

Juno™ Velocity & Torque Control IC

MC78113 Electrical Specifications



Performance Motion Devices, Inc.
1 Technology Park Drive
Westford, MA 01886



NOTICE

This document contains proprietary and confidential information of Performance Motion Devices, Inc., and is protected by federal copyright law. The contents of this document may not be disclosed to third parties, translated, copied, or duplicated in any form, in whole or in part, without the express written permission of PMD.

The information contained in this document is subject to change without notice. No part of this document may be reproduced or transmitted in any form, by any means, electronic or mechanical, for any purpose, without the express written permission of PMD.

Copyright 1998–2017 by Performance Motion Devices, Inc.

Juno, ATLAS, Magellan, ION, Prodigy, Pro-Motion, C-Motion, and VB-Motion are trademarks of Performance Motion Devices, Inc.

Warranty

PMD warrants that its products shall substantially comply with the specifications applicable at the time of sale, provided that this warranty does not extend to any use of any PMD product in an Unauthorized Application (as defined below). Except as specifically provided in this paragraph, each PMD product is provided “as is” and without warranty of any type, including without limitation implied warranties of merchantability and fitness for any particular purpose.

PMD reserves the right to modify its products, and to discontinue any product or service, without notice and advises customers to obtain the latest version of relevant information (including without limitation product specifications) before placing orders to verify the performance capabilities of the products being purchased. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, patent infringement and limitation of liability.

Unauthorized Applications

PMD products are not designed, approved or warranted for use in any application where failure of the PMD product could result in death, personal injury or significant property or environmental damage (each, an “Unauthorized Application”). By way of example and not limitation, a life support system, an aircraft control system and a motor vehicle control system would all be considered “Unauthorized Applications” and use of a PMD product in such a system would not be warranted or approved by PMD.

By using any PMD product in connection with an Unauthorized Application, the customer agrees to defend, indemnify and hold harmless PMD, its officers, directors, employees and agents, from and against any and all claims, losses, liabilities, damages, costs and expenses, including without limitation reasonable attorneys’ fees, (collectively, “Damages”) arising out of or relating to such use, including without limitation any Damages arising out of the failure of the PMD product to conform to specifications.

In order to minimize risks associated with the customer’s applications, adequate design and operating safeguards must be provided by the customer to minimize inherent procedural hazards.

Disclaimer

PMD assumes no liability for applications assistance or customer product design. PMD does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of PMD covering or relating to any combination, machine, or process in which such products or services might be or are used. PMD’s publication of information regarding any third party’s products or services does not constitute PMD’s approval, warranty or endorsement thereof.

Related Documents

Juno Velocity & Torque Control IC User's Guide

Complete description of the Juno Velocity & Torque Control IC features and functions with detailed theory of operations.

Juno Velocity & Torque Control IC Command Reference

Description of all Juno family IC commands, with coding syntax and examples, listed alphabetically for quick reference.

MC78113 Developer's Kit User's Manual

How to install and configure the DK78113 Developer's Kit.

Pro-Motion User's Guide

User's guide to Pro-Motion, the easy-to-use motion system development tool and performance optimizer. Pro-Motion is a sophisticated, easy-to-use program which allows all motion parameters to be set and/or viewed, and allows all features to be exercised.

Table of Contents

1. The Juno MC78113 IC Family	9
1.1 Introduction	9
1.2 Juno Velocity & Torque Control IC Family Overview	9
2. Functional Characteristics	11
2.1 Configurations, Parameters, and Performance.	11
2.2 Physical Characteristics and Mounting Dimensions.	13
2.3 Absolute Maximum Environmental and Electrical Ratings ¹	14
3. Electrical Characteristics	15
3.1 DC Characteristics for MC78113-Series ICs.	15
3.2 AC Characteristics	16
4. Timing Diagrams	19
4.1 Clock	19
4.2 Quadrature Encoder Input.	19
4.3 SPI Timing	20
4.4 Power On Timing	20
4.5 Warm Reset	21
4.6 Pulse & Direction	21
5. Pinouts and Pin Descriptions	23
5.1 Pinouts for the MC78113	23
5.2 Pinouts for the MC71113	24
5.3 Pinouts for the MC73113	25
5.4 Pinouts for the MC74113	26
5.5 Pinouts for the MC75113	27
5.6 MC78113-Series ICs Pin Descriptions.	28
6. Electrical Operational Information	33
6.1 MC78113 Connection Overview	34
6.2 MC78113 Internal Block Diagram	35
6.3 Switching Amplifier Control	35
6.4 Current Control	43
6.5 Drive & DC Bus Safety	46
6.6 Host Communications.	52
6.7 Input Signal Processing.	54
6.8 Reset & Power-up	59
6.9 MC78113 RAM and NVRAM Buffers	60
6.10 Output Signal Status During Powerup	61
6.11 Analog Signal Input	61
7. Application Notes — MC78113	63
7.1 General Design Notes	63
7.2 Design Tips	64
7.3 Power Supplies	66
7.4 Clock Generator, Grounding and Decoupling	68
7.5 Reset Signal.	70
7.6 Serial Communication Interface (SCI)	71

7.7	CAN Communication Interface	74
7.8	SPI Communication Interface.....	76
7.9	Analog Inputs.....	78
7.10	Drive-Related Safety and Monitoring Features	80
7.11	Shunt Resistor Drive.....	82
7.12	PWM High/Low Motor Drive With Leg Current Sensing/Control.....	84
7.13	Using the TI LMD18200 to Drive DC Brush Motors.....	98
7.14	Two Juno Step Motor Amplifiers With Multi-Axis Magellan	100
7.15	Two Juno BLDC Motor Amplifiers With Multi-Axis Magellan	102

List of Figures

2-1	MC78113 physical dimensions	13
4-1	Clock Timing	19
4-2	Quad Encoder Timing	19
4-3	SPI Timing	20
4-4	Power On Timing	20
4-5	Warm Reset Timing	21
4-6	Pulse & Direction Timing	21
5-1	MC78113 Pinouts	23
5-2	MC71113 Pinouts	24
5-3	MC73113 Pinouts	25
5-4	MC74113 Pinouts	26
5-5	MC75113 Pinouts	27
6-1	MC78113 Interconnections	34
6-2	MC78113 Family ICs Internal Block Diagram	35
6-3	PWM High/Low Encoding	36
6-4	PWM High/Low Signal Generation	36
6-5	Brushless DC Motor Bridge Configuration	37
6-6	DC Brush Motor Bridge Configuration	38
6-7	Two-phase Step Motor Bridge Configuration	39
6-8	Sign/Magnitude PWM Encoding	41
6-9	Sign/Magnitude PWM DC Brush Motor Connections	41
6-10	Sign/Magnitude PWM Step Motor Connections	42
6-11	Typical Current Signal Processing Circuitry	44
6-12	Over-temperature Processing Circuitry	47
6-13	Overcurrent Monitoring Circuitry	48
6-14	DC Bus Monitoring Circuitry	49
6-15	Quadrature Encoder Processing Circuitry	55
6-16	Pulse & Direction Processing Circuitry	56
6-17	Hall-Based Phase Diagram	57
6-18	Typical Hall Processing Circuitry	57
6-19	AnalogCmd and Tachometer Circuitry	58
6-20	Typical Reset Processing Circuitry	59
7-1	Basics, Power Supplies, MC78113	67
7-2	Basics, Clock and Bypass Caps, MC78113	69
7-3	Host Communication, RS-232 and RS-485	73
7-4	Host Communication CANbus	75
7-5	Host Communication SPI	77
7-6	Analog Input Interface	79
7-7	Drive Safety and Monitoring	81
7-8	Shunt Drive Circuit	83
7-9	Leg Current Sensing	86
7-10	Low Cost DC Drive with Leg Current Sensing	89
7-11	Step Motor Drive with Leg Current Sensing	91
7-12	BLDC Motor Drive - Leg Current Sensing	93
7-13	BLDC Motor Drive - Power Train	94
7-14	BLDC Drive with Intelligent Power Module	97
7-15	DC Brush Amplifier Using LMD 18200	99



7-16	Two-Axis Step Motor Drive With Multi-Axis Magellan	101
7-17	Two-Axis BLDC Motor Drive With Multi-Axis Magellan Axis	103

1. The Juno MC78113 IC Family

1

In This Chapter

- ▶ Introduction
- ▶ Juno Velocity & Torque Control IC Family Overview

1.1 Introduction

This manual describes the electrical characteristics of the MC78113, MC71113, MC73113, MC74113, and MC75113 ICs from Performance Motion Devices, Inc. These five devices comprise PMD's Juno Velocity & Torque Control IC family.

The Juno ICs provide high performance velocity and current control for Brushless DC, DC Brush, and step motors. They are ideal for a wide range of applications including precision liquid pumping, laboratory automation, scientific automation, flow rate control, pressure control, centrifuge control, hydraulic & pneumatic valve control, and a wide range of other robotic, scientific, and industrial applications.

The desired instantaneous velocity or torque can be input via an analog input, or an SPI input. Alternatively, an internal profile capability can be used which provides acceleration and deceleration to a command velocity with 32-bit precision. Pulse, Direction and AtRest signal inputs are also available to allow direct external position command input.

Juno provides full four quadrant motor control and directly inputs quadrature encoder, index, and Hall sensor signals. It interfaces to external bridge-type switching amplifiers utilizing PMD's proprietary current and switch signal technology for ultra smooth, ultra quiet motor operation.

Additional Juno features include performance trace, programmable breakpoints, FOC (field oriented control), microstep signal generation, and external shunt resistor control. Juno ICs can be pre-configured via NVRAM for auto power-up initialization and standalone operation. Alternatively Juno can interface via SPI, point-to-point serial, multi-drop serial, or CANbus to a microprocessor.

All Juno ICs are packaged in 64-pin TQFPs (thin quad flat packs) and measure 12.0 mm x 12.0 mm including leads.

1.2 Juno Velocity & Torque Control IC Family Overview

There are five members of the Juno IC family, each supporting different motor types or configurations. Developer's Kits are available which support each member of the Juno IC family: The following table shows this:

P/N	Developer's Kit P/N	Motor supported	Comments
MC71113	DK71113	DC Brush	
MC73113	DK73113	Brushless DC	
MC74113	DK74113	Step Motor	Provides quadrature encoder input
MC75113	DK75113	Step Motor	No quadrature encoder input

P/N	Developer's Kit P/N	Motor supported	Comments
MC78113	DK78113	Multi-motor (Brushless DC, DC Brush, Step Motor)	Motor type is user settable

All of the above Developer's Kit versions share the same physical DK78113 card as well as the same software CD. They differ in the specific type of MC78113 family IC that is installed.

The following table summarizes the operating modes and control interfaces supported by the five members of the Juno IC family:

	MC71113 (DC Brush)	MC73113 (Brushless DC)	MC74113 MC75113 (Step Motor)	MC78113 (Multi Motor)
Control Mode				
Velocity	✓	✓		✓
Torque/current	✓	✓	✓	✓
Microprocessor Host Interface				
Serial point-to-point (RS232)	✓	✓	✓	✓
Serial multi-drop (RS485)	✓	✓		✓
CANbus	✓	✓		✓
Direct Input Command Mode				
Analog velocity or torque command	✓	✓		✓
SPI velocity or torque command	✓	✓	✓	✓
Pulse & direction	✓	✓	✓	✓
Signal I/O				
Quadrature encoder input	✓	✓	✓ (MC74113 only)	✓
Hall sensor input		✓		✓
Tachometer analog input	✓	✓		✓
AtRest signal input			✓	✓
Shunt control output	✓	✓		✓



Note that throughout this manual in addition to the MC78113 IC, the term MC78113 may also be used to mean the complete product family; MC78113, MC71113, MC73113, MC51113, MC74113, and MC75113.

2. Functional Characteristics

2

In This Chapter

- ▶ Configurations, Parameters, and Performance
- ▶ Physical Characteristics and Mounting Dimensions
- ▶ Absolute Maximum Environmental and Electrical Ratings

2.1 Configurations, Parameters, and Performance

Command Modes	Internal profile	Velocity or torque command is provided via an internal profile generator function
	Analog	Velocity or torque command is provided via external direct analog input
	SPI	Velocity or torque command is provided via external direct SPI (Serial Peripheral Interface) input
	Pulse & Direction	Position or velocity is provided via external pulse & direction input signals
Current control modes	FOC	For Brushless DC and step motors field oriented control loop provides active current control utilizing leg current input
	Third leg floating	For brushless DC motors Hall-based mode drives two of three legs using active current control with the third leg floating
	Single phase	For DC Brush motors a single phase current loop provides active current control utilizing leg current input
	Current Loop Off	Voltage mode control, no current feedback used
Host communication modes	SPI (Serial Peripheral Interface) Point to point asynchronous serial Multi-drop asynchronous serial CAN bus 2.0B	
Host SPI frequency range	1.0 MHz - 10.0 MHz	
Serial port baud rate range	1,200 baud to 460,800 baud (1,200, 2,400, 9,600, 19,200, 57,600, 115,200, 230,400, 460,800)	
CAN port transmission rate range	10,000 baud to 1,000,000 baud (10,000, 20,000, 50,000, 125,000, 250,000, 500,000, 1,000,000)	
Position range	-2,147,483,648 to +2,147,483,647 counts or steps	
Velocity range	-32,768 to +32,767 counts or steps per cycle with a resolution of 1/65,536 counts or steps per cycle	
Acceleration and deceleration ranges	0 to +127 counts or steps per cycle ² with a resolution of 1/16,777,216 counts or steps per cycle ²	

Velocity filter	Scalable PI with integration limit, output motor command limiting and programmable bi-quad filter for velocity estimation.	
Filter parameter resolution	16 bits	
Biquad filter parameter resolution	32 bits	
Position & Velocity error	32 bits	
Velocity error tracking	Motion error window allows axis to be stopped upon exceeding programmable velocity error	
Motor output modes	PWM High/Low	Individual high and low drive signals for each bridge switch
	Sign/Magnitude PWM	Separate sign and magnitude drive signal for each phase of switching bridge.
Commutation rate	19.53 kHz	
Current loop rate	19.53 kHz	
Current measurement resolution	12 bits	
PWM resolution & rates	1:1,536 @ 20 kHz	
	1:768 @ 40 kHz	
	1:384 @ 80 kHz	
	1:256 @ 120 kHz	
Current loop type	P, I (proportional integral) with integral limit	
Current loop resolution	16 bits	
Drive safety functions	Over current detect, over temperature detect, over voltage detect, under voltage detect, i^2t current foldback	
Brake input modes	Passive braking, full disable	
Output limiting	i^2t , current, and voltage limit	
NVRAM storage size	1,024 16-bit words	
Microstepping waveform	Sinusoidal	
Microsteps per full step	1 to 256	
Maximum encoder rate	25 Mcounts/sec	
Hall sensor inputs	3 Hall effect inputs	
Cycle time range	51.2 microseconds to 1.114 seconds	
Position-capture triggers	Index signal	
Software-invertible signals	Quad A, Quad B, Index, Home, HallA, HallB, HallC, Pulse, Direction, AtRest	
Internal RAM	6,144 16-bit words	
Maximum number of simultaneous trace variables	4	

2.2 Physical Characteristics and Mounting Dimensions

All dimensions are in millimeters.

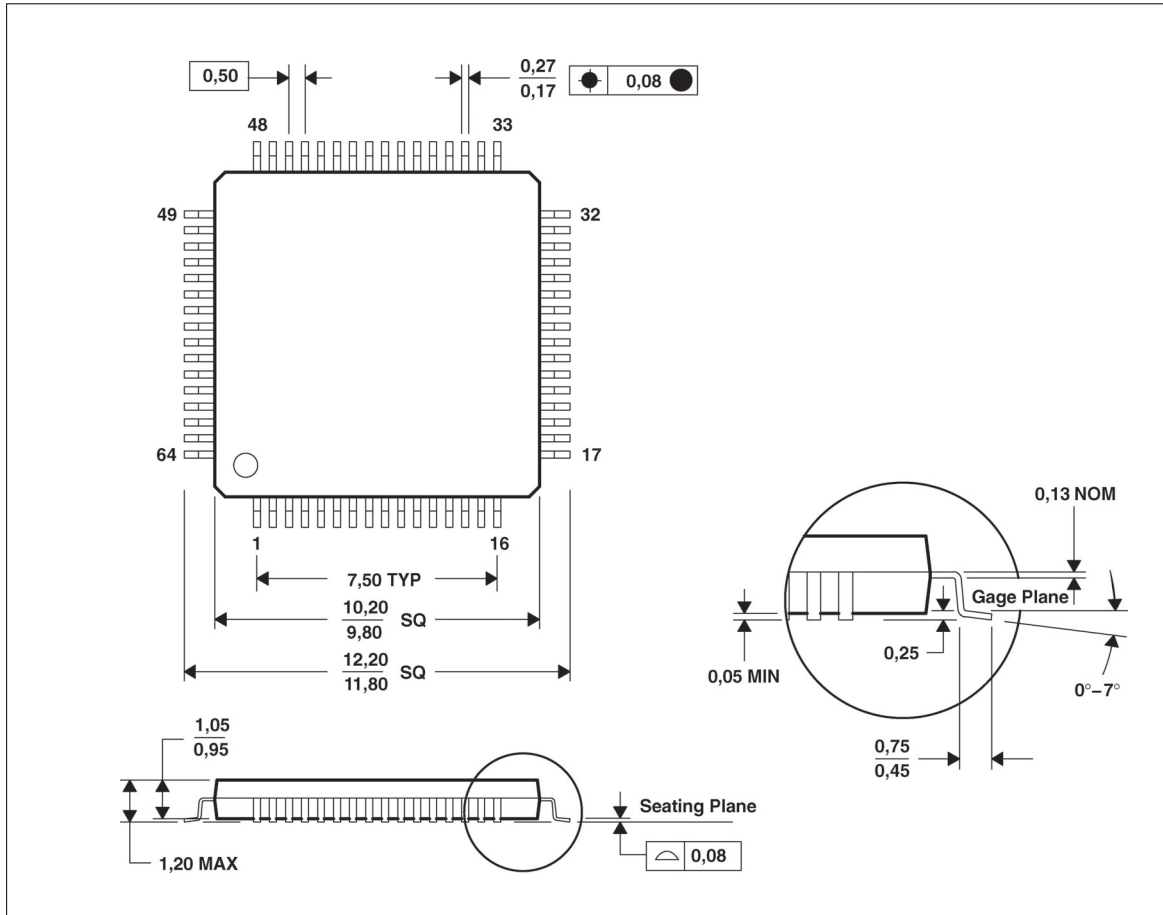


Figure 2-1:
MC78113
physical
dimensions

Notes:

- 1 Juno IC is RoHS compliant and free of Bromine and Antimony based flame retardants.
- 2 Moisture sensitive level: MSL 3

2.3 Absolute Maximum Environmental and Electrical Ratings¹

Supply voltage (Vcc)	-0.3V to +4.6V
FltCap pin voltage range	-0.3V to 2.5V
Analog voltage range with respect to AnalogGND (AnalogVcc)	-0.3V to +4.6V
Input voltage (Vi)	-0.3V to +4.6V
Output voltage (Vo)	-0.3V to +4.6V
Input clamp current (Ii,clamp), peak:	+/-20 mA
continuous:	+/-2 mA
Output clamp current (Io,clamp)	+/-20 mA
Package thermal impedance (θ_{JA})	56.5°C/W
Junction temperature range (Tj) ⁽²⁾	-40°C to 150°C
Storage temperature range (Ts)	-65°C to 150°C
Nominal clock frequency (FclkIn)	10.0 MHz

(1) Unless otherwise noted, all voltages are with respect to GND

(2) Please refer to “Design tips” section for more information

3. Electrical Characteristics

In This Chapter

- ▶ DC Characteristics for MC78113-Series ICs
- ▶ AC Characteristics

3.1 DC Characteristics for MC78113-Series ICs

(V_{cc} and T_a per operating ratings, F_{clkin}=10.0MHz)

Symbol	Parameter	Minimum	Maximum	Conditions
V _{cc}	Supply voltage	2.97V	3.63V	With respect to GND
I _{dd}	Supply current		115 mA	All I/O pins are floating
AnalogV _{cc}	Analog input supply voltage	2.97V	3.63V	With respect to AnalogGND
AnalogI _{dd}	Analog supply current		18 mA	
T _a	Operating free-air temperature	-40°C	105°C	Note 2
T _j	Operating junction temperature	-40°C	150°C	
Input Voltage				
V _{ih}	Logic 1 input voltage	2.0V	V _{cc} +0.3V	
V _{il}	Logic 0 input voltage	-0.3V	0.8V	
Output Voltage				
V _{oh}	Logic 1 Output Voltage	2.4V		I _o =-4 mA
		V _{cc} -0.2V		I _o =-50 μA
V _{ol}	Logic 0 Output Voltage		0.4V	I _o =4 mA
Other				
I _{out}	Tri-state output leakage current	-2 μA	2 μA	V _o =0 or V _{cc}
I _{in}	Input current	2 μA	-205 μA	V _{cc} =3.3V with internal pullup
I _{in,~RESET}	Input current for ~RESET pin	2 μA	-375 μA	V _{cc} =3.3V
C _i	Input capacitance		2 pF	typical
V _{fltcap}	FltCap voltage		1.9V	typical
V _{reset}	V _{cc} BOR trip point	2.50V	2.96V	Falling V _{cc}
V _{reset,hys}	V _{cc} BOR hysteresis		35 mV	typical
T _{reset}	BOR reset release delay time	400 μs	800 μs	Time from removing reset to ~RESET release

Symbol	Parameter	Minimum	Maximum	Conditions
Analog Input				
V_{analog}	Analog input voltage range	0	3.3V	With respect to AnalogGND
C_{ai}	Analog input capacitance		5 pF	typical
E_{dnl}	Differential nonlinearity error. Difference between the step width and the ideal value. No missing codes.	-1	1	LSB
E_{inl}	Integral nonlinearity error. Maximum deviation from the best straight line through the ADC transfer characteristics, excluding the quantization error.	-4	4	LSB
E_{zo}	Zero-offset error	-4	4	LSB

Notes:

(1) V_{cc} and Analog V_{cc} should be within 0.3V from each other.

(2) Please refer to design tips in the Application Notes of this manual for thermal design considerations.

3.2 AC Characteristics

Refer to [Chapter 4, Timing Diagrams](#), for timing diagrams.

3.2.1 Clock

Timing Interval	No.	Min	Max
ClkIn frequency, typical			10 MHz
ClkIn period, typical	T1		100 nSec
ClkIn fall time	T2		6 nSec
ClkIn rise time	T3		6 nSec
ClkIn pulse duration		0.45 T1	0.55 T1

3.2.2 Quadrature Encoder Input

Timing Interval	No.	Min	Max
Encoder pulse width	T4	33.3 nSec	
Dwell time per state	T5	16.7 nSec	
~Index active pulse time	T6	33.3 nSec	

Notes:

(1) ~Index is defaulted as active low, which is shown here. It can be configured to be active high.

3.2.3 Host SPI

Timing Interval	No.	Min	Max
HostSPIClock clock cycle time	T23	100 nSec	
Pulse duration, HostSPIClock high	T24	(0.5 T23-10) nSec	0.5 T23
Pulse duration, HostSPIClock low	T25	(0.5 T23-10) nSec	0.5 T23
~HostSPISetup low to first HostSPIClock high	T26	0.5 T23	
HostSPIClock high to HostSPIXmt valid delay time	T27		21 nSec
HostSPIXmt data valid time after HostSPIClock low	T28	0	
HostSPISetup setup time before HostSPIClock high	T29	26 nSec	
HostSPISetup valid time after HostSPIClock low	T30	(0.5 T23-10) nSec	
Last HostSPIClock low to ~HostSPISetup high	T31	0.5 T23	

3.2.4 Power-on Reset

Timing Interval	No.	Min	Max
Power on pulse duration driven by device (typical) (note 1)	T32		600 μ Sec
Device ready/ outputs initialized (typical)	T33		2 mSec
ClkIn ready to ~Reset release	T34	0	10 mSec
ClkIn high impedance before powerup	T36	0	
ClkIn high impedance after Vcc stabilizes	T37	0	

Note: The device will generate a ~Reset pulse upon power on. An external ~Reset signal is optional.

3.2.5 Warm Reset

Timing Interval	No.	Min	Max
~Reset low duration for warm reset	T35	32 T1	

3.2.6 Pulse & Direction

Timing Interval	No.	Min	Max
Pulse frequency			1.0 Mhz
Pulse width	T38	50 nSec	
Direction setup time before pulse low	T39	26 nSec	
Direction valid time after pulse low	T40	40 nSec	

This page intentionally left blank.

