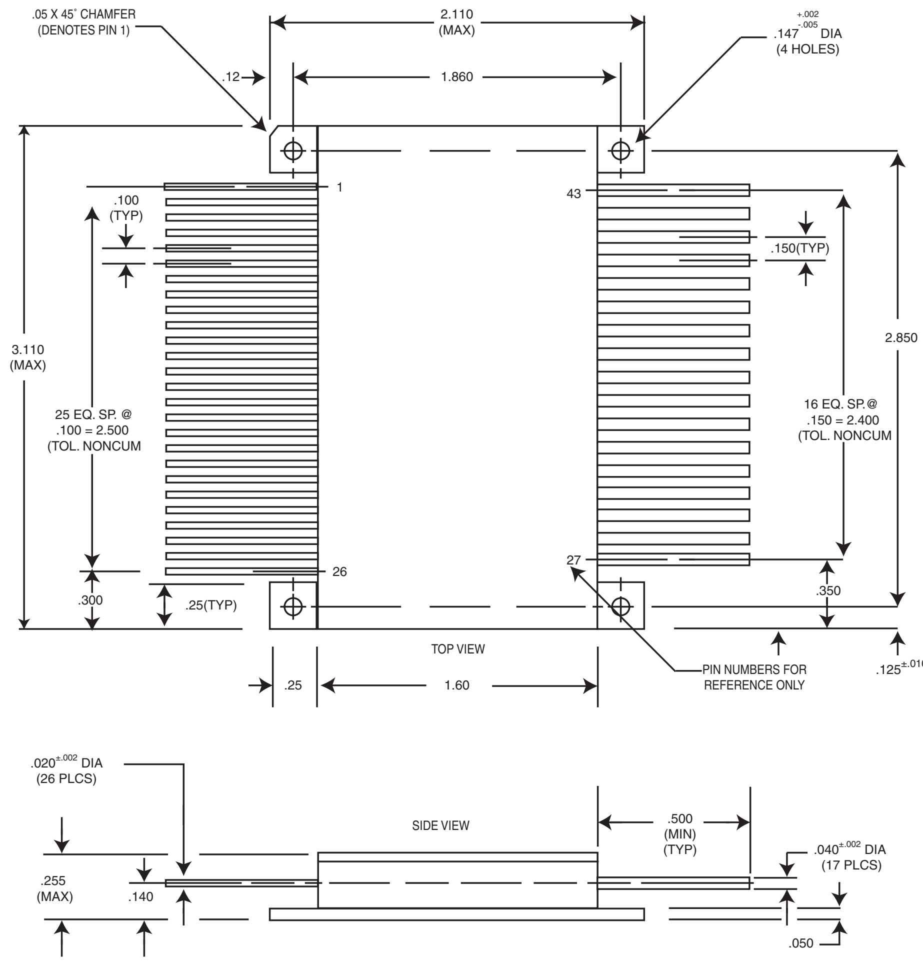
NOTES:
1. DIMENSIONS IN INCHES (MM). TOL = ±0.005 (±0.127)
2. LEAD IDENTIFICATION NUMBERS ARE FOR REFERENCE ONLY.

FIGURE 14. MECHANICAL OUTLINE (X1, X3)



NOTES:
1. DIMENSIONS IN INCHES (MM). TOL = ±0.005 (±0.127)
2. LEAD IDENTIFICATION NUMBERS ARE FOR REFERENCE ONLY.

FIGURE 15. OPTIONAL FLAT PACKAGE OUTLINE (X1, X3)



NOTES:
1. DIMENSIONS IN INCHES (MM). TOL = ±0.005 (±0.127)
2. LEAD IDENTIFICATION NUMBERS ARE FOR REFERENCE ONLY.

FIGURE 16. MECHANICAL OUTLINE (X10)

ORDERING INFORMATION

PWR-82520XX- XX0

Reliability Grade:
0 = Standard DDC Procedures.
1 = Military processing available.
2 = Military processing available but without QCI Testing.

Temperature Range:
1 = - 55 to +125°C
3 = 0 to +70°C

Rating:
1 - 1A
3 - 3A
10 - 10A

Radiation Tolerance
N = Non radiation tolerant
R = 100Krad radiation tolerance

Consult factory for class K processing.

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