4. Timing Diagrams

4

In This Chapter

- ▶ Clock
- ▶ Quadrature Encoder Input
- ▶ SPI Timing
- ▶ Power On Timing
- ▶ Warm Reset
- ▶ Pulse & Direction

For the values of T_n , please refer to the table in [Section 3.2, “AC Characteristics”](#) for more information

4.1 Clock

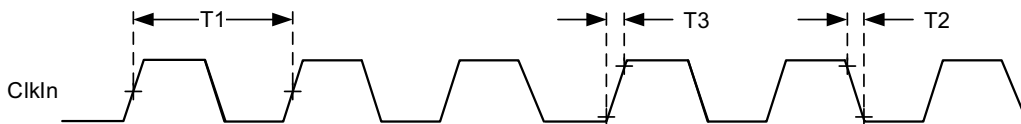


Figure 4-1:
Clock Timing

4.2 Quadrature Encoder Input

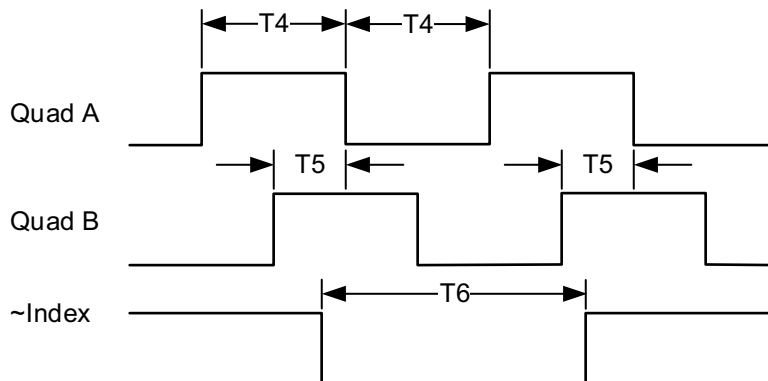
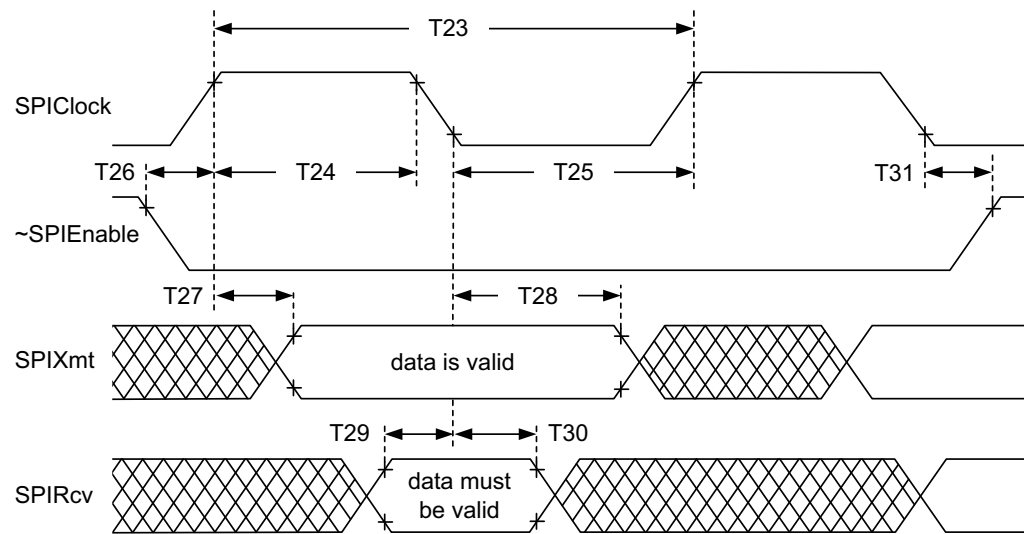


Figure 4-2:
Quad Encoder
Timing

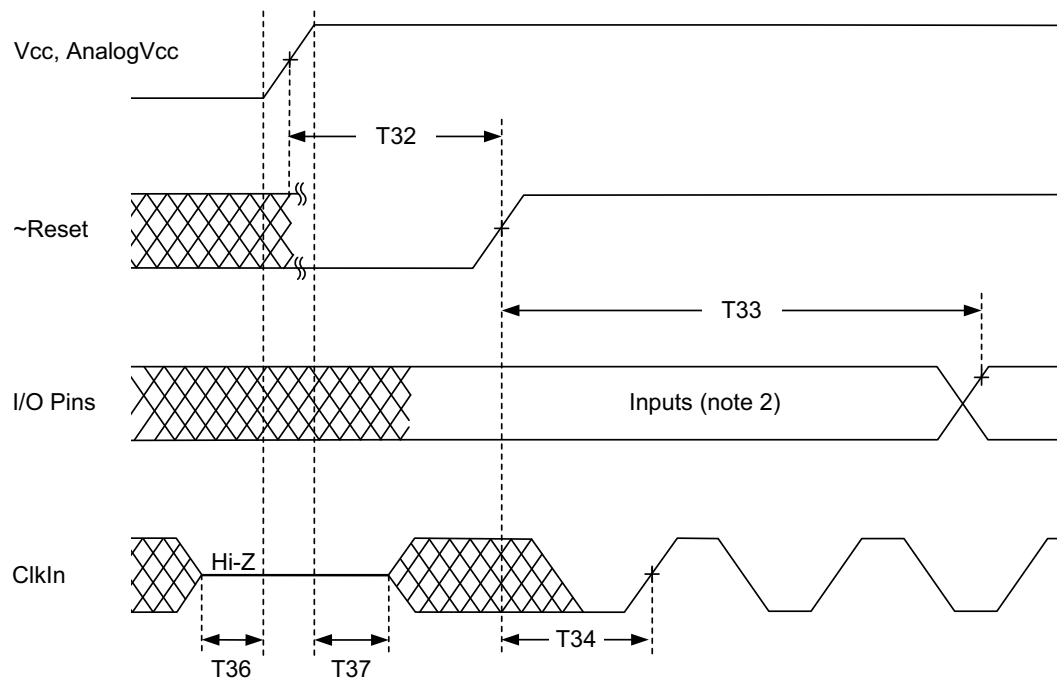
4.3 SPI Timing

Figure 4-3:
SPI Timing



4.4 Power On Timing

Figure 4-4:
Power On
Timing



4.5 Warm Reset

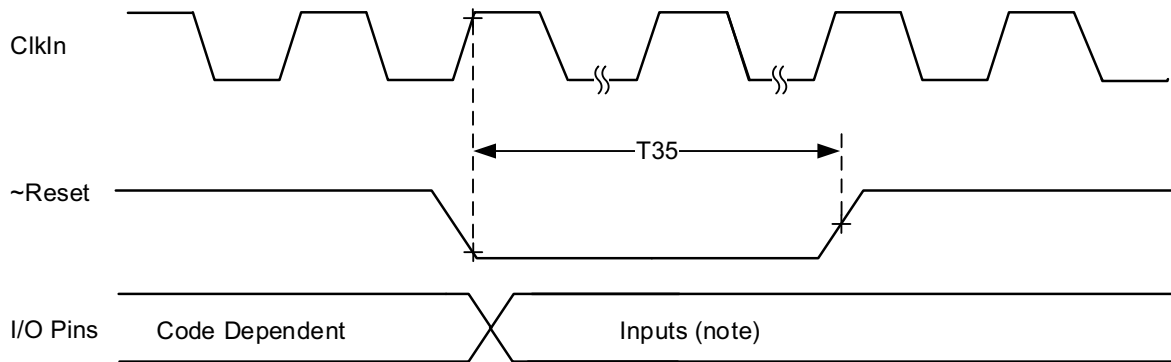


Figure 4-5:
Warm Reset
Timing

Please refer to Note 2 in [Section 3.2.5, “Warm Reset”](#) for more information.

4.6 Pulse & Direction

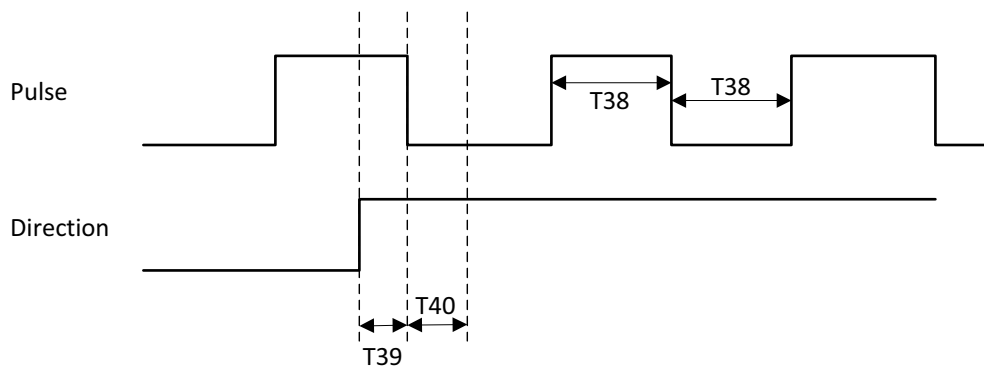


Figure 4-6:
Pulse &
Direction
Timing

This page intentionally left blank.

5. Pinouts and Pin Descriptions

5

In This Chapter

- Pinouts for the MC78113
- Pinouts for the MC71113
- Pinouts for the MC73113
- Pinouts for the MC74113
- Pinouts for the MC75113
- MC78113-Series ICs Pin Descriptions

5.1 Pinouts for the MC78113

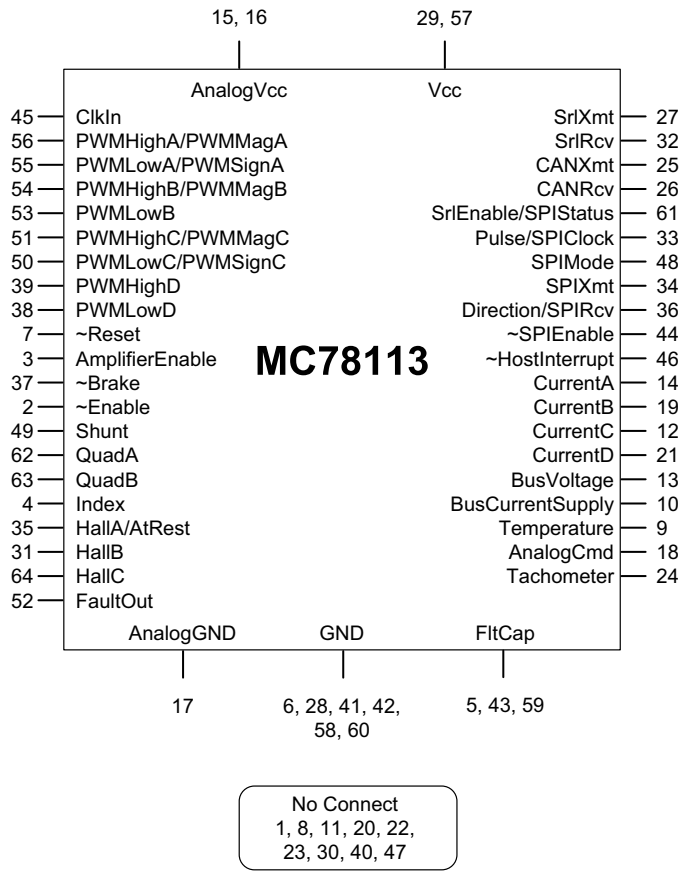
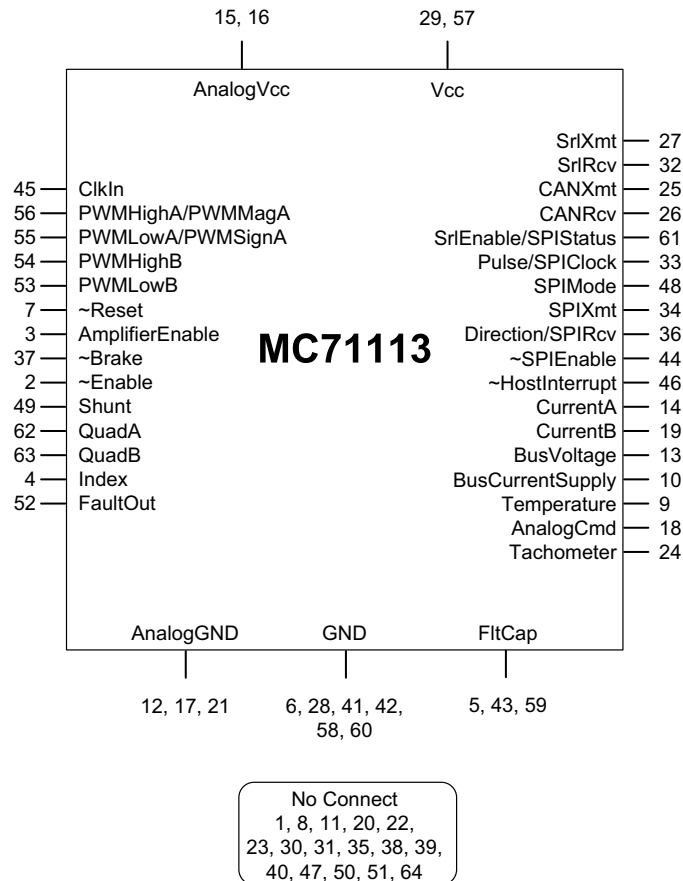


Figure 5-1:
MC78113
Pinouts

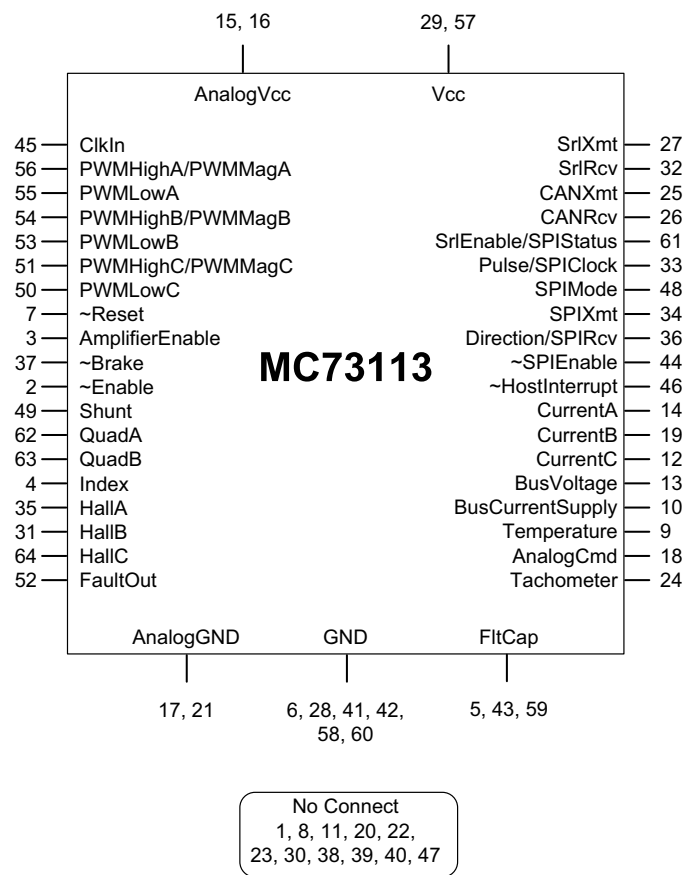
5.2 Pinouts for the MC71113

Figure 5-2:
MC71113
Pinouts



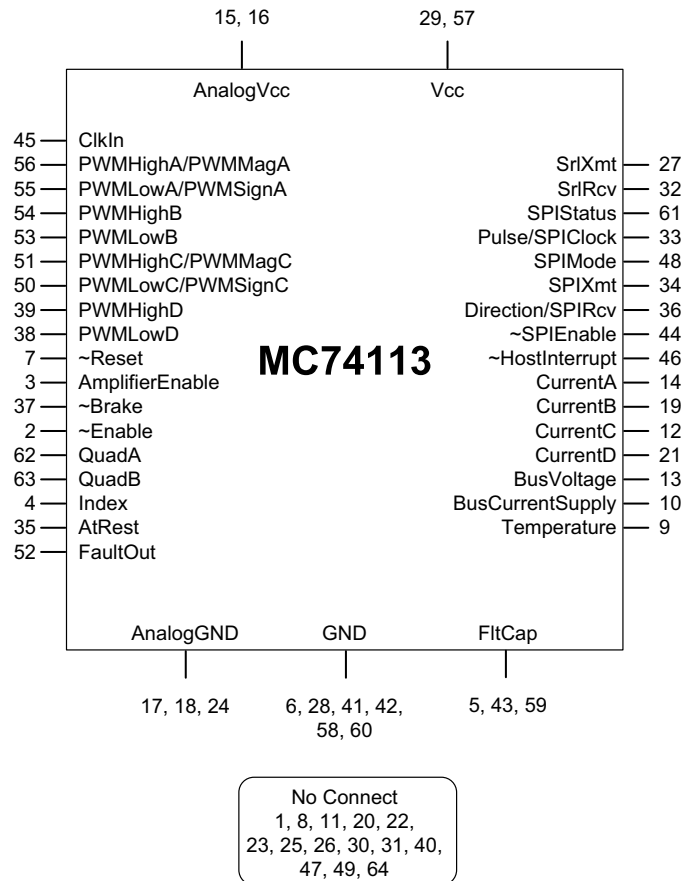
5.3 Pinouts for the MC73113

Figure 5-3:
MC73113
Pinouts



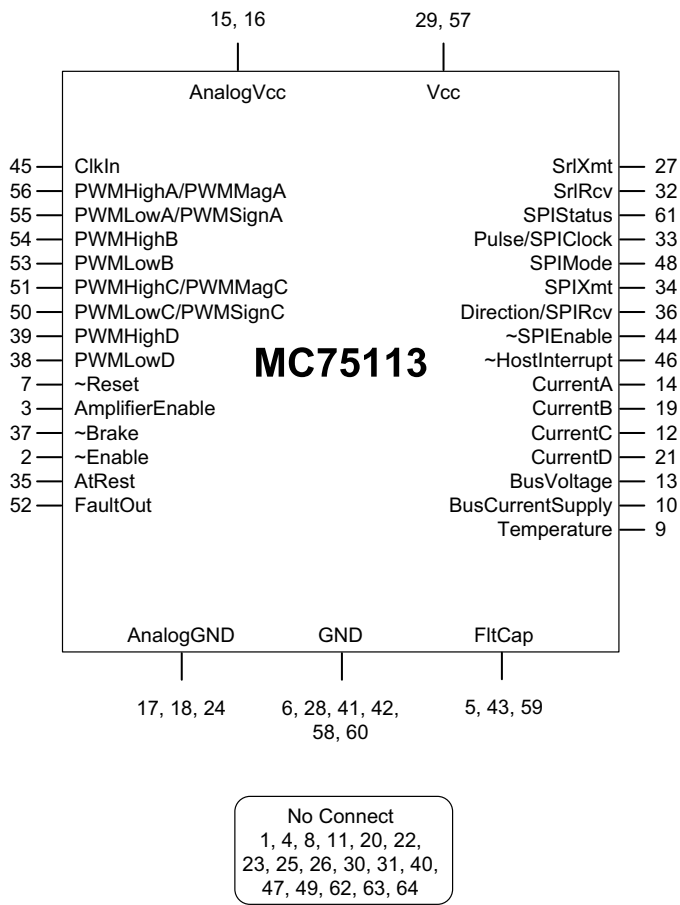
5.4 Pinouts for the MC74113

Figure 5-4:
MC74113
Pinouts



5.5 Pinouts for the MC75113

Figure 5-5:
MC75113
Pinouts



5.6 MC78113-Series ICs Pin Descriptions

The following table details the pinouts for the MC78113 ICs.

Name	Pin #	Direction	Description
$\bar{\text{Reset}}$	7	in/out	<p>This pin is the master reset input. It may be temporarily brought low to reset the MC78113 to its initial conditions and then restored to high for normal operation. During a power-on or reset condition this pin is driven low by the MC78113. If this pin is driven, it must be with an open drain output device.</p> <p>For correct reset operation a 10k pull-up resistor should be added between Reset and Vcc. In addition, a 100nF or smaller capacitor is recommended between Reset and GND for noise filtering.</p> <p>During powerup it is not necessary to provide a reset. The MC78113 generates an internal reset upon powerup.</p>
ClkIn	45	in	<p>This pin is the master clock input. It is driven at a nominal 10 MHz using an external clock. For the MC74113 this pin may be left unconnected, and an internal oscillator will be used to generate the clock.</p>
PWMHighA/ PWMMagA	56	out	<p>Depending upon the selected motor type and output mode, these pins have the following functions:</p> <p><i>PWMHighA/B/C/D</i> signals encode the high side drive for a switching bridge with separate high/low controls. The default encoding is active high, however this can be changed using the SetDrivePWM command.</p> <p><i>PWMLowA/B/C/D</i> signals encode the low side drive for a switching bridge with separate high/low controls. The default encoding is active high, however this can be changed using the SetDrivePWM command.</p> <p><i>PWMMagA/B/C</i> signals encode the magnitude of a pulse width modulated output for use with switching bridges with sign/magnitude controls or level encoded controls. The default encoding is active high, however this can be changed using the SetDrivePWM command.</p> <p><i>PWMSignA/C</i> encode the sign of the pulse width modulated output for use with switching bridges with sign/magnitude controls. The default encoding is active high, however this can be changed using the SetDrivePWM command.</p>
PWMLowA/ PWMSignA	55		
PWMHighB/ PWMMagB	54		
PWMLowB	53		
PWMHighC/ PWMMagC	51		
PWMLowC/ PWMSignC	50		
PWMHighD	39		
PWMLowD	38		
AmplifierEnable	3	out	
$\bar{\text{Brake}}$	37	in	
$\bar{\text{Enable}}$	2	in	<p>This pin is an enable input. To allow normal operations a low signal is asserted. When a high signal is asserted a programmable response may disable motor control operations, although communications and various other operations are still available.</p>
Shunt	49	out	<p>This pin provides a PWM-based shunt signal that may be used with an external switching circuit and high wattage resistor or other energy dissipating device to regulate supply bus overvoltage conditions. The default encoding is active high however this can be changed with the SetDrivePWM command.</p>

Name	Pin #	Direction	Description
QuadA	62	in	<p>These pins input the index signals for the corresponding incremental encoders. By default a valid index pulse is recognized when $\overline{\text{Index}}$ transitions low, however the interpretation of this signal can be changed via the command <code>SetSignalSense</code>.</p> <p>Note: Index capture is not conditioned by the QuadA and QuadB signals. If such conditioning is not provided by the encoder then external circuitry should be used if such conditioning is desired.</p> <p>If unused, these pins may be left unconnected.</p>
QuadB	63		
Index	4		
HallA/AtRest	35	in	<p>These pins input Hall-encoded phasing inputs for brushless DC motors. The A, B, and C signals encode six valid states as follows: A on, A and B on, B on, B and C on, C on, C and A on. By default a sensor is defined as being on when its signal is high, however this signal interpretation can be changed via the command <code>SetSignalSense</code>.</p> <p>Note: Some Hall sensors require a pull up resistor to 3.3V on each signal to establish a proper high signal. Check your Hall sensor's electrical specification.</p> <p>AtRest, which is used for stepper motor control only, indicates that the axis is at rest, and that the motor can be switched to low power or standby. By default a high level on this signal indicates the axis is at rest and a low signal indicates the axis is in motion however this signal interpretation can be changed via the command <code>SetSignalSense</code>.</p> <p>If unused, these pins may be left unconnected.</p>
HallB	31		
HallC	64		
FaultOut	52	out	<p>This pin provides a general purpose fault indicator that can be programmed to indicate a number of conditions including a motion error, drive exception, or various other conditions. A high indicates that a fault condition is present.</p>
SrIXmt	27	out	<p>This pin outputs serial data from the asynchronous serial port.</p>
SrIRcv	32	in	<p>This pin inputs serial data to the asynchronous serial port.</p> <p>If unused, this pin may be left unconnected.</p>
CANXmt	25	out	<p>This pin transmits serial data to the CAN transceiver.</p>
CANRcv	26	in	<p>This pin inputs serial data from the CAN transceiver. If unused, this pin may be left unconnected.</p>
SrIEnable/ HostSPISatus	61	out	<p>When the serial port is configured for multi-drop operation, this pin sets the serial port enable line. <code>SrIEnable</code> is high during transmission and low otherwise.</p> <p>When the serial port is configured for point-to-point operation, this pin is low when there is an SPI command result waiting to be read by the host and high otherwise. In point-to-point mode, if the SPI command interface is not used then this pin will always be high.</p> <p>Whether this pin function is used or not this pin must be connected to a 10 Kohm pullup resistor.</p>
Pulse/SPIClock	33	in	<p><i>Pulse</i> provides a pulse (step) signal for the pulse & direction command input function. A step occurs when this signal transitions from a high state to a low state. This default behavior can be changed using the command <code>SetSignalSense</code>.</p> <p><i>SPIClock</i> inputs the clock signal used with synchronous serial transfer on the host communication SPI bus.</p> <p>If unused, this pin may be left unconnected.</p>
SPIMode	48	in	<p>This pin is used to indicate the data protocol used on the SPI bus. When high, SPI data is interpreted as a stream of host commands encoded as for MC78113. When low, SPI data is interpreted as a stream of 16-bit twos complement words, which represent velocity, torque, or incremental step position commands.</p> <p>If used, this signal must be controlled in series with a 2.2 Kohm resistor.</p> <p>If unused, this pin may be left unconnected, which will result in interpretation of SPI data as host commands (high).</p>

Name	Pin #	Direction	Description
SPIXmt	34	out	This pin transmits synchronous serial data on the host communication SPI bus to the host processor.
Direction/SPIRcv	36	in	<i>Direction</i> indicates the direction of motion for the pulse & direction command input function. By default a high level on this signal indicates a positive direction move and a low level indicates a negative direction move, however this signal interpretation can be changed via the command SetSignalSense. This pin inputs synchronous serial data for the host communication SPI bus. If unused, this pin may be left unconnected.
~SPIEnable	44	in	This pin inputs an enable signal for the host communication SPI bus. This signal is active low, meaning it should be low when an SPI host communication is occurring, and high at all other times. If used, this pin must be controlled in series with a 470 ohm resistor. If unused, this pin may be left unconnected.
~HostInterrupt	46	out	This pin provides a host interrupt signal. When low, it signals an interrupt to the host processor. Whether this pin function is used or not this pin must be connected to a 10 Kohm pullup resistor.
CurrentA	14	in	These pins input analog voltages representing leg current flow through the low sides of the switching bridges. DC Brush motors use the A and B inputs, Brushless DC motors use the A, B, and C inputs, and two-phase step motors use the A, B, C, and D inputs. These signals are only accessible when the PWM output mode is set to PWM High/Low. These signals are used when a current loop is used or when i ² t current monitoring is desired. These signals are sampled by an internal A/D converter. The A/D resolution is 12 bits. The allowed signal input range is zero to 3.3V. If unused, these signals should be connected to AnalogGND.
CurrentB	19		
CurrentC	12		
CurrentD	21		
BusVoltage	13	in	This pin inputs an analog voltage representing the DC bus voltage. The allowed signal input range is zero to 3.3V. If unused, this signal should be connected to AnalogGND.
BusCurrentSupply	10	in	This pin inputs an analog voltage representing the current through the supply terminal of the DC bus. The allowed signal input range is zero to 3.3V. If unused, this signal should be connected to AnalogGND.
Temperature	9	in	This pin inputs an analog voltage representing the temperature of the amplifier or other monitored circuitry. The allowed signal input range is zero to 3.3V. If unused, this signal should be connected to AnalogGND.
AnalogVcc	16 15	N/A	These pins are connected to the analog input supply voltage, which must be in the range of 3.0V to 3.6V. If analog inputs are not used, these pins should be tied to Vcc.
AnalogCmd	18	in	This pin is used for commanding either voltage, torque, or velocity using an analog signal. If unused, this pin should be tied to AnalogGND.
Tachometer	24	in	This pin is used for feedback from a tachometer or other analog device used to measure the effect of the output voltage, torque, or velocity. If unused, this pin should be tied to AnalogGND
AnalogGND	17	N/A	This pin should be connected to the analog input power supply return. Any unused analog inputs (CurrentA-D, BusVoltage, Bus-CurrentSupply, Temperature or AnalogCmd pins) should be tied to AnalogGND.
Vcc	29 57	N/A	All of these pins must be connected to the MC78113 digital supply voltage, which should be in the range of 3.0V to 3.6V.

Name	Pin #	Direction	Description
FltCap	5	N/A	Each of these pins must be connected to a 1.2 μ F (or higher) filtering capacitor which in turn connects to GND.
	43		
	59		
GND	6	N/A	All of these pins must be connected to the digital power supply return.
	28		
	41		
	42		
	58		
	60		
No Connect	1	N/A	These pins must be left unconnected.
	8		
	11		
	20		
	22		
	23		
	30		
	40		
	47		

This page intentionally left blank.

6. Electrical Operational Information

6

In This Chapter

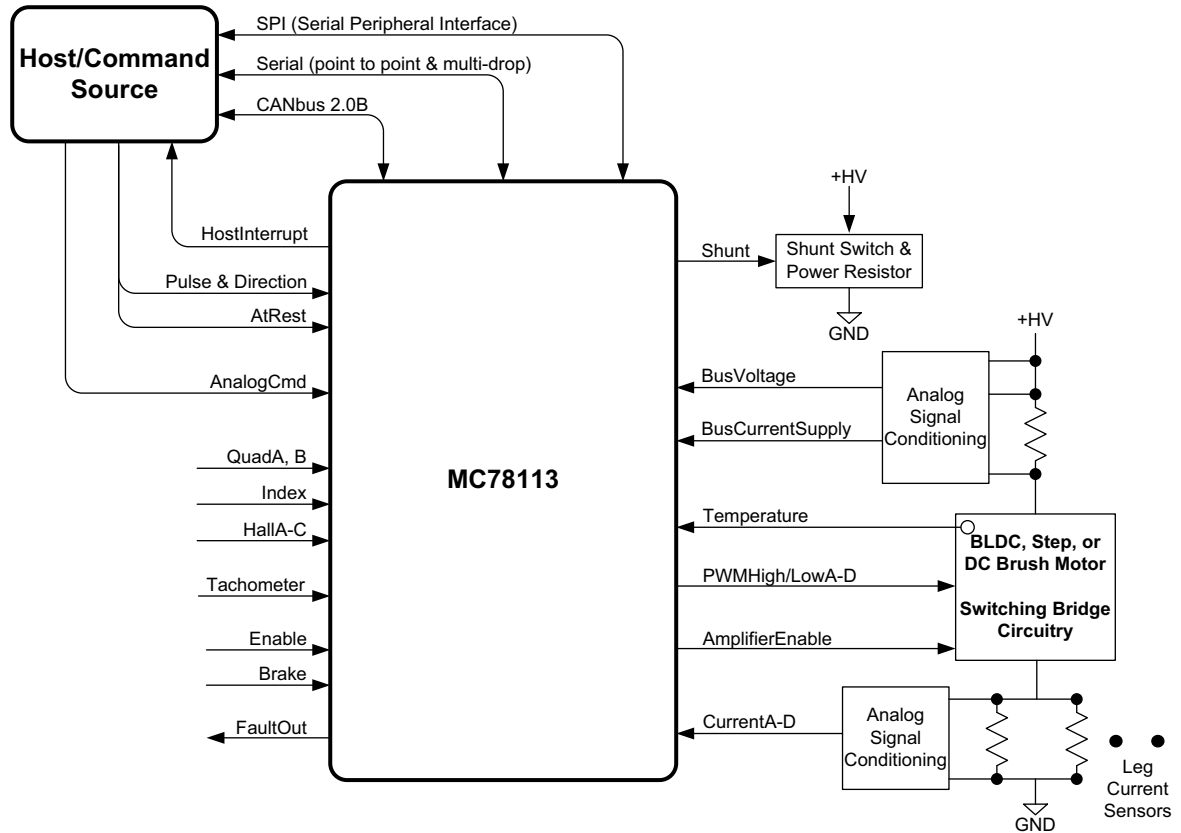
- ▶ MC78113 Connection Overview
- ▶ MC78113 Internal Block Diagram
- ▶ Switching Amplifier Control
- ▶ Current Control
- ▶ Drive & DC Bus Safety
- ▶ Host Communications
- ▶ Input Signal Processing
- ▶ Reset & Power-up
- ▶ MC78113 RAM and NVRAM Buffers
- ▶ Output Signal Status During Powerup
- ▶ Analog Signal Input

6.1 MC78113 Connection Overview

Figure 6-1 shows an overview of the connection scheme for MC78113 family ICs.

For a general description of the MC78113 family ICs see the *Juno Velocity & Torque Control IC User's Guide*. For detailed information on commands supported by the MC78113 ICs see the *Juno Velocity & Torque Control IC Command Reference*.

Figure 6-1:
MC78113
Interconnec-
tions



6.2 MC78113 Internal Block Diagram

Figure 6-2:
MC78113
Family ICs
Internal Block
Diagram

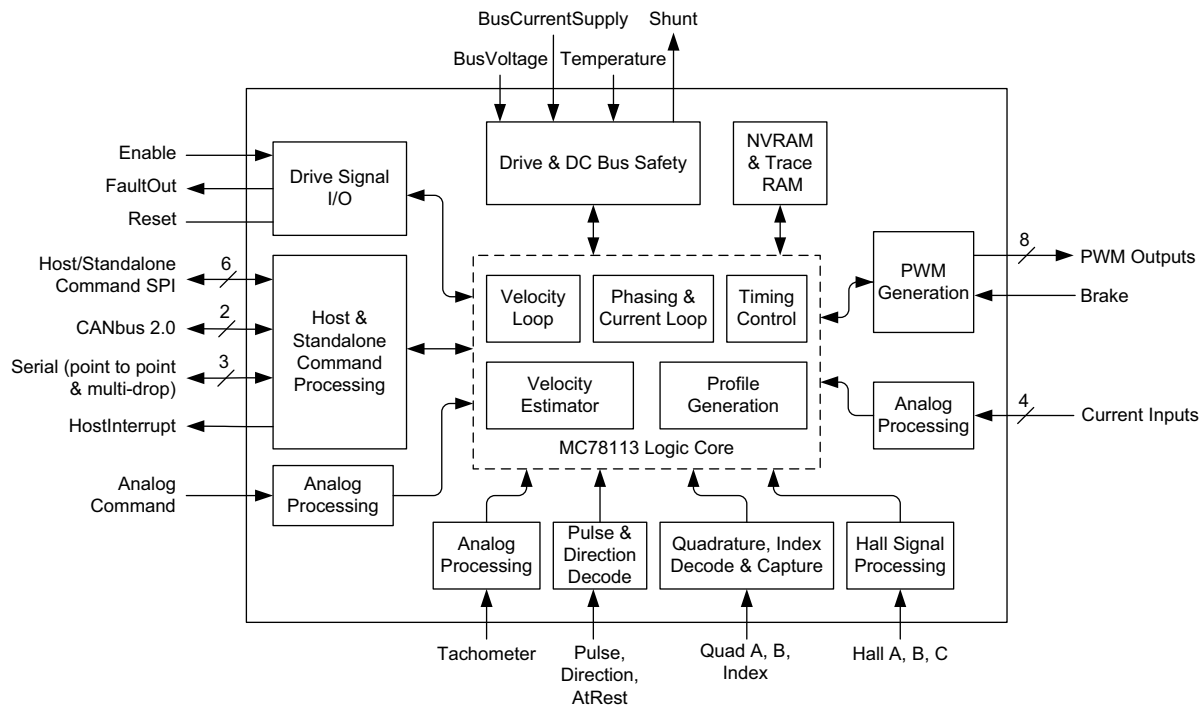


Figure 6-2 shows an internal block diagram for the MC78113 family ICs. The functionality of the MC78113 is divided into several major functional blocks, listed below:

- Switching Amplifier Control
- Current Control
- Drive & DC Bus Safety
- Host Communications
- Input Signal Processing
- NVRAM & Trace RAM

The subsequent sections of this chapter will provide detailed information on these major functional blocks.

6.3 Switching Amplifier Control

The MC78113 family ICs provide two different switch control methods. These switch control methods are known as PWM High/Low, and Sign/Magnitude PWM.

The primary switching control mode that is used when the MC78113's current control facility is utilized is PWM High/Low mode. Sign/Magnitude PWM is typically used with single-IC amplifiers or with bridges that directly input those control interfaces.

The following sections provide detailed operation, connection, and configuration information for each of these two amplifier control modes.

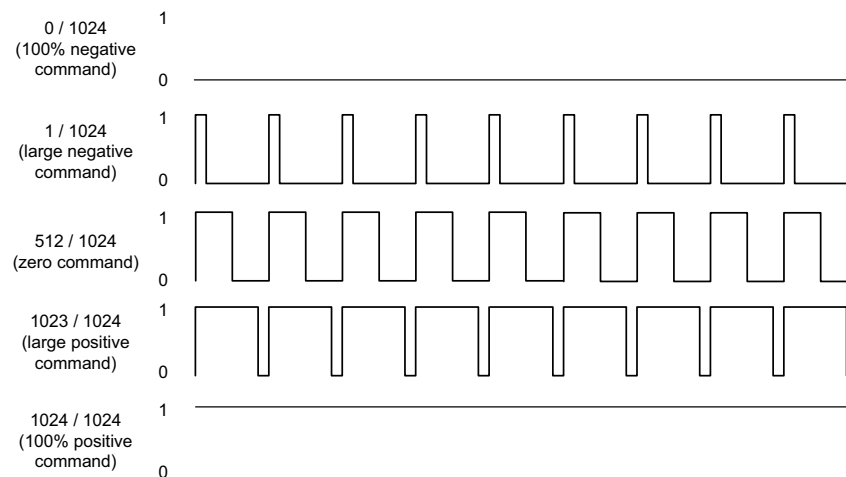
6.3.1 PWM High/Low Motor Output Mode

The MC78113 family ICs can control high-efficiency MOSFET or IGBT power stages with individual high/low switch input control. A different configuration is used for each motor type:

- DC Brush motors are driven in an H-Bridge configuration consisting of 4 switches.
- Brushless DC motors are driven in a triple half-bridge configuration consisting of 6 switches.
- Step motors are driven in a two H-Bridge configuration consisting of 8 switches.

In PWM High/Low mode each signal carries a variable duty cycle PWM signal. A zero desired motor command results in the high side and low side being active for the same amount of time. Positive motor commands are encoded as a high-side duty cycle greater than 50%, and negative motor commands are encoded as a duty cycle less than 50%. This is shown in [Figure 6-3](#).

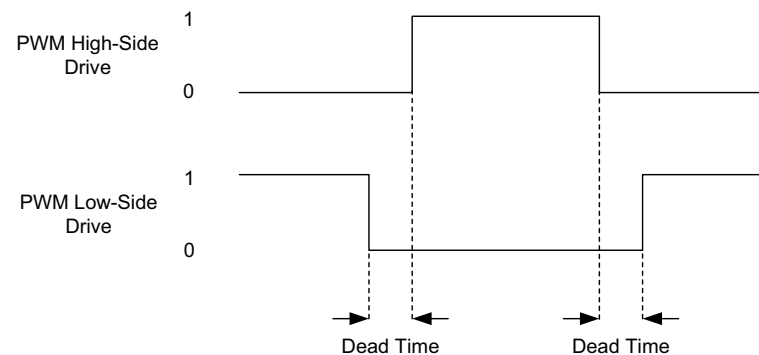
Figure 6-3:
PWM High/Low
Encoding



6.3.1.1 PWM High/Low Signal Generation

In PWM High/Low mode two output pins are used per motor or per motor phase, allowing separate high-side/low-side control of each bridge switch. In this scheme, as [Figure 6-4](#) shows, the high side output and the low side output are never active at the same time, and there is generally a period of time when neither output is active. This period of time is called the dead time, and provides a shoot through protection function for MOSFET or IGBT switches.

Figure 6-4:
PWM High/Low
Signal
Generation



The dead time is specified in nSecs and can be programmed via the command **SetDrivePWM**. The correct value can generally be determined from the MOSFET or IGBT IC manufacturer's data sheet, or you can call PMD technical support if you have questions.

In addition to dead time, some high side switch drive circuitry requires a minimum amount of off time to allow the charge pump circuitry to refresh. This parameter, set using the **SetDrivePWM** command, specifies this refresh time and has units of nSecs. The related parameter of refresh time period, which is the time interval between these off time refreshes, and which is also set using the **SetDrivePWM** command, has units of current loop cycles.

It is also possible to control the maximum allowed PWM duty cycle. This may be useful to limit the effective voltage presented to the motor windings, or to provide some other needed off-time for the switching amplifier circuitry. This PWM Limit parameter is set using the **SetDrivePWM** command.

The MC78113 default values for dead time, refresh time, and refresh period are set to be maximally safe but are not appropriate to drive typical switching hardware. For proper amplifier function these values must be set with values appropriate for the connected switching circuitry.



6.3.1.2 PWM High/Low Brushless DC Motor Drive

[Figure 6-5](#) shows the typical amplifier stage arrangement when a MC53113 IC or MC78113 IC with Brushless DC motor type selected is used in PWM High/Low mode.

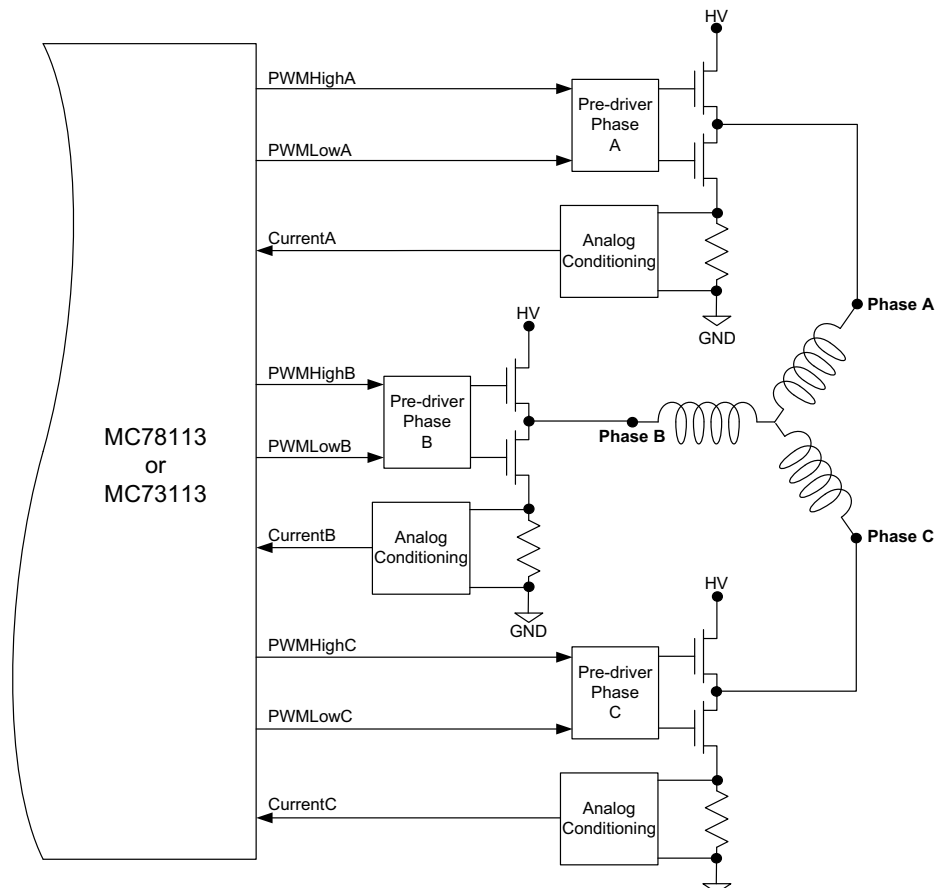


Figure 6-5:
Brushless DC
Motor Bridge
Configuration

As shown in the table below six PWM output signals and, if used, three analog feedback signals for current control interface between the MC78113 IC and the switching amplifier circuitry:

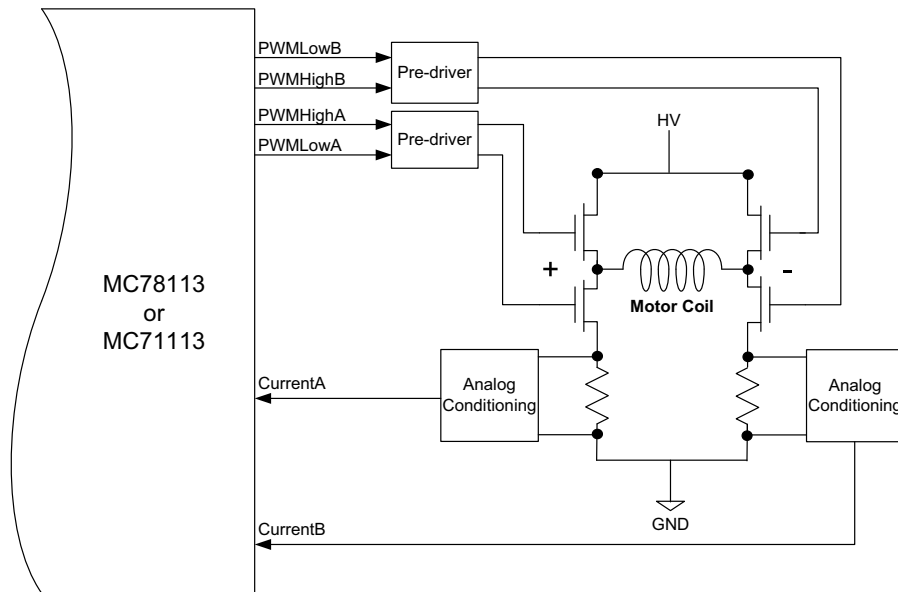
MC78113 signal	Pin #	Description
PWMHighA	56	Digital high side drive output for motor phase A

MC78113 signal	Pin #	Description
PWMLowA	55	Digital low side drive output for motor phase A
PWMHighB	54	Digital high side drive output for motor phase B
PWMLowB	53	Digital low side drive output for motor phase B
PWMHighC	51	Digital high side drive output for motor phase C
PWMLowC	50	Digital low side drive output for motor phase C
CurrentA	14	Analog input containing the current flow through the low side of the switching bridge for phase A.
CurrentB	19	Analog input containing the current flow through the low side of the switching bridge for phase B.
CurrentC	12	Analog input containing the current flow through the low side of the switching bridge for phase C.

6.3.1.3 PWM High/Low DC Brush Motor Drive

Figure 6-6 shows the typical amplifier stage arrangement when a MC71113 IC or MC78113 IC with DC Brush motor type selected is used in PWM High/Low mode.

Figure 6-6:
DC Brush
Motor Bridge
Configuration



As shown in the table four PWM output signals and, if used, two analog feedback signals for current control interface between the MC78113 IC and the switching amplifier circuitry:

MC78113 signal	Pin #	Description
PWMHighA	56	Digital high side drive output for the positive coil terminal
PWMLowA	55	Digital low side drive output for the positive coil terminal
PWMHighB	54	Digital high side drive output for the negative coil terminal
PWMLowB	53	Digital low side drive output for the negative coil terminal
CurrentA	14	Analog input containing the current flow through the positive leg of the bridge
CurrentB	19	Analog input containing the current flow through the negative leg of the bridge

6.3.1.4 PWM High/Low Step Motor Drive

Figure 6-7 shows the typical amplifier stage arrangement when a MC74113 IC, MC75113 IC, or MC78113 IC with step motor type selected is used in PWM High/Low mode.

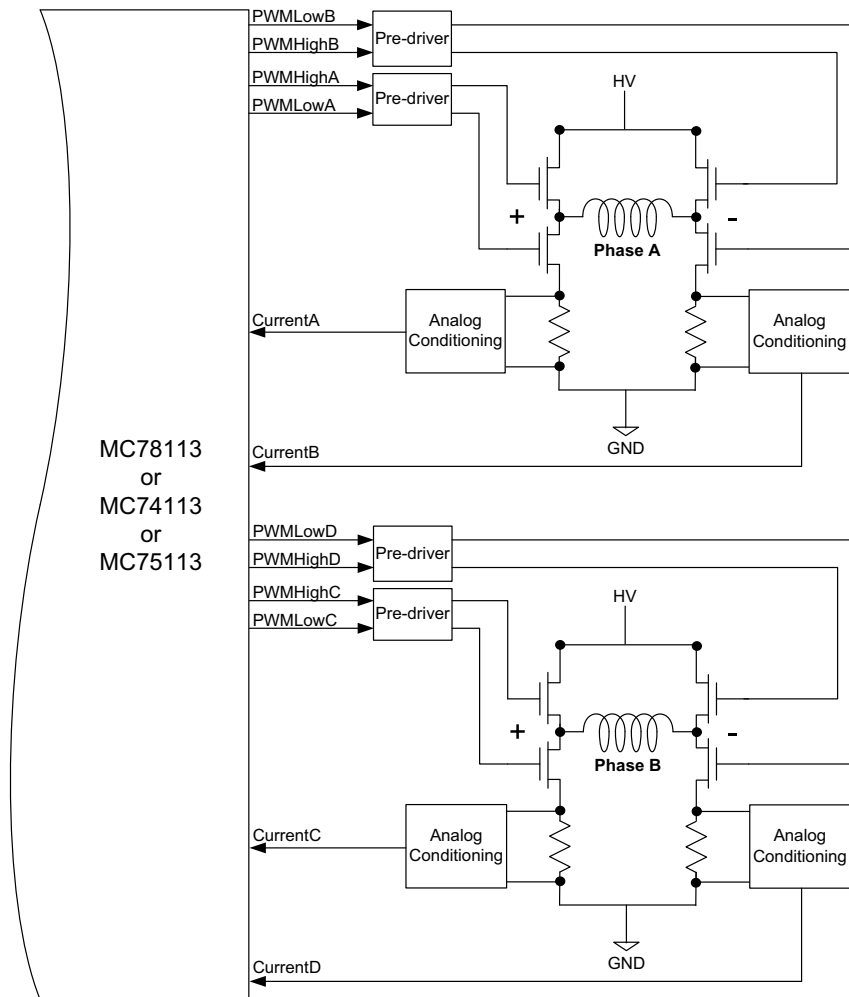


Figure 6-7:
Two-phase
Step Motor
Bridge
Configuration

As shown in the table below eight PWM output signals and, if used, four analog feedback signals for current control interface between the MC78113 IC and the switching amplifier circuitry:

MC78113 signal	Pin #	Description
PWMHighA	56	Digital high side drive output for motor phase A, positive coil terminal
PWMLowA	55	Digital low side drive output for motor phase A, positive coil terminal
PWMHighB	54	Digital high side drive output for motor phase A, negative coil terminal
PWMLowB	53	Digital low side drive output for motor phase A, negative coil terminal
PWMHighC	51	Digital high side drive output for motor phase B, positive coil terminal
PWMLowC	50	Digital low side drive output for motor phase B, positive coil terminal
PWMHighD	39	Digital high side drive output for motor phase B, negative coil terminal
PWMLowD	38	Digital low side drive output for motor phase B, negative coil terminal
CurrentA	14	Analog input containing the current flow through the positive leg of the phase A bridge
CurrentB	19	Analog input containing the current flow through the negative leg of the phase A bridge
CurrentC	12	Analog input containing the current flow through the positive leg of the phase B bridge
CurrentD	21	Analog input containing the current flow through the negative leg of the phase B bridge

6.3.1.5 Using PWM High/Low Mode With Single Input Bridges

An alternate scheme for use of the PWM High/Low output mode is to utilize only the high control signals, leaving the low signals unconnected. This scheme is used to interface with amplifiers that do not provide separate high/low input but rather a single input control signal per high/low switch pair. Note that in this scheme, the **AmplifierEnable** signal, rather than being optional, must be connected to the bridge to control when the bridge should be active. For more information on the **AmplifierEnable** signal, see [Section 6.3.3, “AmplifierEnable”](#).

Since there is no separate high and low side signal to control the switches, the bridge itself, rather than the MC78113 IC, must handle some details of switch timing generation such as shoot through protection. Along those lines the dead time variable (see [Section 6.3.1.7, “PWM High/Low Control Parameters”](#) for details on amplifier-related MC78113 settings) should be set to zero when the MC78113 is connected in this configuration.

6.3.1.6 Low Pass PWM Signal Filtering

Some integrated amplifier ICs expect an analog command input. Using the MC78113 this can be accomplished by low pass filtering the PWM output signal thereby generating an analog signal. Depending on the input voltage required, additional analog processing circuitry may be needed. Note also that depending on the amplifier command format expected, low pass filtering of the Sign/Magnitude PWM signal may be preferred versus the PWM high/low format signal.

As was the case for interconnection to single-input bridges, when analog input integrated bridges are used, current control, if desired, must be provided by the external bridge circuitry.

6.3.1.7 PWM High/Low Control Parameters

There are a number of MC78113 parameters which are used to set up or control the switching amplifier circuitry shown in [Figures 6-5 - 6-7](#) when the motor output mode is set to PWM High/Low. All of the parameters listed below are set using the **SetDrivePWM** command.

The following table shows these amplifier-related control parameters:

Parameter	Range & Units	Description
PWM Switching Frequency	20 KHz 40 KHz 80 KHz 120 KHz	Higher inductance motors should be set for 20 kHz. Lower inductance motors may use 40, 80, or 120 kHz to maximize current control accuracy and minimize heat generation. The default value for this parameter is 20 kHz.
PWM Dead Time	0-16,383 nSec	The correct setting of this parameter depends on the specific switching circuitry used. See the manufacturer's data sheet for more information. The default value for this parameter is 12,787 nSec.
PWM Refresh Time	0-32,767 nSec	Some high-side switch drive circuitry requires a minimum amount of off time, applied at a programmable period interval, to allow the charge pump circuitry to refresh. The default value for this parameter is 32,767 nSec.
PWM Refresh Period	1-32,767 cycles	Some high-side switch drive circuitry requires a minimum amount of off time, applied at a programmable period interval, to allow the charge pump circuitry to refresh. The default value for this parameter is 1 cycle.
PWM Limit	0-16,384 % output/163.84	This parameter allows the maximum PWM duty cycle to be set. The default value for this parameter is 16,384 which corresponds to 100% output.

6.3.2 Sign/Magnitude PWM Output Mode

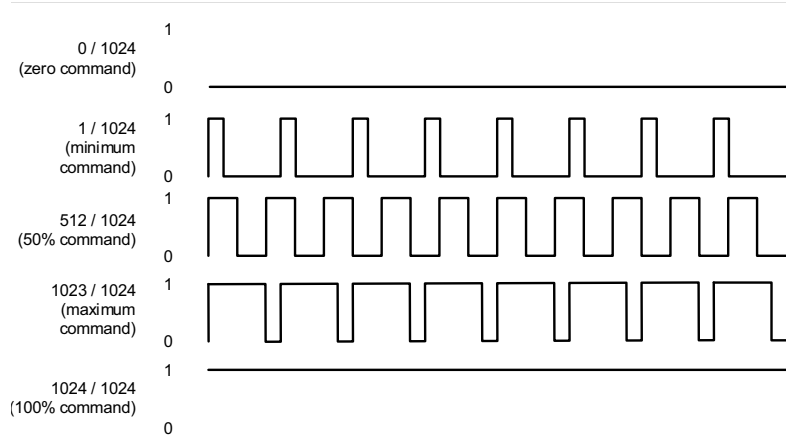


Figure 6-8:
Sign/
Magnitude
PWM Encoding

In Sign/Magnitude PWM mode, two pins are used to output the motor command information for each motor phase. One pin carries the PWM magnitude, which ranges from 0 to 100% as shown in [Figure 6-8](#). A high signal on this pin means the motor coil should be driven with voltage. A second pin outputs the sign of the motor command by going high for positive sign, and low for negative.

In Sign/Magnitude PWM control mode only DC Brush and step motors can be controlled. Brushless DC motors can not be controlled in this mode.



6.3.2.1 Sign/Magnitude PWM DC Brush Motor Drive

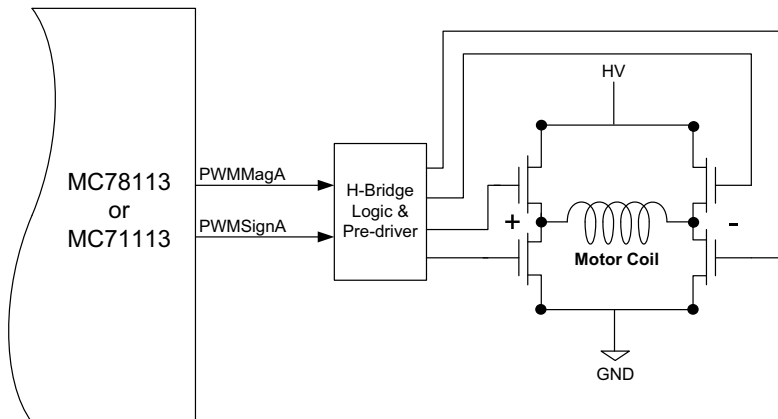


Figure 6-9:
Sign/
Magnitude
PWM DC Brush
Motor
Connections

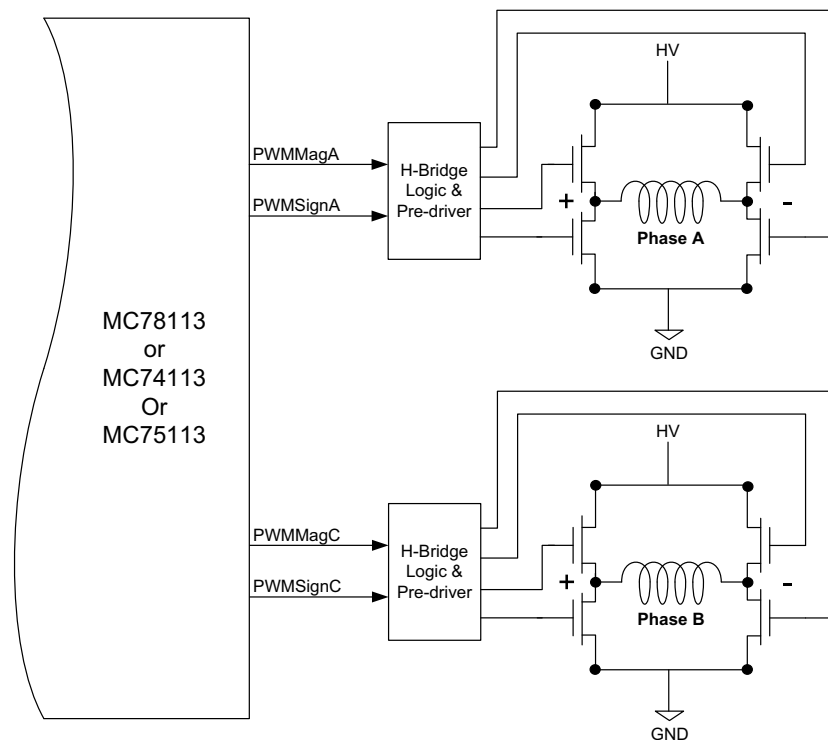
[Figure 6-9](#) shows a typical connection for DC Brush motors or solenoid type actuators when Sign/Magnitude PWM motor output mode is used. Note that in this mode the MC78113 does not provide current control, and therefore if current control is desired this capability must be provided by the amplifier bridge circuitry.

As shown in the table below a PWM magnitude and PMW sign signal are used to interface between the MC78113 IC and the amplifier circuitry.

MC78113 Signal	Pin #	Description
PWMMagA	56	Digital PWM magnitude output for the H-bridge switching amplifier
PWMSignA	55	Digital sign side drive output for the H-bridge switching amplifier

**Figure 6-10:
Sign/
Magnitude
PWM Step
Motor
Connections**

6.3.2.2 Sign/Magnitude PWM Step Motor Drive



[Figure 6-10](#) shows a typical connection for a two-phase step motor when Sign/Magnitude PWM motor output mode is used. Note that in this mode the MC78113 does not provide current control, and therefore if current control is desired this capability must be provided by the amplifier bridges circuitry itself.

As shown in the table below two PWM magnitude and two PWM sign signals are output to interface between the MC78113 IC and the amplifier circuitry.

MC78113 Signal	Pin #	Description
PWMMagA	56	Digital PWM magnitude output for the step motor's phase A H-bridge switching amplifier
PWMSignA	55	Digital sign output for the step motor's phase A H-bridge switching amplifier
PWMMagC	51	Digital PWM magnitude output for the step motor's phase B H-bridge switching amplifier
PWMSignC	50	Digital sign output for the step motor's phase B H-bridge switching amplifier

6.3.2.3 Sign/Magnitude PWM Control Parameters

There are two MC78113 IC parameters which are used to control the switching amplifier shown in [Figures 6-9 - 6-10](#) when the motor output mode is set to Sign/Magnitude PWM.

The following table shows these amplifier-related control parameters.

Parameter	Range & Units	Description
PWM Switching Frequency	20 KHz 40 KHz 80 KHz 120 kHz	Higher inductance motors should be set for 20 kHz. Lower inductance motors may use 40, 80, or 120 kHz to maximize current control accuracy and minimize heat generation. This parameter is set using the SetDrivePWM command. The default value for this parameter is 20 kHz.

Parameter	Range & Units	Description
PWM Limit	0-16,384 % output/163.84	This parameter allows the maximum PWM duty cycle to be set. The default value for this parameter is 16,384 which corresponds to 100% output.

6.3.3 AmplifierEnable

Regardless of whether the motor output mode is set to PWM High/Low or Sign/Magnitude PWM, the MC78113 provides an **AmplifierEnable** signal output that indicates whether the external amplifier circuitry is active or not. While not all external amplifiers will require or provide such an input control, this signal is useful for general safety purposes, as well as to simplify the task of ensuring startup without jogging the motor after powerup.

The output of this signal corresponds directly to the state of the motor output bit and the braking bit of the active operating mode register. If either of these bits are on, the **AmplifierEnable** signal is active. If both bits are off, this signal is inactive. For more information on Juno operating modes see the *Juno Velocity & Torque Control IC User's Guide*.

6.3.4 Brake

The MC78113 **Brake** signal input provides a high speed PWM output disable that may be useful for safety protection when the motor output mode is set to PWM High/Low. When this input is active PWM output is driven to one of two user programmable states; a fully disabled state or a braking state. PWM operation is normal when this signal is inactive.

In the fully disabled state all switches for the selected motor type are open, meaning that all high and low control signals are driven inactive and the **AmplifierEnable** signal is inactive. In the braking state, for the selected motor type all of the high-side switch control signals are driven inactive, all of the low-side switch signals are active, and the **AmplifierEnable** signal is active, thereby closing the lower side switches.

If a brake or disable function occurs, to re-enable normal output the **ResetEventStatus** command is used. For more information on MC78113 event processing see the *Juno Velocity & Torque Control IC User's Guide*.

If the braking feature is programmed it is up to the user to ensure that current flow resulting from back-EMF generation during braking does not damage the motor.



The braking function is only available with the PWM control mode set to PWM High/Low. When the output mode is Sign/Magnitude PWM the **Brake** signal can only control a disable function.



The default setting of the **Brake** signal input is braking. To program this function the **SetEventAction** command is used.

6.4 Current Control

The MC78113 provides the capability for sophisticated current control in connection with the PWM High/Low amplifier control mode. Signals representing the instantaneously measured current of each coil leg are input into the MC78113 in a voltage range of 0.0 to 3.3V with a voltage of 0.0 representing the largest possible negative measured

current, a voltage of 1.65V representing a measured current of 0, and a voltage of 3.3V representing the largest possible positive measured current.

The following table shows the signals that are used to input the measured leg currents:

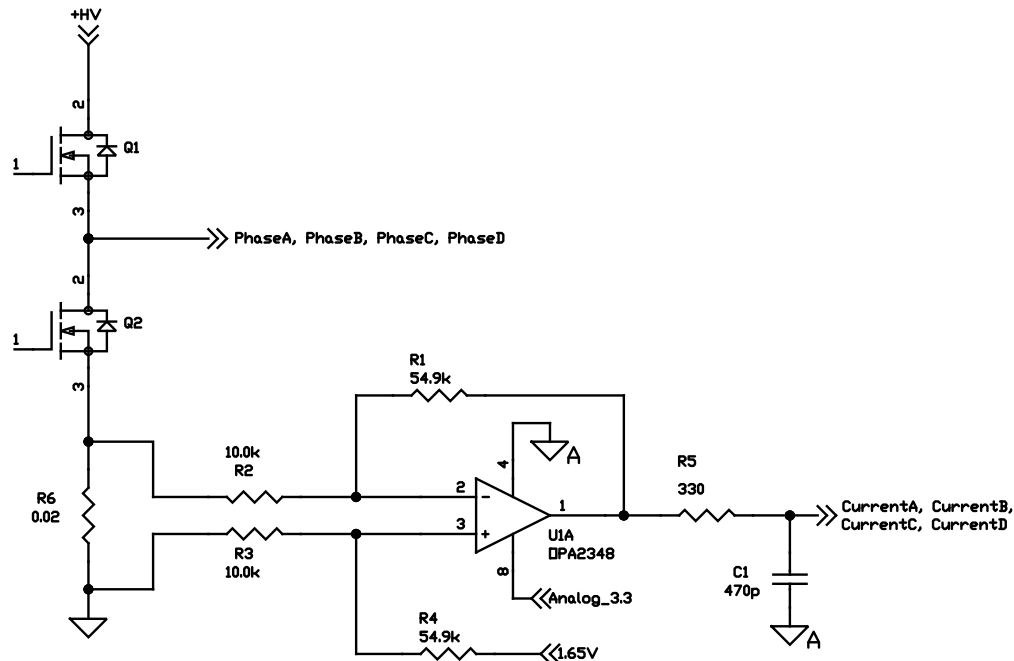
Pin Name	Pin#	Description
CurrentA	14	Measured Current for Leg current input A
CurrentB	19	Measured Current for Leg current input B
CurrentC	12	Measured Current for Leg current input C
CurrentD	21	Measured Current for Leg current input D

Current sensors consist of sense resistors, as shown in [Figure 6-1](#), or linear Hall sensors. If sense resistors are used ground-referenced operational amplifiers may be used.

Current inputs are sampled by the MC78113 at a rate of 20 kHz and should be filtered to minimize noise. A low pass filter with a rolloff of 200 kHz - 1,000 kHz is recommended, with 500 kHz being a typical value for most applications. MC78113s operating at 20 kHz PWM frequency in high noise environments may consider a rolloff on the lower end of the frequency range. MC78113s with PWM frequencies of 40 kHz, 80 kHz, or 120 kHz operating in low or normal noise environments may consider a rolloff on the higher end of this range.

6.4.1 Typical Current Signal Processing Circuitry

Figure 6-11:
Typical Current
Signal
Processing
Circuitry



[Figure 6-11](#) shows a typical leg sensing processing circuit for the MC78113 current signal inputs. Q1 and Q2 are the half-bridges for one motor phase, and R6 is the current sensing resistor. U1A with R1~R4 is a differential amplifier for signal conditioning; it is capable of measuring bidirectional current and has an output of 1.65V at zero current. R5 and C1 form a low pass filter, and they should be placed close to the pins on the MC78113. R1~R4 should be 1% or higher grade. The power rating of R6 should match the winding current with 50% power margin recommended.

See [Section 7.12, “PWM High/Low Motor Drive With Leg Current Sensing/Control”](#) for complete example schematics for various MC78113-based amplifier designs with current control.

The MC78113's current control feature only functions when the PWM output mode is set to PWM High/Low.



6.4.2 Current Scaling

The value of the sense resistors and analog conditioning circuitry shown in [Figures 6-5 - 6-7](#) determine the overall controllable current range of the switching amplifier. The overall current sense range should be 25% to 50% above the largest expected peak current. The commandable current range is 80% of the total current sense range.

Example: A brushless DC motor application will allow a peak current in each phase of 7.5 amps. The total current sense is selected as +/- 10.0 amps, which gives a commandable range of +/- 8.0 amps. A sense resistor and op amp are used to generate +/- 1.65 volts for the desired current range of +/- 10 amps giving a current scaling of 10.0 amps / 1.65 volts or 6.06 amps/volt.

Motor currents are read using the `GetCurrentLoopValue` or `GetFOCValue` command. The returned value is a signed twos-complement number with a full scale negative current value of -20,480, a zero current value of 0, and full scale positive value of 20,470. This same scaling is used to set as well as read quantities that represent motor currents.

Example: In the above system, the scaling of measured current to current in counts is 10.0 amps / 20,479 counts = .488 mA/count. To set an I^2t continuous current of 3.5 amps a value of 3,500 mA / .488 mA/count = 7,172 counts is used.

6.4.3 Minimum Current Read Time

When controlling Brushless DC motors with FOC (field oriented control) current control mode selected the MC78113's minimum current read time parameter is used to insure a valid leg current reading when two of the three phases have a saturated PWM signal. This period of time is affected by the analog processing circuitry. It can be approximated by taking the electrical time constant and multiplying by 3 to 5.

The MC78113 default value for minimum current read time is set to be maximally safe but is not optimum for all analog processing hardware. For proper amplifier function these values must be set with values appropriate for the current sensor circuitry being used.



6.4.4 Leg Current Analog Offsets

To improve efficiency and motion smoothness it is important that the leg current inputs on signals *CurrentA-D* represent the actual current value as accurately as possible.

To facilitate this the MC78113 provides the ability to zero-out analog input offsets that may exist while the motor coils are not being driven by the amplifier and the motor is not moving.

The simplest way to do this is to send a `CalibrateAnalog` command to the MC78113. This command will automatically measure and set the offsets so that the leg current analog inputs are zeroed out. Because a number of samples are taken and averaged, 100 mSec should be allowed for this command to complete. In addition, the operating mode should be set to motor output only before this command is executed.

Alternatively, it is possible to directly read each analog input via the **ReadAnalog** command and then write the same values for the corresponding analog offsets using the **SetAnalogCalibration** command. When using this manual method it is recommended that a number of analog reads of each signal are averaged together to improve the offset accuracy.

Regardless of how the analog offsets are determined, unless explicitly stored into NVRAM they will not be retained after a reset or power cycle. For more information on NVRAM configuration storage see [Section 6.9.2, “Non-Volatile RAM”](#).



Regardless of the motor type (Brushless DC, DC Brush, step motor) having correctly calibrated offsets of the analog leg current inputs is important to maximize motor drive efficiency and smoothness. Failure to calibrate these analog offsets may result in reduced drive efficiency and a reduction in motion smoothness.

6.4.5 Current Control Parameters

There are a number of MC78113 IC parameters which are used to set or control current control shown in [Figures 6-5 - 6-7](#).

The following table summarizes these amplifier-related control parameters.

Parameter	Range & Units	Description
Analog Current Offset A-D	-32,767 to 32,768 counts	The analog offset ‘zero offset values’ are determined when the amplifier is switching with a zero current command. The offsets are generally specific to the external circuitry of each leg current sensor, and should be separately zeroed out for best performance. These parameters are set using the SetAnalogCalibration command or via the CalibrateAnalog command. The default values for these parameters are zero.
Minimum Current Read Time	0-32,767 nSec	When using Brushless DC motors if two of three legs are driven at 100% the analog current reading of the second leg low-side switch needs to be active for a minimum amount of time for a valid current reading. This parameter, set using the SetDrivePWM command, specifies the amount of time needed for a valid analog current read when the drive is in this condition. This parameter has units of nSecs. The default value for this parameter is 32,767 nSec.

6.5 Drive & DC Bus Safety

The MC78113 family ICs provide sophisticated DC Bus management and safety features. These features include overtemperature monitoring, over and under voltage monitoring, overcurrent monitoring, and shunt control.

The following table shows the signals that are used in connection with these features.

Pin Name	Pin#	Description
Temperature	9	Measured Temperature
BusVoltage	13	Measured Bus voltage
BusCurrentSupply	10	Measured DC Bus Current
Shunt	49	Shunt Switch

The following sections provide detailed operational, connection, and configuration information for these DC Bus and safety related features.

6.5.1 Overtemperature Protection

MC78113 supports a *Temperature* sensor input to continuously monitor the temperature of the power electronics or another part of the drive. Although various temperature sensors may be used with the MC78113, the most common type of sensor is a thermistor.

When using a thermistor the *Temperature* input signal should be filtered to minimize noise. The *Temperature* input is sampled by the MC78113 at a rate of 1kHz or higher, and therefore a low pass filter with a rolloff at 500 Hz or lower is recommended.

6.5.1.1 Typical Overtemperature Processing Circuitry

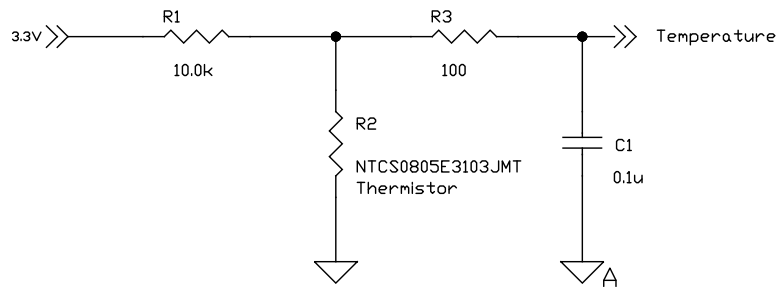


Figure 6-12:
Over-
temperature
Processing
Circuitry

[Figure 6-12](#) shows a typical signal processing circuit for use with the *Temperature* input. The thermistor is a 10k NTC temperature-voltage-decreasing type. C1 is referenced to analog ground and should be placed close to the *Temperature* pin of the MC58113. R3 is optional. It can provide additional filtering to improve noise immunity if needed.

See [Section 7.10, “Drive-Related Safety and Monitoring Features”](#) for a complete example schematic of temperature input using the MC78113.

6.5.1.2 Overtemperature Scaling, Reading and Writing

The value of the temperature sensor and downstream analog conditioning circuitry determine the overall temperature range that can be measured. The overall temperature sense range should be 15% to 25% above the highest expected temperature.

The *Temperature* signal input expects a voltage in the range of 0V to 3.3V representing the sensed temperature. Both temperature-voltage-increasing (voltage increases with increasing temperature) and temperature-voltage-decreasing (voltage decreases with increasing temperature) thermistors are supported. For voltage increasing thermistors 0.0V represents the lowest possible temperature, and for voltage decreasing thermistors 3.3V represents the lowest possible temperature.

The measured temperature can be read using the `GetDriveValue` command. The returned value is an unsigned number with a range from 0 to 32,767. The returned temperature is direction adjusted, meaning for both voltage-increasing and voltage-decreasing thermistors a zero return value indicates the lowest possible temperature and a 32,767 represents the highest possible temperature.

The overtemperature threshold is set using the `SetDriveFaultParameter` command. The sign of the overtemperature threshold selects whether the *Temperature* input increases or decreases with rising temperature; positive thresholds indicate voltage increase while negative thresholds indicate voltage decrease. The actual limit threshold utilized by the MC78113 for the comparison is the absolute value of the specified limit value.

In addition to the settable overtemperature the MC78113 supports a settable temperature hysteresis. This function is used to avoid spurious re-triggering of an overtemperature event. The temperature hysteresis value is set using the `SetDriveFaultParameter` command.

Example: A temperature-voltage-increasing thermistor and associated analog processing circuitry generate a voltage of 2.9V when the switching bridge circuitry is at the hottest safely operable temperature. The overtemperature limit specified using the `SetDriveFaultParameter` command should thus be set to $32,768 * 2.9V / 3.3V = 28,796$.

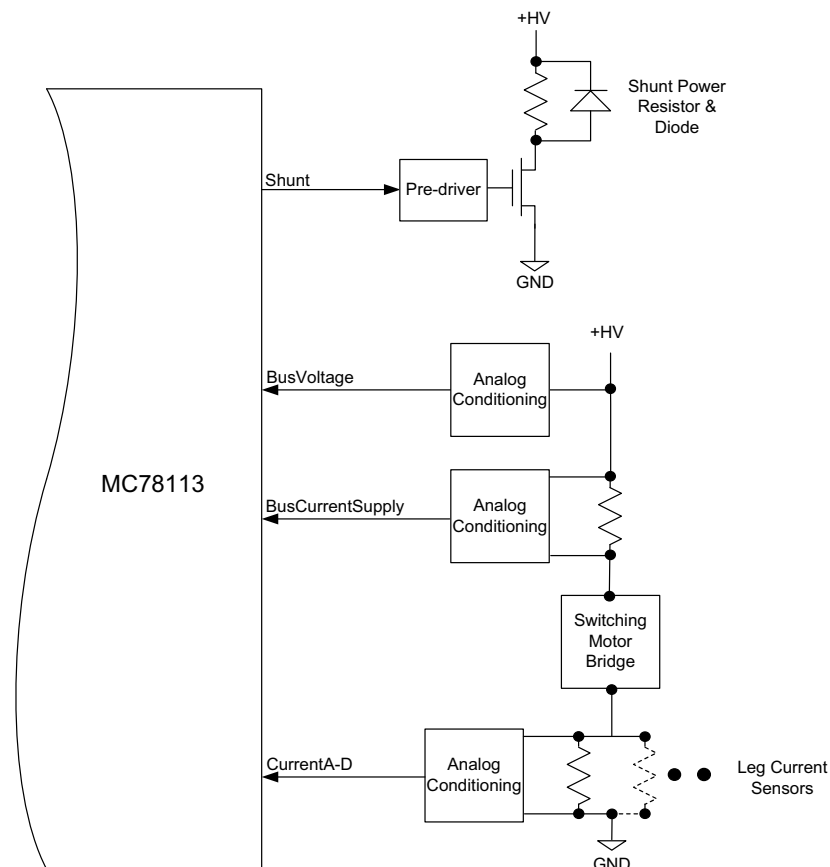
The overtemperature functions continuously once programmed. To disable the overtemperature check a threshold value of 32,767 is set.



Converting MC78113-readable values to an actual temperature in units of degrees C is often complex. For this reason the MC78113's overtemperature protection mechanism compares directly against the unconverted temperature value in units of counts, not units of degrees C.

6.5.2 Overcurrent Monitoring

Figure 6-13:
Overcurrent
Monitoring
Circuitry



[Figure 6-13](#) shows the DC bus monitoring scheme used with the MC78113 IC. MC78113 monitors both the supply-side and return-side DC bus current to detect overcurrent conditions. Each can measure somewhat different overcurrent conditions. Supply side current measurement detects all excessive current flow including shorts of the motor windings to ground, shorts of the windings to each other, or a stalled rotor. Return current measurement can not measure shorts to ground, but can measure winding shorts to each other and a stalled rotor.

The *BusCurrentSupply* signal directly encodes the total current flowing through the motor amplifier bridge(s) from the +HV supply. The return-side overcurrent monitoring occurs via the leg current sensors also used during current control.

The DC bus current supply sensor typically consists of a sense resistor, as shown in [Figure 6-13](#), or a linear Hall sensor. The analog processing circuitry required for each is somewhat different. If a dropping resistor is used an isolating operational amplifier, current mirror, or similar circuit should be used. Linear Hall sensors typically use just a ground-referenced operational amplifier.

The *BusCurrentSupply* input range is 0.0V to 3.3V with 0.0V representing no (zero) current flowing and 3.3 volts representing the maximum measurable amount of current flowing. The signal should be filtered to minimize noise, and the source impedance of the signal conditioning circuit should be less than 100 ohms. Current inputs are sampled by a dedicated high speed circuit internal to the MC78113. To minimize false positives a low pass filter with a rolloff of 200 kHz - 500 kHz is recommended with a typical value of 350 kHz.

6.5.2.1 Typical Overcurrent-Processing Circuitry

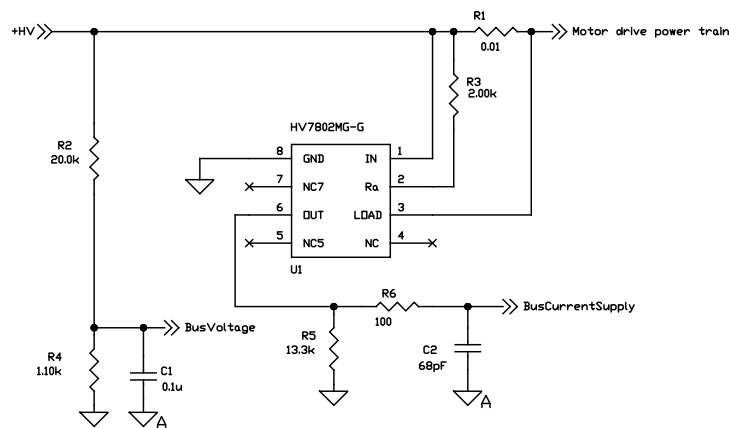


Figure 6-14:
DC Bus
Monitoring
Circuitry

[Figure 6-14](#) shows a typical processing circuit for DC Bus voltage and *BusCurrentSupply* over current sensing. The bus current sensing includes R1, U1, U2A and related passive parts. U1 is a high-side bus current sensing IC, and its output on R7 represents the bus current.

Although it is possible to trace and read the value of the supply current input the resultant readings may be noisy due to the switching activity of the PWM drive. If a trace or read value for this signal is desired a peak holding circuit may be added with a hold time of 100μsec.

During motor deceleration or other motion conditions it may be possible for the DC bus supply current flow to be negative. Care should be taken to insure that negative currents do not generate a negative voltage at the MC78113's *BusCurrentSupply* analog input pin. This is generally accomplished via a diode. See [Section 7.10, "Drive-Related Safety and Monitoring Features"](#) for examples of DC bus safety-related schematics.

See [Section 7.10, "Drive-Related Safety and Monitoring Features"](#) for complete example schematics of MC78113-based DC bus overcurrent protection designs.

6.5.2.2 DC Bus Supply Current Scaling, Reading and Writing

The value of the sense resistor and downstream analog conditioning circuitry determine the overall current range that can be measured. For the DC bus supply current input this range should be approximately double the maximum expected DC bus peak current flow. Note that in the case of step motors the maximum DC bus current is 150% of the peak phase current.

The measured bus supply current can be read using the **GetDriveValue** command. The returned value is an unsigned 16-bit number with range of 0 to 65,535. The DC bus supply overcurrent threshold is set using the **SetDriveFaultParameter** command. Typical threshold settings are 75-95% of the current sense range.

Example: An isolating op-amp and sense resistor generate 3.3V at a DC bus supply current flow of 15 amps. The scaling of current reads is $15.0\text{A}/65,536 = .228\text{ mA/count}$. The overcurrent threshold is set at 12.0 amps, or $12,000\text{ mA}/.228\text{ mA/count} = 52,631$.

The DC Bus supply overcurrent threshold function operates continuously once programmed. To disable an overcurrent check a threshold value of 65,535 is set.

6.5.2.3 DC Bus Return Overcurrent Measurement

Return current flow from the DC bus is measured via the leg current sensors as part of the current control mechanism. See [Section 6.4.2, "Current Scaling"](#) for more information on leg current scaling.

The bus return current can be read using the **GetDriveValue** command. The returned value is an unsigned 16-bit number with range of 0 to 20,479. The DC bus return overcurrent threshold is set using the **SetDriveFaultParameter** command.

The DC Bus return overcurrent threshold function operates continuously once programmed. To disable an overcurrent check a threshold value of 32,767 is set.



Return current measurement is only available when the motor output mode is set to PWM High/Low.



If current control is not implemented then it is not possible for the MC78113 to measure DC bus return current. DC bus supply current measurement is not affected however and can function with or without current control active.

6.5.3 DC Bus Voltage Monitoring

The MC78113 can monitor the DC bus voltage for overvoltage and undervoltage conditions utilizing the **BusVoltage** analog input signal. Overvoltage and undervoltage detection is accomplished by checking the measured voltage of the DC bus and comparing with user-provided thresholds.

The DC Bus voltage sensor typically consists of a voltage divider, which may be created from an isolating operational amplifier, current mirror, or similar circuit.

The **BusVoltage** signal should be filtered to minimize noise. The DC bus voltage input is sampled by the MC78113 at a rate of 20kHz, and therefore a low pass filter with a rolloff of 10 kHz or less is recommended.

6.5.3.1 DC Bus Voltage-Related Circuitry

[Figure 6-14](#) shows a typical processing circuit for DC Bus voltage monitoring. The bus voltage sensing consists of R2, R4 and C1. R2 and R4 scale the bus voltage, between 0 and 3.3V. C1 is referenced to analog ground and should be placed close to the **BusVoltage** pin of the MC78113.

See [Section 7.10, “Drive-Related Safety and Monitoring Features”](#) for complete example schematics of MC78113-based DC bus management designs.

6.5.3.2 DC Bus Voltage Scaling, Reading and Writing

The value of the sense resistor and downstream analog conditioning circuitry determines the overall voltage measurement range. This overall voltage range should be 15% to 50% above the maximum expected DC bus voltage.

The **BusVoltage** input range is 0.0V to 3.3V, with 0.0V representing a DC bus voltage of 0V, and +3.3V representing the largest measurable DC bus voltage. The measured bus voltage current can be read using the **GetDriveValue** command. The returned value is an unsigned 16-bit number with range of 0 to 65,535. The over and undervoltage thresholds are set using the **SetDriveFaultParameter** command, and have the same units.

Example: In an application that will have a motor voltage of 48 volts, external circuitry has been selected to present 3.3V at the **BusVoltage** input when the DC bus voltage is 65 volts. The scaling is $65\text{V}/65,536$ or $.992\text{ mV/count}$. To set an undervoltage threshold of 45V a value of $45,000\text{ mV}/.992\text{ mV/count} = 45,362$ is specified. To set an overvoltage threshold of 52V a value of $52,000\text{ mV}/.992\text{ mV/count} = 52,419$ is specified.

The under and overvoltage thresholds function continuously. To disable the under voltage or over voltage check, threshold values are set to 0 or 65,535 respectively.

6.5.4 Shunt Resistor

As shown in [Figure 6-13](#) the MC78113 controls a shunt PWM output, which in turn typically drives a MOSFET or IGBT switch which connects the voltage to the DC bus ground via a power resistor, thereby lowering the DC bus voltage.

The shunt functions by continually comparing the DC bus voltage, as presented at the **BusVoltage** signal, to a user programmable threshold. If the DC bus voltage exceeds the comparison threshold the **Shunt** signal outputs a PWM waveform at a user programmable duty cycle. This PWM frequency is equal to the motor drive PWM frequency. Once active, shunt PWM output will stop when the DC bus drops to 2.5% below the threshold comparison value.

Once programmed, the shunt comparison function operates continuously. To disable it, a value of 32,767 should be programmed. The shunt function is not active when motor output is not enabled (the active operating mode output bit is not set).

6.5.4.1 Shunt Related Circuitry

The shunt resistor connected should have a resistance such that the current flow through the shunt switch, diode and resistor do not exceed the ratings of those components at the expected DC bus voltage.

The diode, which is connected in parallel to the resistor, should have a voltage and current rating at least equal to those of the switch. See [Figure 6-13](#) for more information.

6.5.4.2 Shunt Reading and Writing

To set the shunt DC bus voltage comparison threshold the **SetDriveFaultParameter** is used. The scaling and units are the same as for the over and undervoltage functions. The shunt PWM duty cycle is set using the **SetDriveFaultParameter** command, and the provided value is an unsigned 16-bit number with range of 0 to 32,767.

Example: In the system from the example in [Section 6.5.3.2, “DC Bus Voltage Scaling, Reading and Writing”](#) the shunt will be activated when the DC bus voltage climbs to 51 volts with a duty cycle of 95%. The shunt comparison threshold is set to 51,000 mV/1.98 mV/count = 25,757 and the duty cycle value is $.95 * 32,768 = 31,130$.

It is possible to determine whether the shunt output is active at any given moment. To do this the command `GetDriveStatus` is used.

6.5.5 Drive & DC Bus Safety Control Parameters

There are a number of MC78113 parameters which are used to set up or control Drive & DC bus safety-related circuitry shown in [Figure 6-13](#).

The following table summarizes these control parameter settings:

Parameter	Range & Units	Description
Overtemperature Limit	0 - 32,767 counts	Sets the overtemperature threshold that is compared against the <i>Temperature</i> signal input to determine if an overtemperature condition is occurring. The default value of this parameter is 32,767 indicating that the overtemperature detect function is disabled.
Temperature hysteresis	0 - 6,400 counts	Sets the overtemperature threshold detection hysteresis value. After an overtemperature event has occurred the temperature must fall below the overtemperature threshold by this hysteresis value to no longer be in an overtemperature condition. The default value of this parameter is 0.
Supply Overcurrent Limit	0 - 65,534 counts	Sets the overcurrent threshold for the DC Bus supply that is compared against the <i>BusCurrentSupply</i> signal input to determine if an overcurrent condition is occurring. The default value of this parameter is 65,534 indicating that the supply overcurrent detect function is disabled.
Return Overcurrent Limit	0 - 65,534 counts	Sets the overcurrent threshold for the DC Bus return current that is compared against the <i>CurrentA-D</i> (depending on motor type) signal inputs to determine if an overcurrent condition is occurring. The default value of this parameter is 65,534 indicating that the return overcurrent detect function is disabled.
Overvoltage Limit	0 - 65,535 counts	Sets the overvoltage threshold for the DC Bus supply voltage that is compared against the <i>BusVoltage</i> signal input to determine if an overvoltage condition is occurring. The default value of this parameter is 65,535 indicating that the overvoltage detect function is disabled.
Undervoltage Limit	0 - 65,535 counts	Sets the undervoltage threshold for the DC Bus supply voltage that is compared against the <i>BusVoltage</i> signal input to determine if an undervoltage condition is occurring. The default value of this parameter is 0 indicating that the undervoltage detect function is disabled.

6.6 Host Communications

6.6.1 Serial

The MC78113 series ICs provide two overall serial communication modes; point to point (used with RS232 or RS422), and multi-drop (used with RS485). All of the MC78113 serial-related signals are digital TTL level signals, so for typical

cable-based use of these communication modes external transceiver chips are used. See [Section 7.6, “Serial Communication Interface \(SCI\)”](#) for example schematics for serial communications.

The table below provides a summary of the MC78113 signals used with serial communications:

Pin Name	Pin #	Description
SrIRcv	32	Serial Receive inputs the serial data for all serial modes.
SrIXmt	27	Serial Transmit outputs the serial data for all serial modes.
SrIEnable	61	SrIEnable is held high in point-to-point mode. In multi-drop mode SrIEnable is high during transmission only.

By default the MC78113 powers up in point to point communication mode at 56 Kbaud. This configuration information can be changed via the **SetSerialPortMode** command.

6.6.2 CANbus

The MC78113 series IC provide CANbus 2.0 compatible communications. All of the MC78113 CANbus-related signals are digital TTL level signals, so for typical cable-based use of this communication mode external transceiver chips are used. See [Section 7.7, “CAN Communication Interface”](#) for example schematics for CANbus communications.

The table below provides a summary of the MC78113 signals used with CANbus communications:

Pin Name	Pin #	Description
CANRcv	26	CANbus receive inputs the CANbus data
CANXmt	25	CANbus transmit output the CANbus data

MC78113 ICs will coexist (but not communicate) with CANOpen nodes on that network. MC78113 uses CAN to receive commands, send responses, and (optionally) send asynchronous event notifications and uses different addresses for each as indicated in the table below:

Message Type	CAN Address
Command received	0x600 + nodeID
Command response	0x580 + nodeID
Event Notification	0x180 + nodeID

By default the MC78113 CANbus nodeID is 0, and the CAN baud rate is 20,000. This configuration information can be changed via the **SetCANMode** command.

6.6.3 SPI (Serial Peripheral Interface)

The MC78113 series ICs provide SPI communications both for host communications, and for direct input commands such as the continuous instantaneous desired velocity or torque. For more information on the formatting of SPI host communications refer to the *Juno Velocity & Torque Control IC User's Guide*.

All of the MC78113 SPI-related signals are digital TTL level signals. Some applications may directly connect microprocessors, FPGAs, or other on-card logic to these signals. Other applications, depending on signal lengths and



noise level may benefit from external drivers to improve signal integrity of the SPI bus. See [Section 7.8, “SPI Communication Interface”](#) for example schematics for SPI communications.

SPI is a serial hardware bus intended for communications within a PCB substrate only. It is not recommend for card to card communications. It is the responsibility of the user to insure the signal integrity of the SPI bus for the application in which it is used.

The MC78113's SPI interface utilizes three digital input pins *SPIEnable*, *SPIClock* and *SPIRcv*, and two digital output pins *SPICmd* and *SPIstatus*. These signals represent the standard SPI enable, chip select, clock, and data functions, along with a protocol packet processing status indicator. The MC78113 acts as an SPI slave, and the host processor acts as an SPI master.

The table below provides a summary of the MC78113 signals used with SPI communications:

Pin Name	Pin #	Description and when used
SPIRcv	36	SPIRcv inputs synchronous serial data for the SPI bus
SPIXmt	34	SPIXmt transmits synchronous serial data for the SPI bus
SPIClock	33	SPIClock inputs the clock signal used with synchronous serial transfer on the SPI bus
SPIEnable	44	SPIEnable inputs an enable for SPI bus communications
SPIStatus	61	SPIStatus is used during host communications to synchronize host commands with responses. It is not used with direct input SPI commands.
SPIMode	48	SPIMode selects between the host command SPI protocol and the direct input SPI protocol.

For complete electrical timing information for all SPI bus operations see [Section 3.2.3, “Host SPI”](#).

6.7 Input Signal Processing

6.7.1 Quadrature Encoder Signals

Incremental encoder input along with an index pulse and associated high speed capture system is supported by all members of the MC78113 family except MC75113. All of the MC78113 encoder related signals are digital TTL level signals, so for typical cable-based connection to a motor encoder differential transceiver chips are used.

QuadA and *QuadB* are expected to be offset from each other by 90 degrees, as shown in [Figure 6-15](#). When the motor moves in the position direction, *QuadA* should lead *QuadB*. When the motor moves in the negative direction *QuadB* should lead *QuadA*. Four resolved quadrature counts occur for one full phase of each A and B channel.

The *Index* signal provides a capture trigger for the instantaneous up/down quadrature position.

The table below provides a summary of the MC78113 signals encoder related functions.

Pin Name	Pin #	Description
QuadA	62	Quad A input
QuadB	63	Quad B input
Index	4	Index input

By default the *Index* capture signal is active low. This default value can be changed via the *SetSignalSense* command.

6.7.2 Typical Quadrature Encoder Processing Circuitry

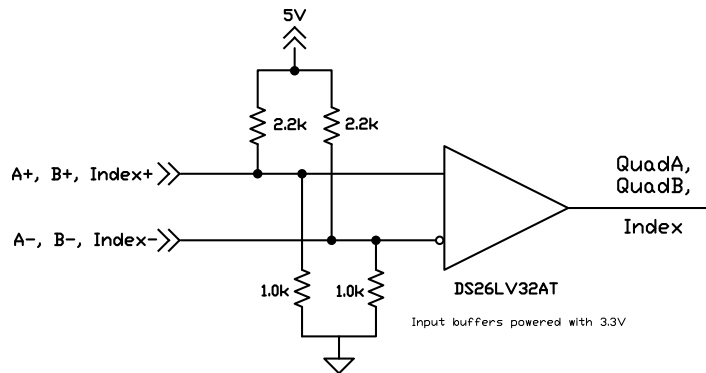


Figure 6-15:
Quadrature
Encoder
Processing
Circuitry

Figure 6-15 shows a typical circuit for processing differential quadrature and index signals. The pull-up and pull-down resistors provide both termination and a bias voltage. When single ended encoder signals are used connect to the positive input and leave the negative input unconnected.

6.7.3 Pulse & Direction

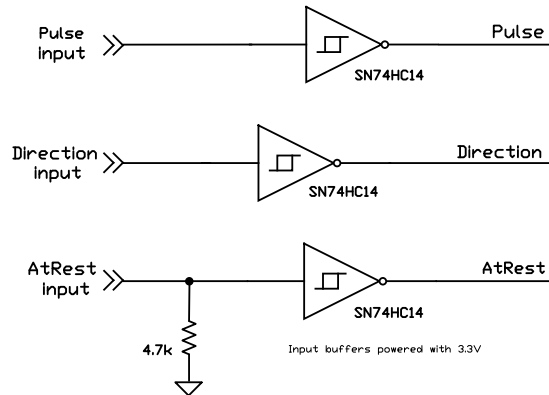
Pulse & Direction along with *AtRest* input is supported by all members of the MC78113 family. All of these signals are digital TTL level, so for typical cable-based connection buffering circuits are recommended.

The table below provides a summary of the MC78113 pulse & direction related signals:

Pin Name	Pin #	Description
Pulse	33	Pulse provides a step pulse) signal for the pulse & direction position command input source.
Direction	36	Direction indicates the direction of motion for the pulse & direction position command input source.
AtRest	35	AtRest indicates that the axis is at rest and not actively moving. It is used to select between the 'in motion' programmable step motor torque levels and the 'at rest' level.

By default the *Pulse* signal is active low. This configuration information along with interpretation of the *Direction* and *AtRest* signals can be changed via the *SetSignalSense* command.

Figure 6-16:
Pulse &
Direction
Processing
Circuitry



[Figure 6-16](#) shows a typical circuit for processing the *Pulse* & *Direction*, and *AtRest* signals. The buffered signals are inverted and have a pull-down resistor at the *AtRest* input so the output of the buffer is low to ensure a deterministic state when *AtRest* is unconnected.

6.7.4 Hall Sensors

Although not required by the MC78113, Hall signals are commonly used when driving Brushless DC motors. All of the MC78113 Hall signal inputs are digital TTL level signals, so for typical applications external signal processing circuitry is used.

The table below provides a summary of the MC78113 Hall-based signals:

Pin Name	Pin #	Description
HallA	35	HallA input
HallB	31	HallB input
HallC	64	HallC input

There is some variation in how typical motors are wired, so [Figure 6-17](#) shows the expected relationship of the three Hall signals to other phased waveforms such as the back EMF and the commanded phase current. For convenience the MC78113 provides the ability to change the signal sense interpretation of these incoming signals.

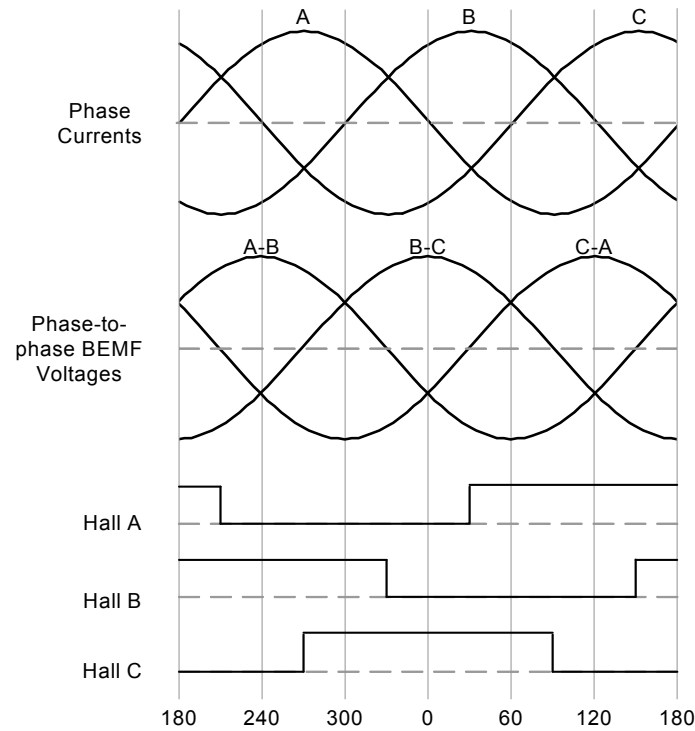


Figure 6-17:
Hall-Based
Phase Diagram

6.7.4.1 Typical Hall Processing Circuitry

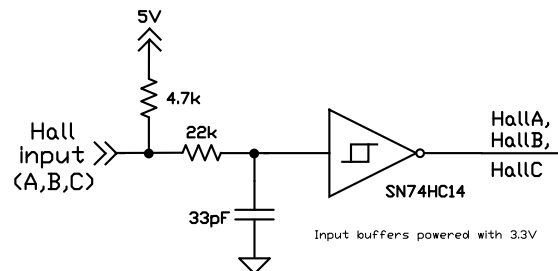


Figure 6-18:
Typical Hall
Processing
Circuitry

[Figure 6-18](#) shows a typical circuit for processing Hall sensor signals. The 4.7k resistor pull-up resistor is required when the Hall signals are open-collector. The 22k resistor and 33pF capacitor provide a low-pass filter with a bandwidth of 219 kHz. The selection of the low-pass filter bandwidth depends on noise and Hall signal frequency. This buffer stage has an inversion on its output.

6.7.5 AnalogCmd & Tachometer

MC78113 supports input of an *AnalogCmd* direct input signal to provide a bi-polar desired velocity or torque command for the motor or actuator being controlled. In addition a *Tachometer* input signal can be used to provide velocity feedback to the MC78113.

The table below provides a summary of the MC78113 *AnalogCmd* & *Tachometer* signals:

Pin Name	Pin #	Description
AnalogCmd	18	Analog torque or velocity command input
Tachometer	24	Analog velocity feedback used by velocity loop

6.7.5.1 AnalogCmd

The analog input range at the MC78113 is 0.0V to 3.3V with the maximum positive command represented with a value of 3.3V, the maximum negative command having a value 0.0V, and a command value of 0 having a value of 1.65V.

On-card circuitry that directly outputs an analog signal in a compatible format may directly connect to the MC78113 input pin. External connections via cable require on-card signal conditioning to insure proper scaling and filtering.

The *AnalogCmd* input is sampled by the MC78113 at a rate of 20kHz and therefore a low pass filter with a rolloff at 50kHz - 200kHz is recommended.

6.7.5.2 Tachometer

MC78113 supports input of a *Tachometer* signal which provide a bi-polar measured velocity for the motor or actuator being controlled. All aspects of voltage range and scaling for this signal are the same as for the *AnalogCmd* signal. The analog input range at the MC78113 is 0.0V to 3.3V and the maximum and minimum velocity feedback readings have a value of 3.3V and 0.0V respectively. See [Figure 6-19](#) for an example schematic that inputs from an external circuit with a range of +/-10 V.



In addition to measuring motor velocity, the *Tachometer* signal can also be used to input other non-velocity feedback measurements such as pressure, air flow rate, or temperature. When this type of measurement is input, although not actually controlling velocity, the MC78113's velocity loop will drive toward the measured quantity allowing use of the Juno MC78113 IC as a general purpose pressure, fluid flow, or temperature controller.

6.7.5.3 Typical AnalogCmd & Tachometer Processing Circuitry

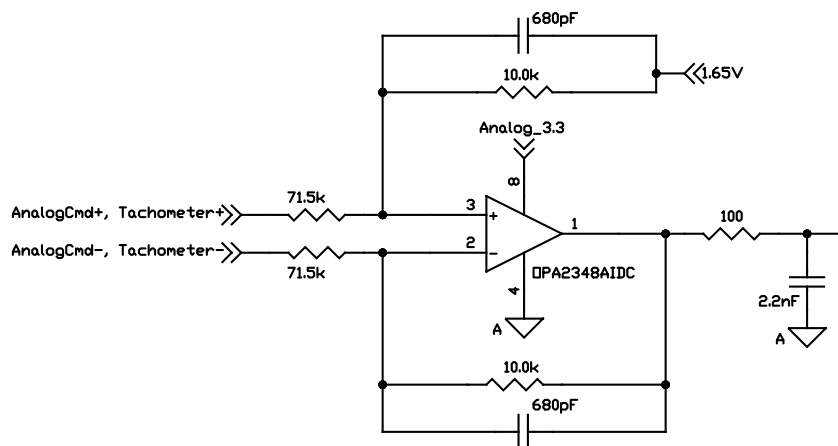


Figure 6-19:
AnalogCmd
and
Tachometer
Circuitry

Figure 6-19 shows a typical circuit for processing $\pm 10\text{V}$ differential input command or tachometer signals. The output has an offset of 1.65V corresponding to a zero command. The bandwidth of this circuit is 23.4kHz . The 100ohm resistor and 2.2nF capacitor should be placed close to the *AnalogCmd* input pin of MC78113. All resistors used should be 1% or higher grade. All capacitors should be X7R or higher grade.

6.7.5.4 AnalogCmd & Tachometer Scaling and Reading

The value of the analog command and downstream analog conditioning circuitry determine the overall velocity or torque command range that can be specified. When reading the analog command via the MC78113's *GetVelocityLoopValue* command or via a trace the returned value is a signed number with a range from $-32,768$ to $32,767$.

Example: Analog processing circuitry converts a $\pm 10\text{V}$ signal to the full scale of the 0 to 3.3V input range. An incoming signal voltage of -7.0V is received, representing a request for 70% of available maximum velocity or torque in the negative direction. This incoming signal results in a voltage of 0.495V at the MC78113's *AnalogCmd* pin which after being read results in numerical command value of $-22,937$.

6.8 Reset & Power-up

MC78113 requires various conditions to be present on the *Reset* and *ClkIn* pins for proper reset and powerup.

In particular, *ClkIn* must be kept in a high impedance state during powerup until the MC78113's V_{CC} and *AnalogVcc* stabilize.

The table below provides a summary of the MC78113 reset related signals:

Pin Name	Pin #	Description
Reset	7	Reset input
ClkIn	45	Clock input

6.8.1 Typical Reset Processing Circuitry

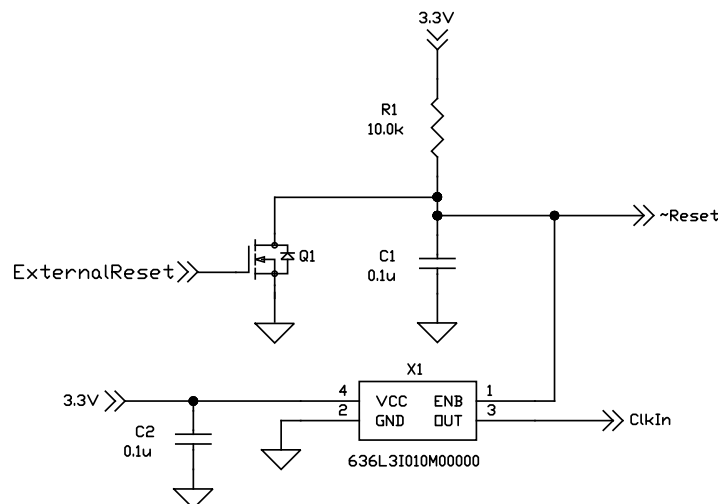


Figure 6-20:
Typical Reset
Processing
Circuitry

Figure 6-20 shows a typical reset circuit for the MC78113. Although included in this circuit, external control of the *Reset* signal is not required since the MC78113 will trigger an internal reset upon power up. If external reset is implemented an open-drain device is used.

The \sim Reset pin is driven low by the MC78113 under a power-on or reset condition. [Figure 6-20](#) uses \sim Reset signal to meet the *ClkIn* high impedance requirement. At power on, MC78113 pulls down \sim Reset signal and puts X1 output to high impedance.

6.8.2 Initialization

A power-up where no user-provided initialization parameters have been stored in NVRAM takes approximately 250mSec. At the end of this sequence all parameters are at their default values, and both the current loop module and the power stage module are disabled. At this point MC78113 is ready to receive commands and begin operation.

MC78113 also supports the ability to store initialization parameters that are automatically applied during the power up sequence. For this purpose, a 1,024 word memory that is non-volatile (NVRAM) is provided.

If the non-volatile initialization memory has been loaded with initialization information the MC78113 sequence detects this and begins executing the commands stored in the non-volatile memory. Once execution of these commands is completed, the MC78113 initialization is done and normal operation begins. Note that processing stored commands may increase the overall initialization time depending on the command sequence stored.

See [Section 6.9.2, “Non-Volatile RAM”](#) for more information on the MC78113’s NVRAM.

6.9 MC78113 RAM and NVRAM Buffers

MC78113 provides two user-accessible types of memory storage, a 6,144 16-bit word RAM used primarily for trace and a 1,024 16-bit word NVRAM used primarily to store initialization configuration parameters. The RAM will be lost upon a power cycle or reset function while the NVRAM is permanent and will be retained even after a power cycle.

For more information on Juno IC memory buffers and trace, see the *Juno Velocity & Torque Control IC User’s Guide*.

6.9.1 Trace RAM

The MC78113’s internal RAM volatile memory is most often used for performance trace, but it may also be used for general purpose storage of user-specified data. All RAM access occurs via the MC78113’s buffer access commands. Buffer access commands allow memory areas to be written to and read from the memory areas using different word sizes. In addition all trace operations use buffers to specify where the trace data will be written to and read from.

The starting address of the MC78113’s RAM is 0. For convenience the MC78113 RAM memory area is pre-defined as BufferID #0

To learn more about Juno’s buffer access commands and very powerful trace features for tuning and performance optimization refer to the *Juno Velocity & Torque Control IC User’s Guide*.

6.9.2 Non-Volatile RAM

The MC78113 supports a memory segment that is non-volatile (NVRAM). The primary purpose of the NVRAM is to allow MC78113 configuration information to be stored, so that upon power up it can be loaded automatically rather than requiring an external controller to perform this configuration initialization function.

The starting address of MC78113’s NVRAM is 0x2000 0000. For convenience the NVRAM memory area is pre-defined as BufferID #1.

All data stored in the MC78113 NVRAM utilizes a data format known as PMD Structured data Storage Format (PSF). Users who rely only on PMD’s Pro-Motion software package to communicate with MC78113 and store and retrieve

initialization parameters need not concern themselves with the details of PSF. Users who want to address the NVRAM from their own software, or who want to create their own user-defined storage should refer to the *Juno Velocity & Torque Control IC User's Guide* for detailed information on PSF.

6.10 Output Signal Status During Powerup

The following table summarizes the MC78113's output signal states during power up and after powerup when no initialization data is stored in the MC78113's NVRAM.

Pin Name	Pin#	State during powerup	State after power up
PWMHighA/PWMMagA	56	Tri-stated	Tri-stated
PWMLowA/PWMSignA	55	Tri-stated	Tri-stated
PWMHighB/PWMMagB	54	Tri-stated	Tri-stated
PWMLowB	53	Tri-stated	Tri-stated
PWMHighC/PWMMagC	51	Tri-stated	Tri-stated
PWMLowC	50	Tri-stated	Tri-stated
PWMHighD	39	Tri-stated	Tri-stated
PWMLowD	38	Tri-stated	Tri-stated
AmplifierEnable	3	Pulled high	Driven low
Shunt	49	Tri-stated	Tri-stated (until output mode is set)
FaultOut	52	Tri-stated	Driven low
SrIXmt	27	Pulled high	Pulled high
CANXmt	25	Pulled high	Pulled high
SrIEnable/SPIStatus	61	Pulled high	Driven low
SPIXmt	34	Pulled high	Driven low
~HostInterrupt	46	Pulled high	Driven high

If configuration data has been stored in the MC78113's NVRAM then the final powerup condition of various outputs signals may be affected. See the detailed description of the specific commands that are stored into the NVRAM for details.



See [Section 6.9.2, “Non-Volatile RAM”](#) for more information on NVRAM initialization storage.

6.11 Analog Signal Input

The following table summarizes the MC78113's analog signals and indicates how they may be addressed during trace or for other operations such as `ReadAnalog`, or `SetAnalogCalibration` commands.

MC78113 Signal	Pin #	Channel
CurrentA	14	0
CurrentB	19	1
CurrentC	12	2
CurrentD	21	3

MC78113 Signal	Pin #	Channel
AnalogCmd	18	4
Tachometer	24	5
Temperature	9	6
BusCurrentSupply	10	7
BusVoltage	13	8

If used, for best performance, it is highly recommended that the *CurrentA-D*, *AnalogCmd*, and *Tachometer* signals be calibrated and offset. See [Section 6.4.4, “Leg Current Analog Offsets”](#) for information on analog input offsetting.

For the *Temperature* and *BusVoltage* signals, offsetting is allowed but generally not necessary. The *BusCurrentSupply* signal does not support an offset calibration nor is one needed for proper functioning.



Regardless of how the analog offsets are determined, unless explicitly stored into NVRAM analog offsets will not be retained after a reset or power cycle.

7. Application Notes — MC78113

7

- ▶ General Design Notes
- ▶ Design Tips
- ▶ Power Supplies
- ▶ Clock Generator, Grounding and Decoupling
- ▶ Reset Signal
- ▶ Serial Communication Interface (SCI)
- ▶ CAN Communication Interface
- ▶ SPI Communication Interface
- ▶ Analog Inputs
- ▶ Drive-Related Safety and Monitoring Features
- ▶ Shunt Resistor Drive
- ▶ PWM High/Low Motor Drive With Leg Current Sensing/Control
- ▶ Using the TI LMD18200 to Drive DC Brush Motors
- ▶ Two Juno Step Motor Amplifiers With Multi-Axis Magellan
- ▶ Two Juno BLDC Motor Amplifiers With Multi-Axis Magellan

7.1 General Design Notes

Logic functions presented in the example schematics are implemented by standard logic gates. In cases where specific parameters are of significance (propagation delay, voltage levels, etc.) a recommended part number is given.

In the schematics, pins with multiple functions are referenced by the name corresponding to the specified functionality. For example, pin 56 on the MC78113 is named “PWMHighA/PWMMagA” but will be referenced by the name “PWMHighA” in the PWM High/Low motor drive example and “PWMMagA” in the DC brush motor schematics.

The schematic designs presented in this chapter are accurate to the best of PMD’s knowledge. They are intended for reference only and have not all been tested in hardware implementations.



7.1.1 Interfacing to Other Logic Families

When integrating different logic families, consideration should be given to timing, logic level compatibility, and output drive capabilities. The MC78113 is 3.3V CMOS input/output compatible and cannot be directly interfaced to 5V CMOS components. In order to drive a 5V CMOS device, level shifters from the 5V CMOS AHCT (or the slower HCT) families can be used. When using a 5V CMOS component to drive the CP, a voltage divider may be used or a member from the CMOS 3.3V LVT family may serve as a level shifter.

7.2 Design Tips

7.2.1 Controlling PWM Output During Reset

When the MC78113 is in a reset state (when the reset line is held low), or immediately after a power on, PWM output will be in a high impedance state, which will provide design flexibility to prevent undesirable motor movement at system level. For example, when the power train is active high in PWM High/Low mode, pull-down resistors can be used to keep the power train off during reset and power up. For an active low power stage, pull-up resistors can be used.

7.2.2 Thermal Considerations

The recommended operating junction temperature range for the MC78113 is between -40°C and 150°C. Proper thermal design will ensure the system reliability. Based on a simplified resistor model for heat transfer, following thermal matrices under different conditions are provide to for thermal design.

AIR FLOW				
Parameter	0 lfm	150 lfm	250 lfm	500 lfm
θ_{JA} [°C/W] High k PCB	56.5	44.7	42.9	40.3
ψ_{JT} [°C/W]	0.15	0.42	0.51	0.67

θ_{JA} is the junction-to-ambient thermal resistance. Although it is an important design reference, this thermal metric highly depends on the board design and system configurations. Directly using it for junction temperature estimation could result in misleading results because the environmental factors are different from design to design.

ψ_{JT} (junction to top of package) is provides as an useful thermal metric for estimating the in-situ junctional temperature. The environmental factors do not affect this metric as much, and it can be easily measured. Also, because ψ_{JT} is small, if a user chooses to, the top of package temperature might be approximated as the junctional temperature for design estimation when enough thermal design margin is included.

This page intentionally left blank.

7.3 Power Supplies

In the schematic shown in [Figure 7-1](#) the design is powered by an external +5VCC power source. The MC78113 requires a 3.3V supply input. +3.3Vs, the 3.3V digital supply, is generated by the TPS76733QPWPRG4, a 1.0 Amp fixed 3.3V low-dropout voltage regulator.

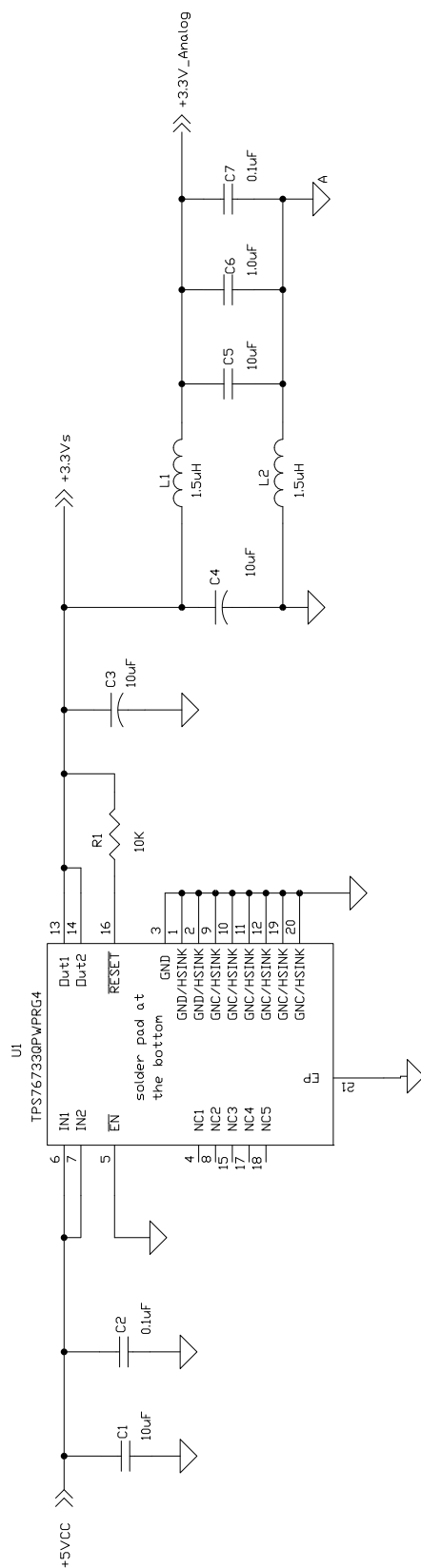
If the MC78113 analog-to-digital converter (ADC) is used it should be supplied with a filtered +3.3Vs supply.

The following is the list of supplies which are referenced in the example schematics within this application notes section of the manual:

- +3.3Vs and +3.3V_Analog: +3.3Vs is the main digital supply for the MC78113 device. +3.3V_Analog is the filtered version of the +3.3Vs supply for ADC and its related conditioning circuitry. The extra filtering is used to provide additional decoupling of the analog elements from the digital elements in the circuitry.

Notes:

- The power supplies schematic provided in [Figure 7-1](#) is for reference only, and is designed only to meet the requirements of the example schematics used in the application notes section of the manual. The actual supplies used should be designed according to the stability and precision requirements of the application.
- Power supplies for the motor drive amplifiers/switchers are not shown. Care should be taken when designing these power supplies, as they should be capable of sinking high switching currents.



Performance Motion Devices, Inc			
Title		Power Supplies	
Size	Document Number	Rev	A
B			
Date:	Wednesday, April 12, 2017	Sheet	1 of 1

Figure 7-1:
Basics, Power
Supplies,
MC78113

7.4 Clock Generator, Grounding and Decoupling

7.4.1 Clock Generator — MC78113

An external 3.3V 10MHz clock oscillator output should be supplied to the MC78113's ClkIn pin.

During power up, the pin ClkIn could glitch. In [Figure 7-2](#), MC78113's ~Reset pin is connected to ENB pin of the clock oscillator. During power up, ~Reset pin holds low and keeps the output of clock oscillator at high impedance to prevent I/O conflict.

7.4.2 Grounding and Decoupling

As shown in [Figure 7-2](#), each of the MC78113 digital supply voltage pins should be connected to the +3.3 Vcc. A minimum of 1.2uF capacitor should be used to decouple each Vcc pin. A 2.2uF ceramic capacitor is recommended. If the +3.3 Vcc source is noisy, additional ferrite bead can be placed in series with the decoupling cap to form a LC filtering network on the power pin.

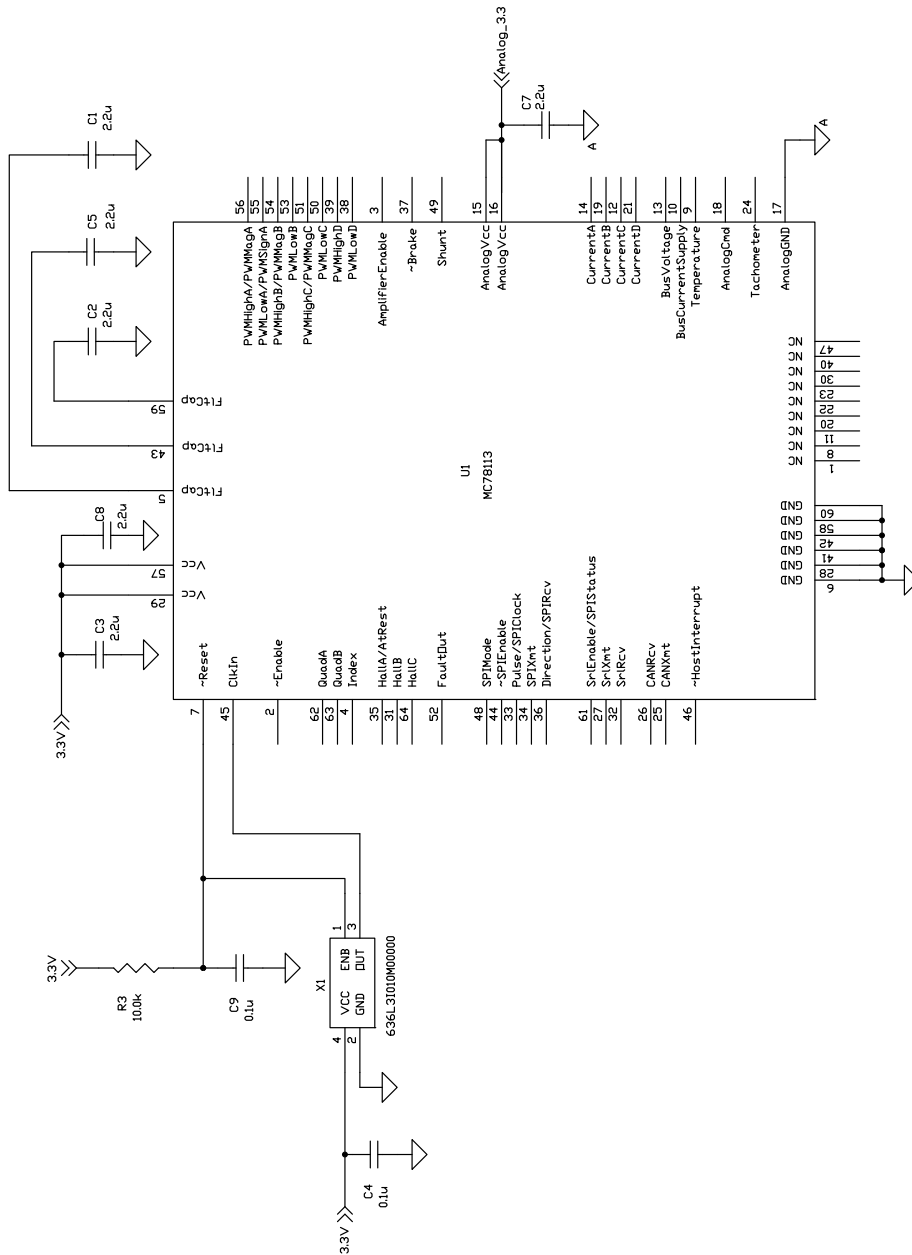
Each of the “FltCap” pins should be connected to a minimum of 1.2uF filtering capacitor which in turn connects to ground. A 2.2uF ceramic capacitor is used in the schematic. The filtering capacitors must be placed as close as possible to each one of the “FltCap” pins. This general rule applies to all analog and digital components, although in some of the schematics that follow these capacitors are not shown for reasons of brevity. In some cases, especially for analog processing circuitry, it may be beneficial to run a separate power line from the power supply to the component in order to prevent power supply fluctuations from impacting low-level signal components.

The same points should be considered when designing the ground. A good board layout practice should have a star connection at one point in the power supply.

Additional filtering, such as ferrite beads, may be inserted between the analog and digital grounds to suppress high frequency ground noise. Some components, such as motor drivers, require special grounding. The system designer should refer to the component data sheets of selected components in order to ensure correct usage of the grounding methods.

7.4.3 Decoupling of the On-chip ADC

The voltage supply to the ADC should be decoupled with a 2.2uF ceramic capacitor (typical) on the pin. It should be placed as close as possible to the ADC power supply input pins.



Performance Motion Devices

Title Clock, Reset and Bypass Caps - MC78113

Size B Document Number

Rev A

Date: Wednesday, April 12, 2017 Sheet 1 of 1

Figure 7-2:
Basics, Clock and
Bypass Caps,
MC78113

7.5 Reset Signal

The MC78113 chip has a built-in power supervisory circuitry that generates an internal reset signal when a power-on or brown-out condition occurs. As such, no external circuitry is needed to generate a reset input pulse. An R-C circuit must be connected to this pin for noise immunity reasons.

The supervisor reset release delay time is typically 600 μ sec after the power-on or brown-out condition event is removed. If need be, an external circuit may also drive this pin to assert a device reset. In this case, it is recommended that this pin be driven by an open-drain device.

All digital output signals have an internal pullup except for **FaultOut** and the **PWM** signals. See [Section 6.10, “Output Signal Status During Powerup”](#) for more information. If the **AmplifierEnable** and **FaultOut** signals are used they should have an external pull down resistor to prevent any glitches during reset.

During the initialization period, the MC78113 is configured with the default initialization parameters for motor type, serial communication and CAN communication, analog offsets, control loop gains etc. If necessary, the MC78113's on chip non-volatile storage can be used to store user-programmed initialization parameters. For more information see the *Juno Velocity & Torque Control IC User's Guide*.

7.6 Serial Communication Interface (SCI)

In this section the serial communication interface to the host is described. On power-up or after a reset, unless the on board non volatile storage has been used to store alternate defaults, the MC78113 configures the SCI to its default configuration of 57,600 baud, no parity, one stop bit, point-to-point mode.

This section demonstrates the use of RS-232 and RS-485 line-drivers for interfacing to a remote host.

7.6.1 Asynchronous Serial Communications

When the host and motion control IC are located on the same physical board it is most likely that simply wiring the transmit and receive lines directly between the host and MC78113 chip is all that is required (assuming they are both 3.3V CMOS devices).

For communications between cards or modules TIA/EIA standards provide reliable communication over varying cable lengths and communication rates. The most commonly used standards are RS-232 and RS-485. These standards are separated into two categories: single-ended and differential. RS-232 is a single-ended standard allowing for moderate communication rates over relatively short cables. RS-485 is differential, offering higher data rates and longer cable runs.

Line drivers and receivers (transceivers) are commonly used in order to mediate between the cable interface and the digital circuitry signal levels. There are several design considerations that should be taken into account when deciding which of these two communication methods is the best fit for an application.

- Full-duplex vs. half-duplex

The terms full-duplex and half-duplex are used to distinguish between a system having two separate physical communications lines from one having one common line for transmission and reception.

- Line contention

This problem can occur in half-duplex systems. Most line-drivers supply physical protection against such conditions but there is no automatic recovery of lost data in these levels. When interfacing the MC78113 to a half-duplex communication system the designer should note that the turn-around time for command processing and response is at least 1 byte at the current baud rate. As a result the host should release the communication line before this time elapses so that contention can be avoided.

- Termination impedance

Long cables and/or high data rates require termination resistors if the transceiver is located at the end of the transmission lines. One way to determine if termination is required is if the propagation delay across the cable is larger than ten times the signaling transition time. If this condition is satisfied, then termination is required. The RS-485 standard specifies the signaling transition time to be less than 0.3 times the signaling period, thus imposing an upper limit on the maximum cable length for a specified baud rate.

The termination resistor should match the characteristic impedance of the cable with 20% tolerance. Resistors with a value of 80-120 are typically used. Note that for transceivers placed in the middle of the cable, no termination resistors are required. However, the stubs should be kept as short as possible to prevent reflections.

- Pin SrlEnable/HostSPISStatus at power up and reset

MC78113's SrlEnable/SPISStatus pin must be '1' at power up and reset; only pull-up resistor is allowed. In RS-485 communication, it would enable the line driver output and affect ongoing communication so hot swap operation is not supported.

The schematic in [Figure 7-3](#) employs the ADM3202 and ADM3491 transceivers as an example of RS-232 and RS-485 interfaces respectively. Other RS-232 transceivers may be used, such as Maxim's MAX3321E. The ADM3491 circuitry

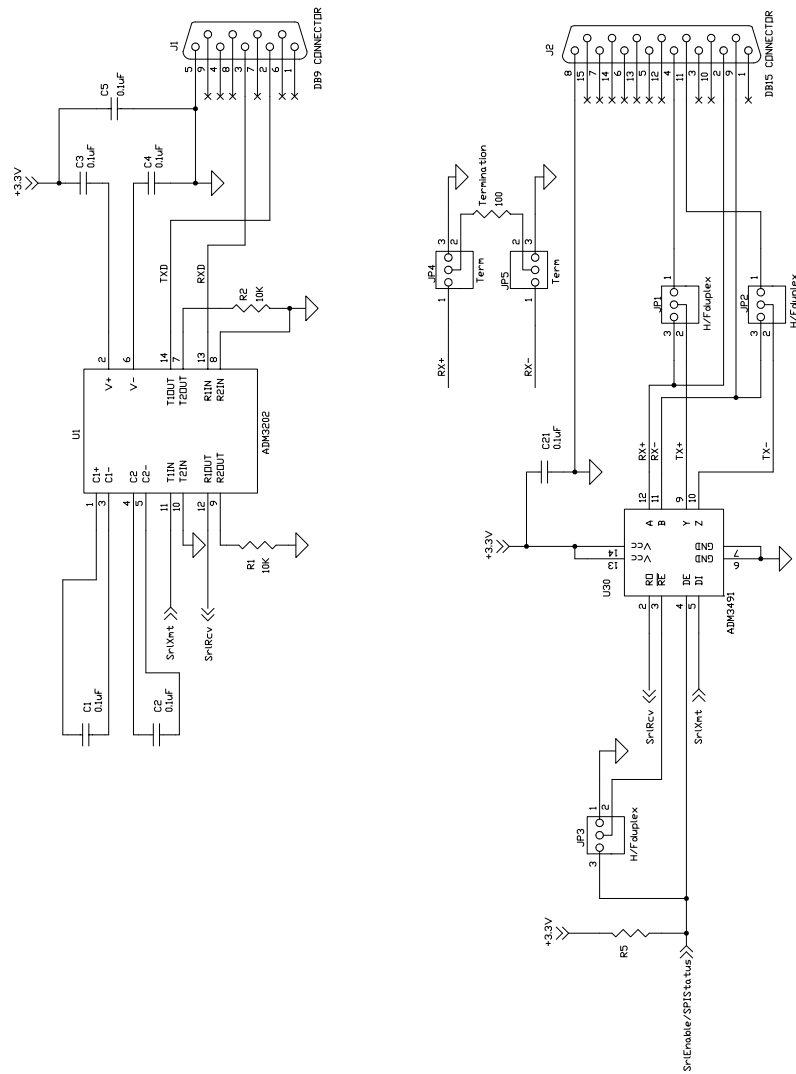
can be configured for both full-duplex and half-duplex communications, and may include termination resistors. As an alternative, transceivers from the MAX307xE family may be used.

The following table shows configuration options for the RS-422/485 circuitry of [Figure 7-3](#):

Configuration	Jumper Position	Application
Half Duplex ¹	JP1/2/3 in 2-3	RS-422/485 in multipoint system
Full Duplex	JP1/2/3 in 1-2	RS-422/485 in point to point system
Termination on ²	JP4/5 in 1-2	RS-422/485. For high transmission rates and/or long cable. Only when placed at the end of the cable.
Termination off	JP4/5 in 2-3	RS-422/485. For low transmission rates and short cable. Or when placed at the middle of the cable.

1. JP3 should only be placed in the half duplex state (2-3) if multi-point communication is being used.

2. Note that the reference circuitry does not support resistance termination on the transmitting side when operated in full duplex because it is assumed that RS-422/485 will only be used in the half-duplex configuration.



Performance Motion Devices, Inc.			
Title			
Host Communication - RS232 and RS485			
Size	Document Number	Rev	
B		A	
Date	Wednesday, April 12, 2017	Sheet	1 of 1

Figure 7-3:
Host
Communication, RS-232
and RS-485

7.7 CAN Communication Interface

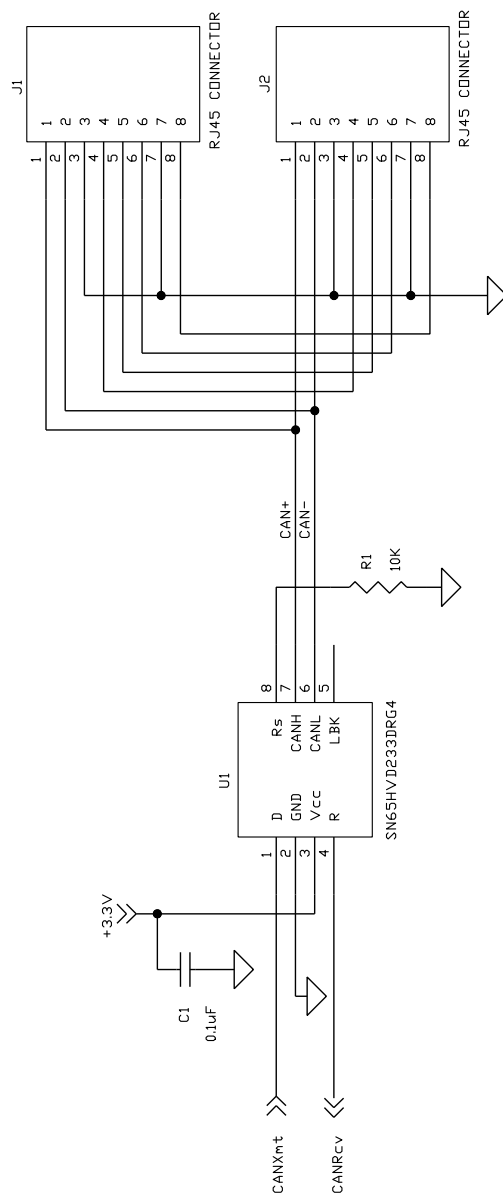
The following example illustrates an interface to a CAN backbone using TI's SN65HVD233 transceiver, which supports the ISO 11898 standard. This port can be operated at various communication rates from 10,000 to 1,000,000 bps (bits per second). In addition, each CANbus device is assigned three CAN identifiers (also called addresses); one for transmission of messages, one for reception of messages, and one for event messages. Generally, the CAN high-speed standard ISO 11898 provides a single line bus structure as a network topology. The bus line is terminated at both ends with a termination resistor of $\sim 120\Omega$. Consult CAN ISO 11898 standard for more information on termination schemes and EMC considerations.

7.7.1 CAN Configuration During Power-up or Reset

On power-up or after reset, the MC78113 configures the CAN controller to its default configuration: 20 kbps with a Node ID of 0. The MC78113's on board non-volatile storage can be used to store user-programmed initialization parameters. If a non-default CAN configuration is required, please contact PMD sales representative to learn more. PMD may ship MC78113s pre-loaded with user-specified parameters.

The RS pin of the SN65HVD233 provides for three modes of operation: high-speed, slope control, or low-power standby mode. This programmable input pin may be used to adjust the rise and fall times of the transmitter. This may be important in unshielded, low-cost systems in order to reduce electromagnetic interference. This pin provides three different modes of operation: high-speed, slope control, and low-power modes. The high-speed mode of operation is selected by connecting this pin to ground, allowing the transmitter output transistors to switch on and off as fast as possible with no limitation on the rise and fall slopes. The rise and fall slopes can be adjusted by connecting a resistor to ground at this pin, since the slope is proportional to the pin's output current. This slope control is implemented with external resistor values of $10\text{k}\Omega$, to achieve a $15\text{-V}/\mu\text{s}$ slew rate, to $100\text{k}\Omega$, to achieve a $2\text{-V}/\mu\text{s}$ slew rate.

If transmitter's rise/fall times do not require adjusting, the RS pin should be tied to GND or the simpler SN65HVD232 can be used.



Performance Motion Devices, Inc.			
Title Host Communication - CAN Bus			
Size B	Document Number	Rev A	
Date: Tuesday, July 15, 2014	Sheet 1	of 1	

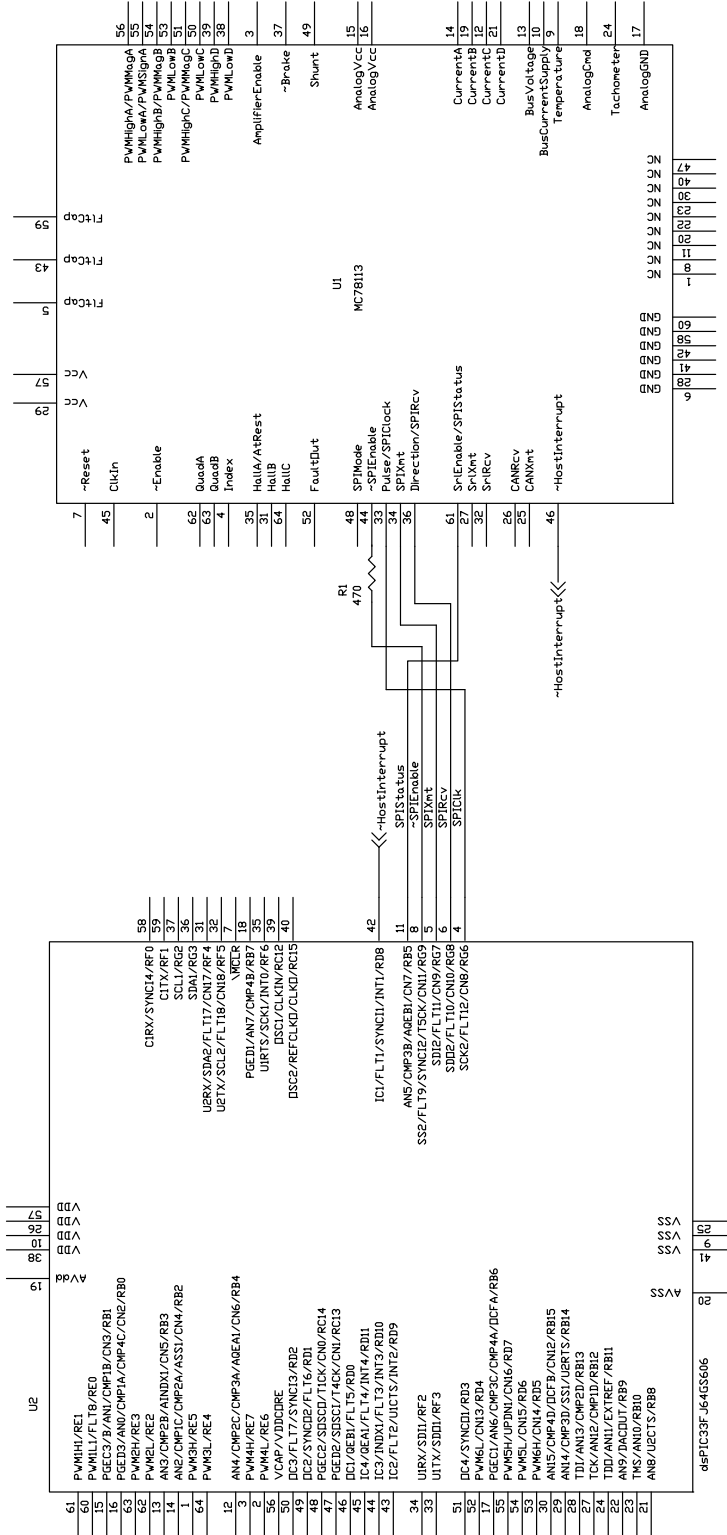
Figure 7-4:
Host
Communication CANbus

7.8 SPI Communication Interface

The MC78113 motion control IC supports SPI (Serial Peripheral Interface) for communications with a host processor such as a microcontroller. The SPI interface is an alternative to the Serial or CAN bus interfaces, and provides fast communication on a single board or over short distances.

The SPIClock pin receives the host clock signal. *SPIXmt* signal transmits the synchronous serial data to the host, the *SPIRcv* signal receives the synchronous serial data from the host processor and the active low *~SPIEnable* should be asserted by the host when Host SPI communication is occurring. The normally high *SPIStatus* signal is asserted low when the command is finished processing by the MC78113 and the data is ready to be received by the host. *SPIMode* is left unconnected in this example, and it is high with internal pull-up resistor. When high, SPI data is interpreted as a stream of host commands encoded as for MC78113. When *SPIMode* is pulled low to ground through a 2.2kohm resistor, SPI data is interpreted as a stream of 16-bit twos complement words, which are interpreted as velocity, torque, or incremental microstep position.

The following example schematic in [Figure 7-5](#) illustrates the Host communication via the SPI ports. The host controller is the Microchip's dsPIC33FJ64GS606. The microcontroller's SPI port is used for the host SPI communication.



Performance Motion Devices, Inc.

Title		Host Communication - SPI	
Size	B	Document Number	
Rev	A		
Date	Wednesday, April 12, 2017	Sheet	1 of 1

Figure 7-5:
Host
Communication SPI

7.9 Analog Inputs

The Juno IC products support analog command signal and tachometer analog feedback signal. The following example schematic in [Figure 7-6](#) illustrates the analog conditioning circuit.

The MC78113 is equipped with a 12-bit ADC. The ADC converts from 0 to 3.3V fixed full scale range. The ADC power supply should be decoupled with a low-ESR capacitor. For example, place a 2.2uF ceramic capacitor or a 2.2-6.8 uF tantalum capacitor in parallel with a 0.01-0.1 uF ceramic capacitor as closely as possible to the power supply and ground pins.

The digital value for analog command signal and tachometer analog feedback signal derived from the input analog voltage is determined using the following formula.

Digital value = 0 when input = Vref

Digital value = $32,768 \times (\text{input voltage} - \text{Vref}) / 3.3\text{V}$ when $0\text{V} \leq \text{input} \leq 3.3\text{V}$

where Vref is 1.65V typical, and the user can set offset value to compensate the offset in the circuit.

[Figure 7-6](#) shows a differential signal conditioning circuit for +/-10V analog command signal. The analog command signal is assumed to be differential, AnalogCmd+ and AnalogCmd-. For single-ended input signal, connect the input signal to AnalogCmd+ and the AnalogCmd- end to ground. The same circuit can be used for tachometer analog feedback signal conditioning.

The differential amplifier stage scales the input signal to the range of 0 and 3.3V as

$\text{AnalogCmd} = G(\text{AnalogCmd+} - \text{AnalogCmd-}) + 1.65\text{V}$

For +/-10V input and Vref as 1.65V, the gain is $G = 0.165$.

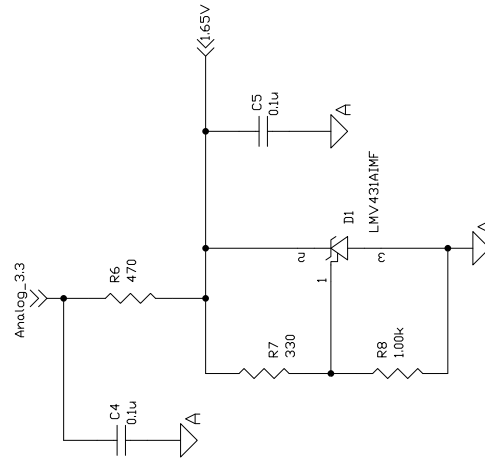
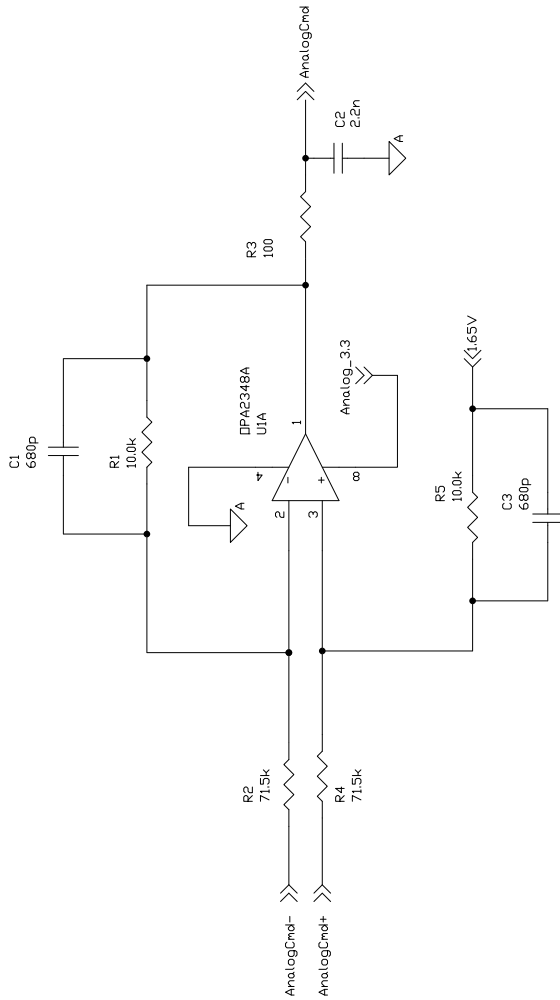
When $R1 = R5$, and $R2 = R4$, its DC gain is

$\text{AnalogCmd} = (R1/R2)(\text{AnalogCmd+} - \text{AnalogCmd-}) + 1.65\text{V}$

When $R1 = R5 = 10.0 \text{ kohms}$ and $R2 = R4 = 71.5 \text{ kohms}$, the gain is 0.14, which is slightly lower than 0.165 to accommodate offsets and tolerances. Please use 1% or better grade resistors for better common mode performance

C1 and C3 set the bandwidth of the filter. With $C1 = C3$, the bandwidth is $1/(2\pi R1 C1)$. For $R1 = 10.0 \text{ kohms}$ and $C1 = 680 \text{ pF}$, the bandwidth is 23.4kHz.

The low-pass RC filter of R3 and C2 limits the load on the opamp. C2 should be placed close to the ADC input pin, as it partially drives the sample capacitor of the ADC.



Performance Motion Devices, Inc			
Title Analog Command Input, +/-10V			
Size B	Document Number	Rev A	
Date: Wednesday, April 12, 2017	Sheet 1	of 1	

Figure 7-6:
Analog Input
Interface

7.10 Drive-Related Safety and Monitoring Features

This example shows the motor drive-related analog monitoring features. Please refer to [Section 7.12, “PWM High/Low Motor Drive With Leg Current Sensing/Control”](#) for leg current sensing functions.

The block of R9, R10, R13 and C5 is for temperature sensing. R13 is a thermistor, and its resistance depends on the temperature. MC78113 will sense the scaled voltage and convert it into temperature reading. C5 need to be tied close to the Temperature pin to improve noise immunity.

In this example, it is assumed that the thermistor is away from the MC78113 and close to the power train, which usually has the highest temperature. Accordingly, C5 is referred to the analog ground, and R13 to digital ground. R10 is optional to improve the noise immunity. If R13 is close to the analog portion, Vcc can be AnalogVcc instead and R13 be tied to the analog ground.

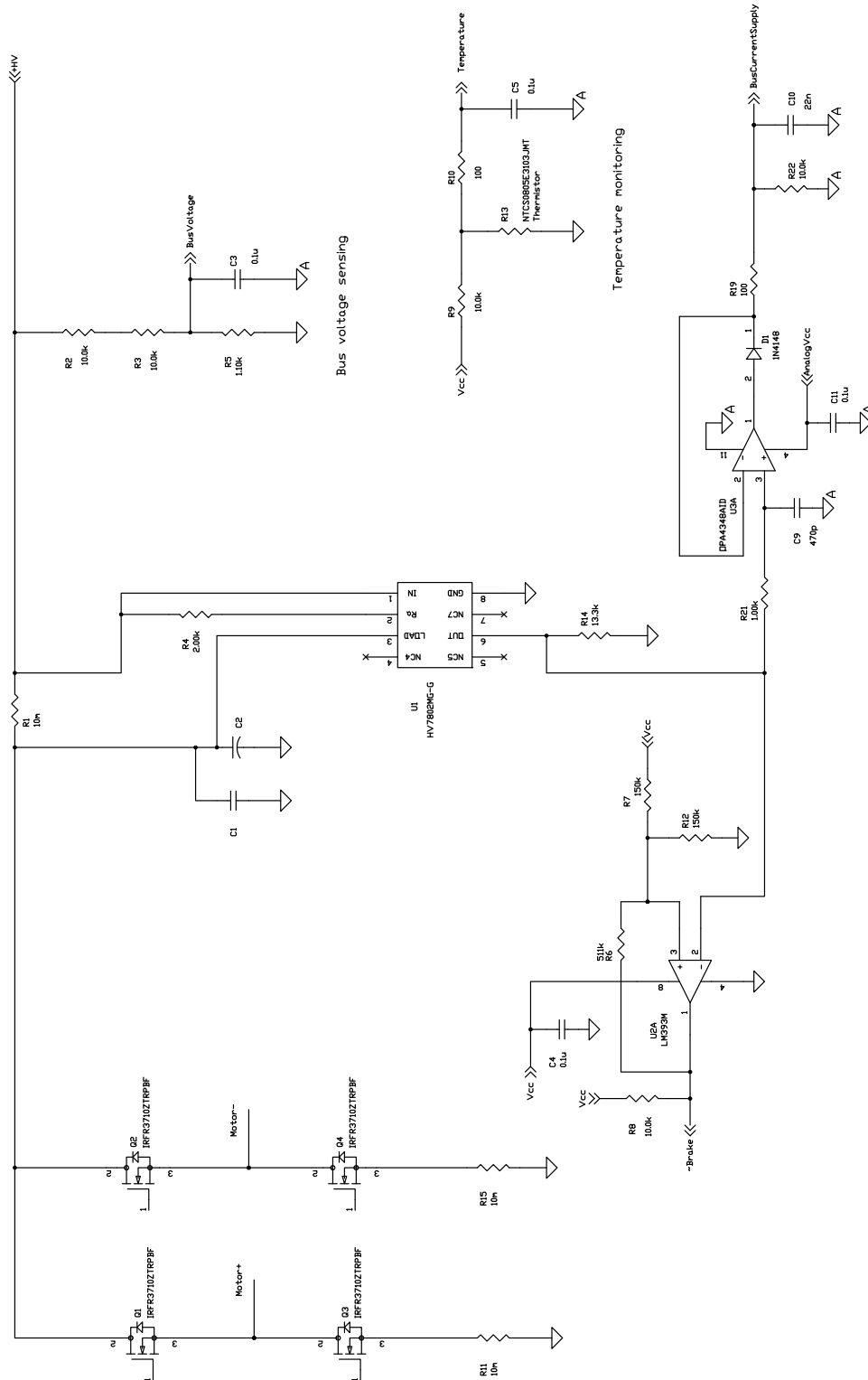
The block of R2, R3, R5 and C3 is for input voltage sensing. This voltage divider will scale the +HV into the range between ground and 3.3V. In this example, it will scale 63V to 3.3V. C3 need to be tied close to BusVoltage pin. The voltage divider is referenced to digital ground while C3 is to analog ground. An optional resistor can be put between R5 and C3 to improve noise immunity as R10 does for temperature sensing function. This block is also a low-pass filter with bandwidth of 1.5kHz. This bandwidth should be selected to respond to real voltage fault event while attenuating bus noise.

U1 is the high side bus current sensing IC. With current sensing resistor R1 at 10mOhm, U1 has a current scaling factor of $(13.3/2 \times 0.01) = 66.5\text{mV/A}$.

U2A is for short circuit protection. R12 and R7 set the protection trigger point, and R6 provides a hysteresis. When Vcc is 3.3V, the trigger point is 1.65V with hysteresis. *~PWMOutputDisable* will go to low and trigger protection when U1 output is over 1.65V, which is $(1.65/66.5\text{mV/A}) = 25\text{A}$.

The output of U1 also goes to U3A, which is a peak-detection circuit. MC78113 will sample the analog input at 20kHz. The peak-detection circuit will hold the maximum peak current reading between the sampling points so MC78113 can detect the maximum current. The necessity of this peak-detection circuit depends on the power train design. For example, if C1 and C2 have big enough capacitance so that the current in R1 will be close to DC, U3A can be a buffer instead.

MC78113 support leg current sensing with current loop control, and R11 and R15 are leg current sensing resistors.



Performance Motion Devices, Inc.			
File	Drive safety and monitoring	Rev	1
Size	Document Number	Sheet	1 of 1
B			
DATE			

Figure 7-7:
Drive Safety and Monitoring

7.11 Shunt Resistor Drive

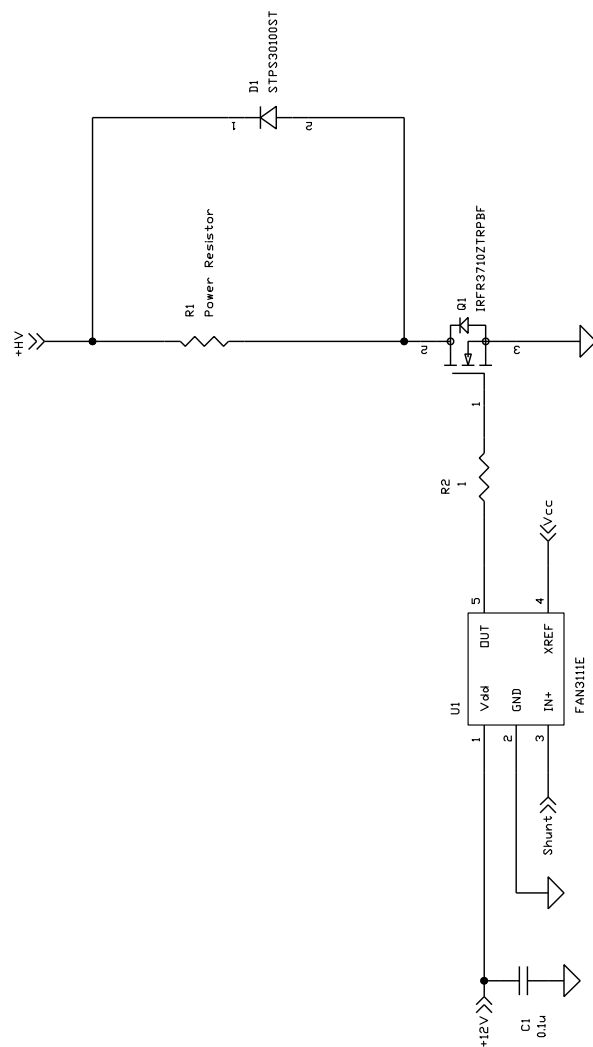
This example shows the shunt function driving a brake resistor.

The power train driven by the MC78113 is capable of regeneration. It could harvest the mechanical energy during slow down or direction reversion and transfer the energy back to the power input. When the input power supply cannot handle the regenerative power, input voltage +HV will go up and over-voltage is possible. The Shunt pin can implement dynamic braking, which will convert the energy into heat and stabilize the +HV voltage.

The shunt signal is controlled based on the input voltage sensing, and it will become active when input voltage is too high.

Shunt is a PWM-based signal and drives MOSFET Q1 through driver U1. When Q1 is turned on, current will flow through R1 and consume energy. When Q1 is turned off, D1 will provide a free-wheeling path for the current in R1 decaying to zero. Q1 and D1 should be sized to handle the current. Also, R1, Q1 and D1 should be sized to handle both the instantaneous power and average power during braking operation.

Upon power up or during reset, the *Shunt* pin is high impedance. In this example, U1 has internal pull-down resistor to ensure Q1 is off. If a different driver is used a pull-down or pull-up resistor might be necessary to ensure the shunt function is off for safe power up and reset.



Performance Motion Devices, Inc			
Title Shunt Drive Circuit			
Size B	Document Number	Rev A	
Date: Wednesday, July 23, 2014	Sheet 1	of 1	

Figure 7-8:
Shunt Drive
Circuit

7.12 PWM High/Low Motor Drive With Leg Current Sensing/Control

This section presents several design examples PWM high/low motor drive with leg current sensing. The examples focus on different priorities including power rating, cost, and noise immunity. Also, although specific motor type is shown in the examples, the design considerations apply to all motor types.

7.12.1 Leg Current Sensing

[Figure 7-9](#) shows an example for leg current sensing. Only phase A is shown here while the design for other legs are the same.

This example has two functional sections. The first is the current sensing sensor, and the second is the analog signal conditioning circuit.

In this example, the leg current sensor is a resistor, R2. Q1 and Q2 are the half-bridge power train for motor winding phase A. Current sensing resistor R2 senses the leg current in Q2, which equals the motor winding current when Q2 conducts.

Q2 is switching at the PWM frequency, and the voltage drop on R2 is proportional to the motor winding current when Q2 is on. Therefore, the voltage signal is also a chopping signal. MC78113 always sample the signal when Q2 is on to ensure an accurate reading. Also, the voltage drop can be positive, negative or zero depending on the winding current direction.

U1 and the passive parts are the analog conditioning circuit. It scales and filters the voltage signal on R2 and input to the MC78113 ADC input pin CurrentA.

U1A is configured as a differential amplifier with R3=R5 and R1=R6. It amplifies the voltage drop across R2, which is the differential voltage. It also attenuates the common mode noise including the noise on the power train.

D1 provide a 1.65V voltage bias source as half the 3.3V ADC range. This bias can be shared with current sensing stages of other phases. With this voltage bias, MC78113 can sense R2 current in either direction.

By default, the MC78113 takes 1.65V reading as zero current. The MC78113 provides commands to compensate the error introduced by the offsets and tolerances of the current sensing circuit.

R4 and C1 is a low pass filter to reduce output noise. It also alleviates the signal glitch due to ADC sampling. R4 and C1 have to be placed close to MC78113 CurrentA pin. Please note, because the signal on R2 is a chopping signal at the PWM frequency, the bandwidth of R4 and C1 should be much higher than the PWM frequency preventing signal distortion/delay.

The gain of the current sensing circuit is

$$V_{\text{CurrentA}} = I_{\text{leg}} \cdot R2 \cdot R1 / R3 + 1.65$$

For this example, it is

$$V_{\text{CurrentA}} = I_{\text{leg}} \cdot 0.02 \cdot 54.9 / 10.0 + 3.3 / 2 = 0.1098 \cdot I_{\text{leg}} + 1.65$$

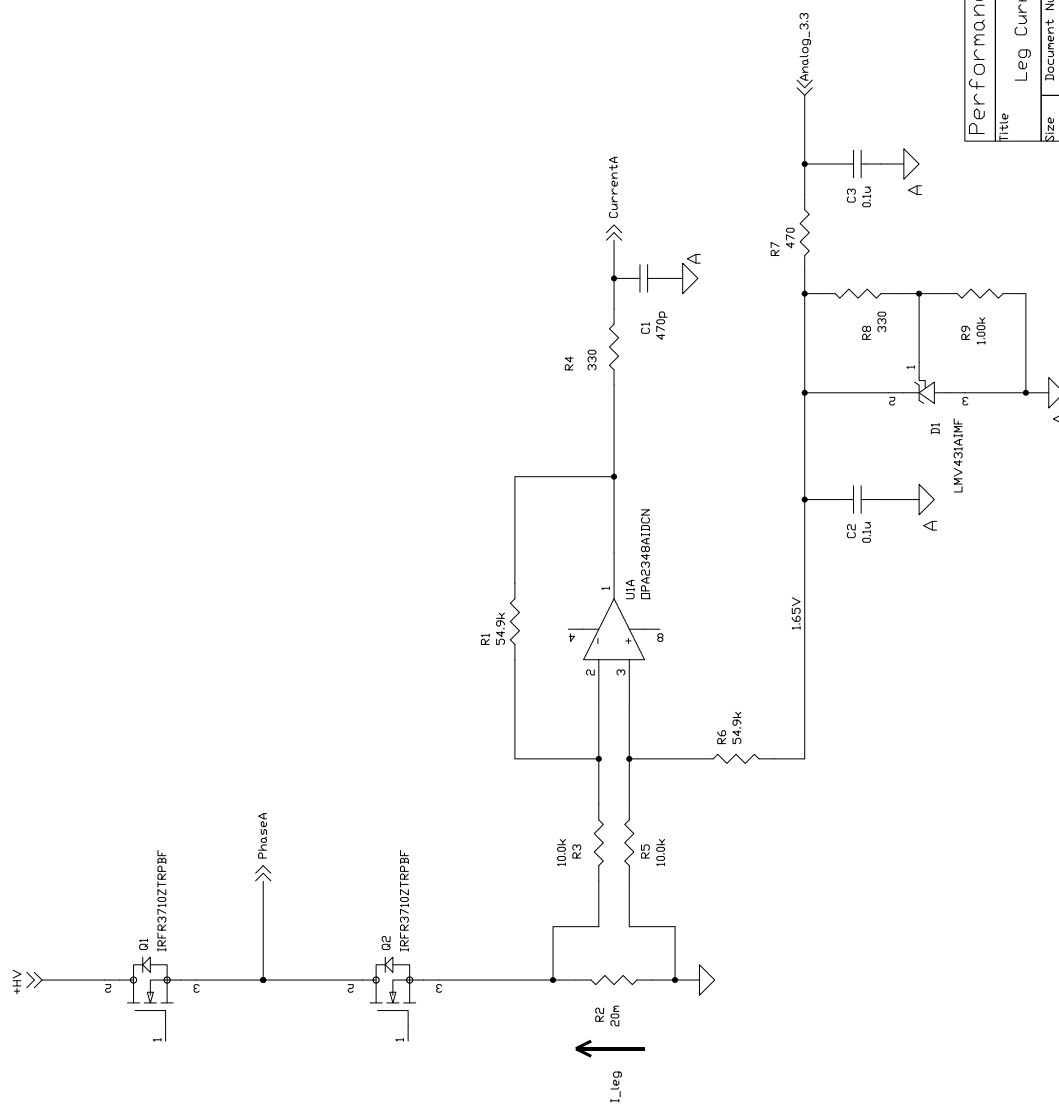
I_{leg} is defined as positive flowing from the ground to Q2 as shown in the schematic. It is because the current out of the half bridge and into motor winding is defined as positive.

Therefore, the current sensing range is $\pm 15\text{A}$. This current range should include the peak current during dynamic regulation. For example, during acceleration, the instantaneous current could be twice of the continuous current or even more.

With the continuous current and peak current known, the power rating of the current resistor can be determined. The conservative design rule is to assume that the current will go through R2 continuously, and the power dissipation is $I^2 \cdot R_2$. However, the current will only flow through the resistor when Q2 is on; that is, if the duty cycle is known for this leg, the power dissipation can be approximated as $I^2 \cdot R_2 \cdot (T_{Q2ON} / T_{PWM})$ and resistor can be sized accordingly.

The board layout is critical for an optimal current sensing signal. The current sensing traces (to R3/R5) should be separated from the power path through R2, and these two traces should be routed in pair to improve its common-mode noise immunity. Also, a motor power train has multiple current sensing resistors, and these resistors are referred to ground. During layout, please treat those ground traces (e.g. trace to R5) as separated traces for each leg.

Figure 7-9:
Leg Current
Sensing



Performance Motion Devices, Inc			
Title Leg Current Sensing (Phase A shown)			
Size B	Document Number	Rev A	
Date: Wednesday, April 12, 2017	Sheet 1	of 1	

This page intentionally left blank.

7.12.2 Low Cost DC Motor Drive

This example presents a low-cost, high performance DC motor drive.

The power train shown is an H-bridge (two half-bridge) for DC motor winding Motor+ and Motor-. The input voltage can be up to 24V. It is capable of driving 1A continuous current with peak current of 2A.

The design for the two half-bridges and their current sensing circuits are the same. Using Motor+ as an example, the half bridge has a P-channel MOSFET as the upper switch and an N-channel MOSFET as the lower switch, which is driven by PWMHighA and PWMLowA through buffer U1.

During normal operation, PWMLowA is active low. A logic “0” will generate 5V output at U1B, which turn on the lower N-channel MOSFET. R15, R7 and D5 provide an unsymmetrical turn-on and turn-off capability.

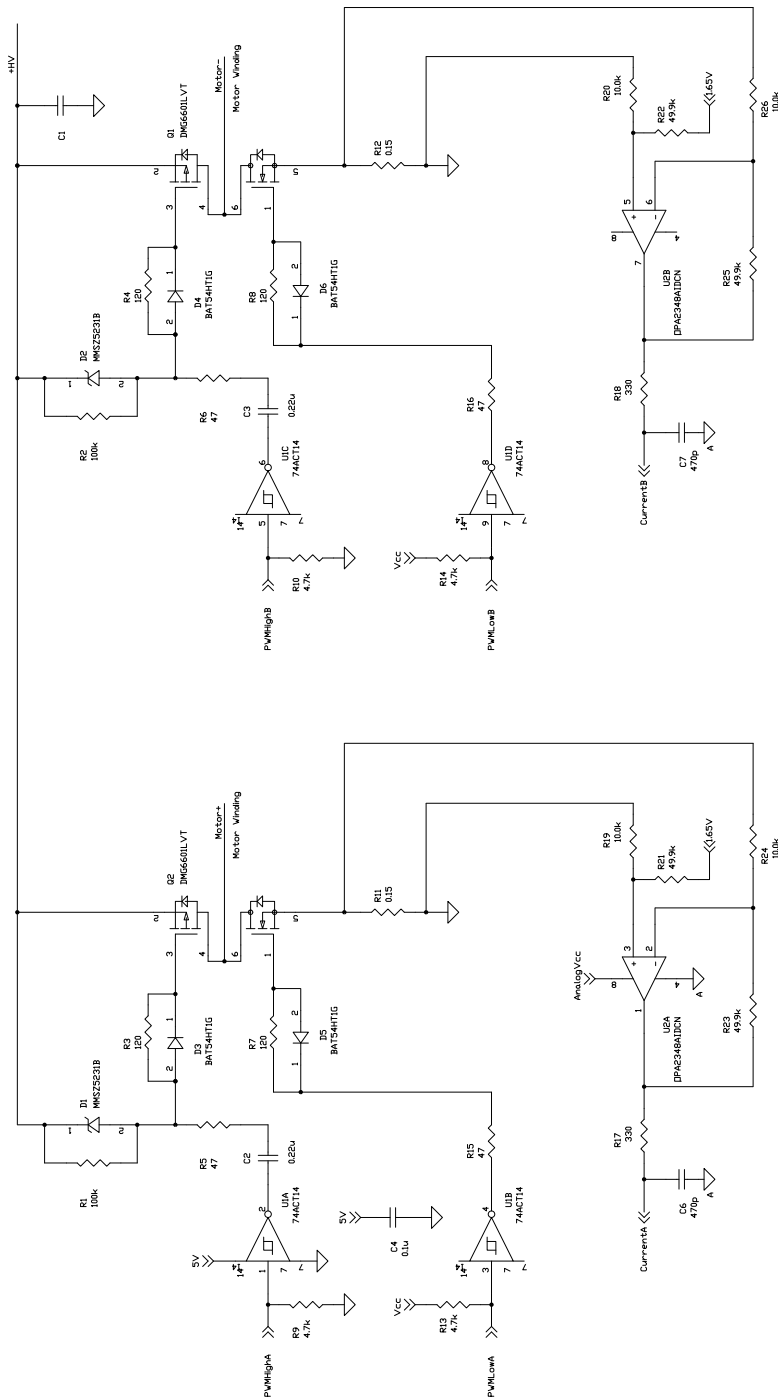
PWMHighA is active high. A logic “1” will generate 0V output at U1A, which will pull C2 to ground. +HV will charge C2 through D1 and R1 with voltage clamped by D1 (5.1V typical). This clamped voltage will turn on the P-channel MOSFET. When PWMHighA is “0”, U1A outputs 5V, and C2 will discharge and turn off the P-channel MOSFET. R3, D3 and R5 provide an unsymmetrical turn-on and turn-off capability.

The MC78113 allows the user to configure the active polarity of all PWMs.

Upon power up or during reset, PWMHighA and PWMLowA outputs are high impedance. Therefore, pull-up resistor R13 and pull-down resistor R9 are used to ensure that the upper and lower switches are all off. Also, when a hard fault is triggered, PWMHighA and PWMLowA will go into high impedance, and R13 and R19 will turn off the MOSFET and put the output of the half bridge into high impedance.

R11 is the current sensing resistor, and U2A is the differential amplifier for signal conditioning. Please see [Section 7.12.1, “Leg Current Sensing”](#) for more design considerations on leg current sensing.

This design has a low BOM cost and a small board footprint suitable for cost-sensitive or size-sensitive applications. However, its limits are also obvious. For example, the MOSFET driver’s driving capability is limited by U1, and current capability is limited by the P-channel MOSFET. Therefore, this design is a good candidate for low voltage and low current applications. For higher voltage and higher current applications, please refer to following examples for half-bridge design.



Performance Motion Devices, Inc.			
Title	Low Cost DC Drive With Leg Current Sensing	Rev	1
Size	Document Number	Rev	1
Page	8	Sheet	1 of 1
Date	Wednesday, April 12, 2017	Sheet	1 of 1

Figure 7-10:
Low Cost DC
Drive with Leg
Current
Sensing

7.12.3 Step Motor Drive

This example shows a step motor drive with leg current sensing. The power train has four half-bridges for the step motor's four winding terminals. The input voltage in this example can be up to 56V. It is capable of driving 5A continuous current with peak current of more than 10A.

The design considerations for the four half-bridges and their current sensing circuits are the same. Using PhaseA+ as example, the half bridge uses N-channel MOSFETs for both the higher and the lower switches to achieve high efficiency. The half bridge is driven by PWMHighA and PWMLowA through MOSFET driver U1, which is powered by 12V.

During normal operation, PWMHighA and PWMLowA are active high. For PWMLowA, a logic “1” turns on the MOSFET Q3. R5, R6 and D3 provide an unsymmetrical turn-on and turn-off capability.

A logic “1” PWMHighA will turn on Q1. C3 is the bootstrapping capacitor, and it is charged through D1 when Q3 is turned on. C3 provides the power to turn on Q1, and C3 needs to be a low-ESR capacitor such as a ceramic capacitor. D1 should be a fast switching diode with low leakage current, and its voltage rating should be chosen based on +HV and the +12V. R3 is optional; it can limit the charging current, especially during power up when C3 is zero voltage. R1, R4 and D2 provide an unsymmetrical turn-on and turn-off capability.

Upon power up or during reset, PWMHighA and PWMLowA output are high impedance. Therefore, pull-down resistors R13/R14 ensure that the upper and lower switches are all off so that the half bridge output is high impedance. Also, when a hard fault is triggered, PWMHighA and PWMLowA will go into high impedance, and the pull-down resistors will turn off the MOSFETs and put the output of the half bridge into high impedance. Usually the MOSFET driver has internal pull-up or pull-down resistors, and the user needs to check the driver's datasheet and decide if the resistors are necessary.

R9 is the current sensing resistor, and U3 is the differential amplifier for signal conditioning. Please see [Section 7.12.1, “Leg Current Sensing”](#) for more design considerations on leg current sensing.

This design uses dedicated MOSFET drivers and N-channel MOSFETs to achieve high efficiency and high performance. This example provides a balanced design reference between performance and cost for applications up to 56V and current up to 10A. With different MOSFETs, higher voltage and current capabilities can be achieved. Please refer to the low cost DC drive example if cost is critical and to BLDC drive example for high voltage and/or high current applications in noisy environments.

7.12.4 Brushless DC Motor Drive

This example shows a brushless DC motor drive with leg current sensing. The power train has three half-bridge for BLDC motor's three winding terminals. The input voltage in this example can be up to 56V. It is capable of driving 15A continuous current with peak current of more than 25A.

The design considerations for each half-bridge and their current sensing circuits are the same. Using PhaseA+ as example, the half bridge uses N-channel MOSFETs for both the higher and the lower switch to achieve high efficiency. The half bridge is driven by PWMHighA and PWMLowA through MOSFET driver U4, which is powered by 15V.

During normal operation, PWMHighA and PWMLowA are active high. For PWMLowA, a logic “1” turns on the MOSFET Q3. R25, R26 and D3 provide an unsymmetrical turn-on and turn-off capability.

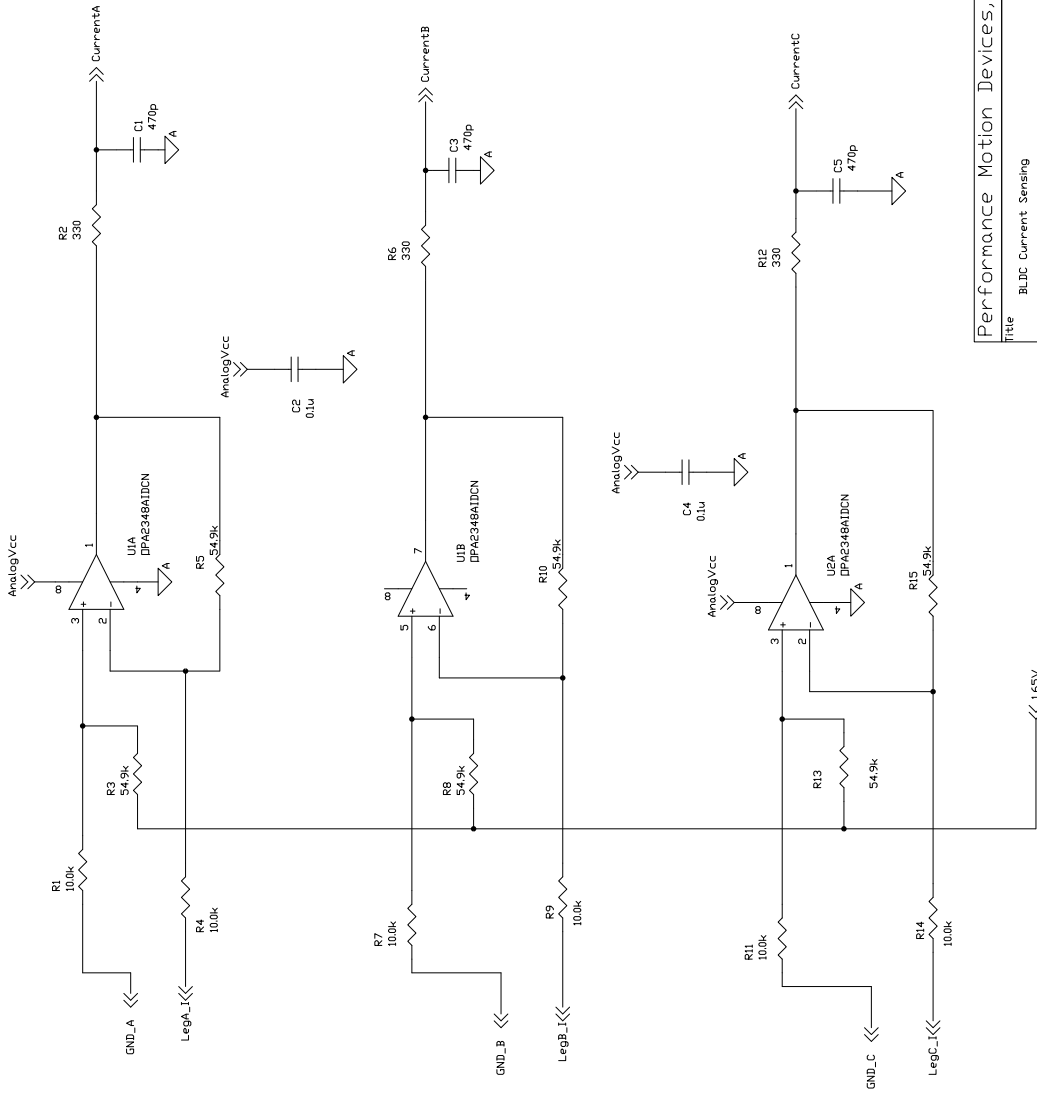
A logic “1” PWMHighA will turn on Q1. C11 is the bootstrapping capacitor, and it is charged through D1 when Q3 is turned on. C11 provides the power to turn on Q1, and C11 needs to be a low-ESR capacitor such as a ceramic capacitor. D1 should be a fast switching diode with low leakage current, and its voltage rate should be chosen based on +HV and the +15V. R23 is optional; it can limit the charging current, especially during power up when C11 is zero voltage. R20, R24 and D2 provide an unsymmetrical turn-on and turn-off capability.

Upon power up or during reset, PWMHighA and PWMLowA output are high impedance. Therefore, pull-down resistors R36 and R37 ensure that the upper and lower switches are all off so that the half bridge output is high impedance. Usually the MOSFET driver has internal pull-up or pull-down resistors, and the user needs to check the driver's datasheet and decide if the resistors are necessary.

The MC78113 has an AmplifierEnable output, and it is used to shut down the MOSFET driver through the SD pin. Upon power up or during reset, AmplifierEnable is high impedance, and pull-down resistor R19 will ensure all motor output high impedance. When AmplifierEnable pin is used, the pull-down resistors R36/R37 are options.

R29 is the current sensing resistor, and U1A is the differential amplifier for signal conditioning. Please see [Section 7.12.1, “Leg Current Sensing”](#) for more design considerations on leg current sensing.

This design uses dedicated MOSFET drivers and N-channel MOSFETs to achieve high efficiency and high performance. This example is suitable for applications in high noise environments. The MOSFET driver U4 has two ground references: Vss for the digital side and COM for the power side. The MOSFET turn-on and turn-off current out of pin LO will return from dedicated traces to pin COM instead of ground plane, which makes the board layout easier for noise immunity. The COM connection scheme shown also applies for H-bridge and 3-phase MOSFET driver with dedicated COM pin. For this example with independent half-bridge MOSFET drivers, COM pins can also be connected to respective MOSFET source pins to further improve the driving performance. Please refer to the low cost DC drive example if cost is critical and to the Stepper drive example for general-purpose applications.

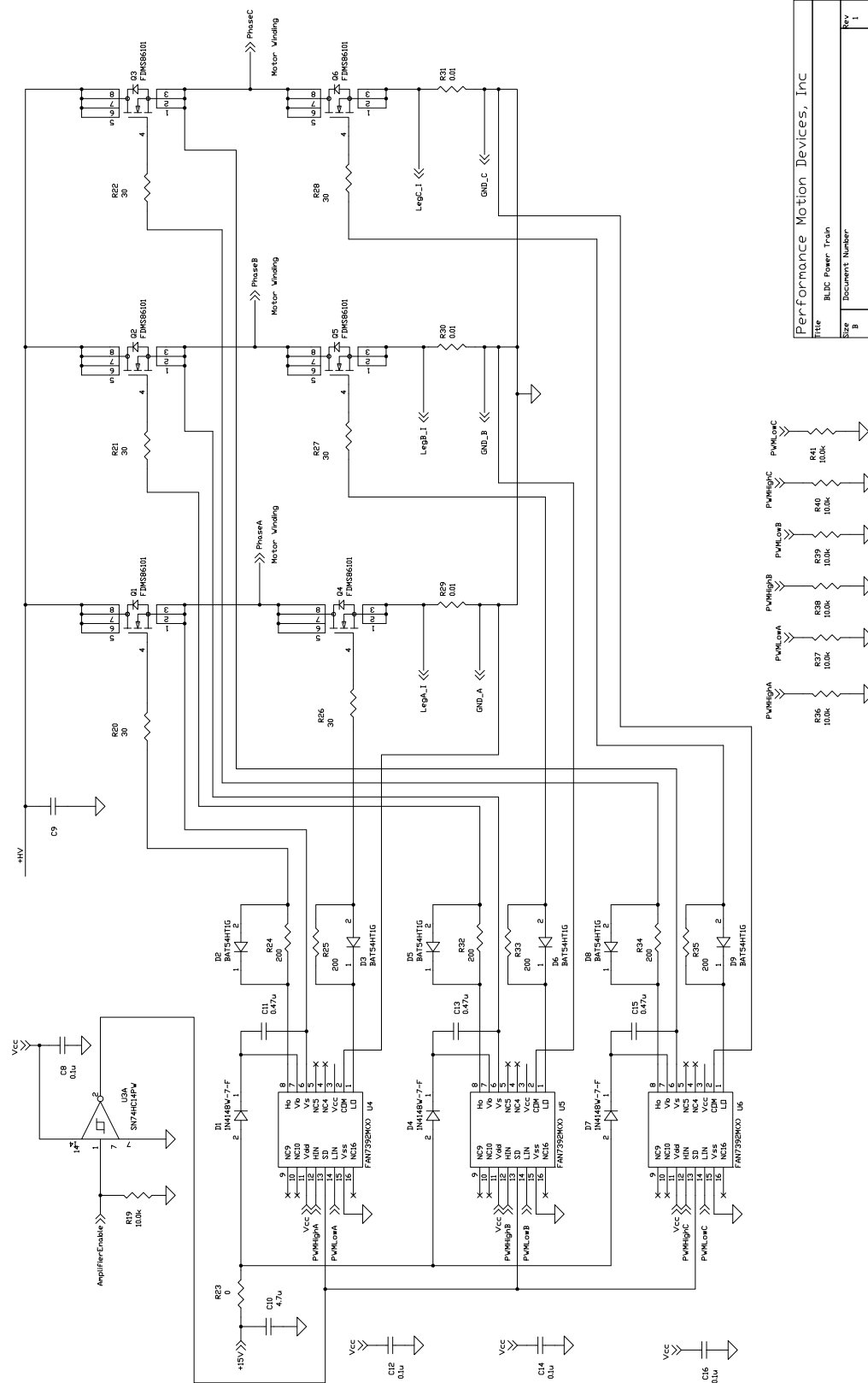


Performance Motion Devices, Inc

Title	BLDC Current Sensing
Size	Document Number
Rev	1
Date	Thursday, April 13, 2017
Sheet	1 of 2

Figure 7-12:
BLDC Motor
Drive - Leg
Current
Sensing

Figure 7-13:
BLDC Motor
Drive - Power
Train



This page intentionally left blank.

7.12.5 Brushless DC Motor Drive With Intelligent Power Module

Intelligent power modules integrate a power train, gate driver and protection circuitry into a single package. They have advantages of simple design, improved system reliability and fast time-to-market. This schematic shows an example of a BLDC drive with an intelligent power module with current capability of 1A.

The module operates in the same way as the discrete solution as shown in previous sections. Please refer to the section on BLDC motor power train and step motor drive power train for details.

Because intelligent power modules have control signals and a noisy power train in one package some special filters might be required. Please refer to the specific power module's user guide for details.

7.13 Using the TI LMD18200 to Drive DC Brush Motors

In the following schematic, a magnitude and direction *PWM* signal is used to drive a DC brush motor with a nominal 24V, 2A drive. The H-bridge driver selected for this task is the LMD18200, which can be driven directly from a 3.3V CMOS logic output and as such can be directly interfaced to the MC78113.

There are two methods in which the output current of the H-bridge may be controlled.

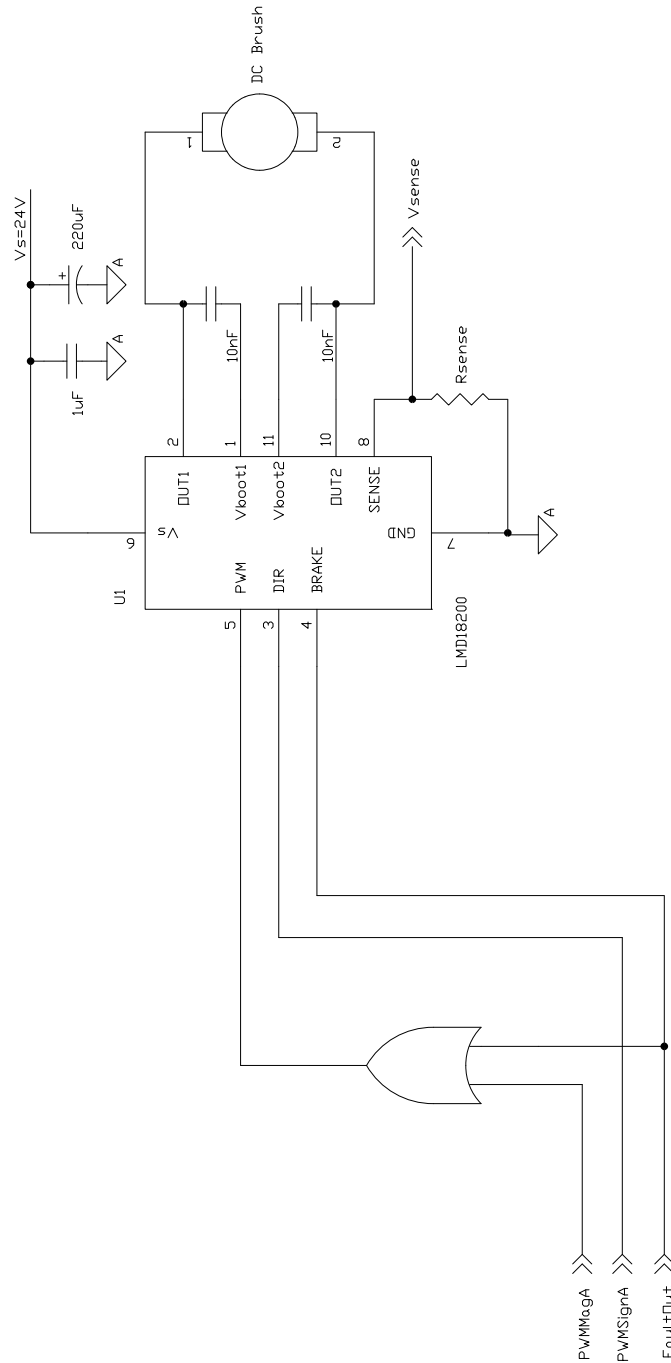
First, in the *locked anti-phase control* mode (see the LMD18200 data sheet), a 50/50 *PWM* signal is applied to the LMD18200 DIR input, while the PWM input is tied high. The current ripple in this mode is relatively high, as the circulating currents are quickly decaying.

Second, in the *sign/magnitude control* mode, sign and magnitude *PWM* signals are applied to both the PWM and DIR inputs of the LMD18200. In this mode, the resultant current ripple is reduced resulting in smoother operation of the motor. When the acceleration/deceleration requirements for the motor are not high, the sign/magnitude PWM control mode is preferred. This method is demonstrated in the example.

The LMD18200 is equipped with an internal overcurrent circuit, which is tuned to a 10A threshold. External overcurrent circuitry may be added for currents with a lower threshold by using the sense output. In order to detect malfunctions, the *Vsense* signal may be used to sense the amount of current flowing through the motor windings. The sense output of the LMD18200 samples only a fraction of the drive current, with a typical 377 μ A sensing per 1A driving current. .



Note that the circuitry provided in this section does not provide active current control. See [Section 7.12, “PWM High/Low Motor Drive With Leg Current Sensing/Control”](#) for PWM-based application examples using the MC78113 IC that provide active current control.



Performance Motion Devices, Inc

Title			PWM - DC Brush using LMD18200		
Size			Document Number		
Rev			A		
Date:			Thursday, April 13, 2017		
Sheet			1 of 1		

Figure 7-15:
DC Brush
Amplifier Using
LMD 18200

7.14 Two Juno Step Motor Amplifiers With Multi-Axis Magellan

The following schematic shows a two-axis application with two Juno Step motor amplifiers in pulse & direction mode with a multi-axis Magellan.

In this schematic the host controller is a four-axis Magellan MC58420. Only the connections with MC75113 and MC74113 are shown. For complete Magellan wiring, please refer to the *MC58000 Electrical Specifications*.

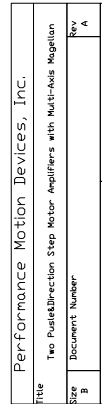
7.14.1 MC75113 Axis 1

For Axis 1, the MC75113 receives *Pulse*, *Direction* and *AtRest* from Magellan and controls the motor with PWM high/low and leg current sensing. Please refer to [Section 7.12.3, “Step Motor Drive”](#) for more details.

7.14.2 MC74113 Axis 2

For Axis 2, the MC74113 receives *Pulse*, *Direction* and *AtRest* from Magellan and controls the motor with PWM high/low and leg current sensing. Please refer to [Section 7.12.3, “Step Motor Drive”](#) for more details.

Compared to Axis 1 with MC75113, MC74113 receives encoder input for continuous encoder position comparison.



Axis 2: Puse&Direction	Step Motor Amplifier	with Continuous Encoder	Position Compare

7.15 Two Juno BLDC Motor Amplifiers With Multi-Axis Magellan

The following schematic shows a two-axis application with two Juno BLDC motor amplifiers in torque mode with a multi-axis Magellan.

7.15.1 SPI Communication

MC73113 receives control commands through an SPI interface and functions as an SPI slave. The MC58420 will output a continuous stream of desired torques to each MC73113 via SPI. To set the MC73113 for direct input SPI operation the SPI Mode bit must be pulled low via a 2.2kohm resistor. SPI communication is enabled when \sim SPIEnable is pulled down. Only one MC73113 can be enabled at any given time.

In this schematic the SPI master is a four-axis Magellan MC58420. Only the connections with MC73113 are shown. For complete Magellan wiring, please refer to the *MC58000 Electrical Specifications*. In this example, axis 1 and axis 2 are under control. The MC58420 sends torque commands to MC73113s by pulling *SPIEnable1* and *SPIEnable2* low, respectively.

7.15.2 MC73113 Axis 1

For Axis 1, the MC73113 is in torque mode with encoder-based commutation. It receives torque command from Magellan and controls the motor with PWM high/low and leg current sensing. Please refer to [Section 7.12.4, “Brushless DC Motor Drive”](#) for more details.

The encoder signals go to both Magellan and MC73113. Magellan uses the encoder information for position control while MC73113 for commutation.

7.15.3 MC73113 Axis 2

For Axis 2, the MC73113 is in torque mode with Hall-based commutation. It receives torque command from Magellan and controls the motor with PWM high/low and leg current sensing. Please refer to [Section 7.12.4, “Brushless DC Motor Drive”](#) for more details.

Magellan uses the encoder information for position control, and MC73113 uses Hall signals for commutation.

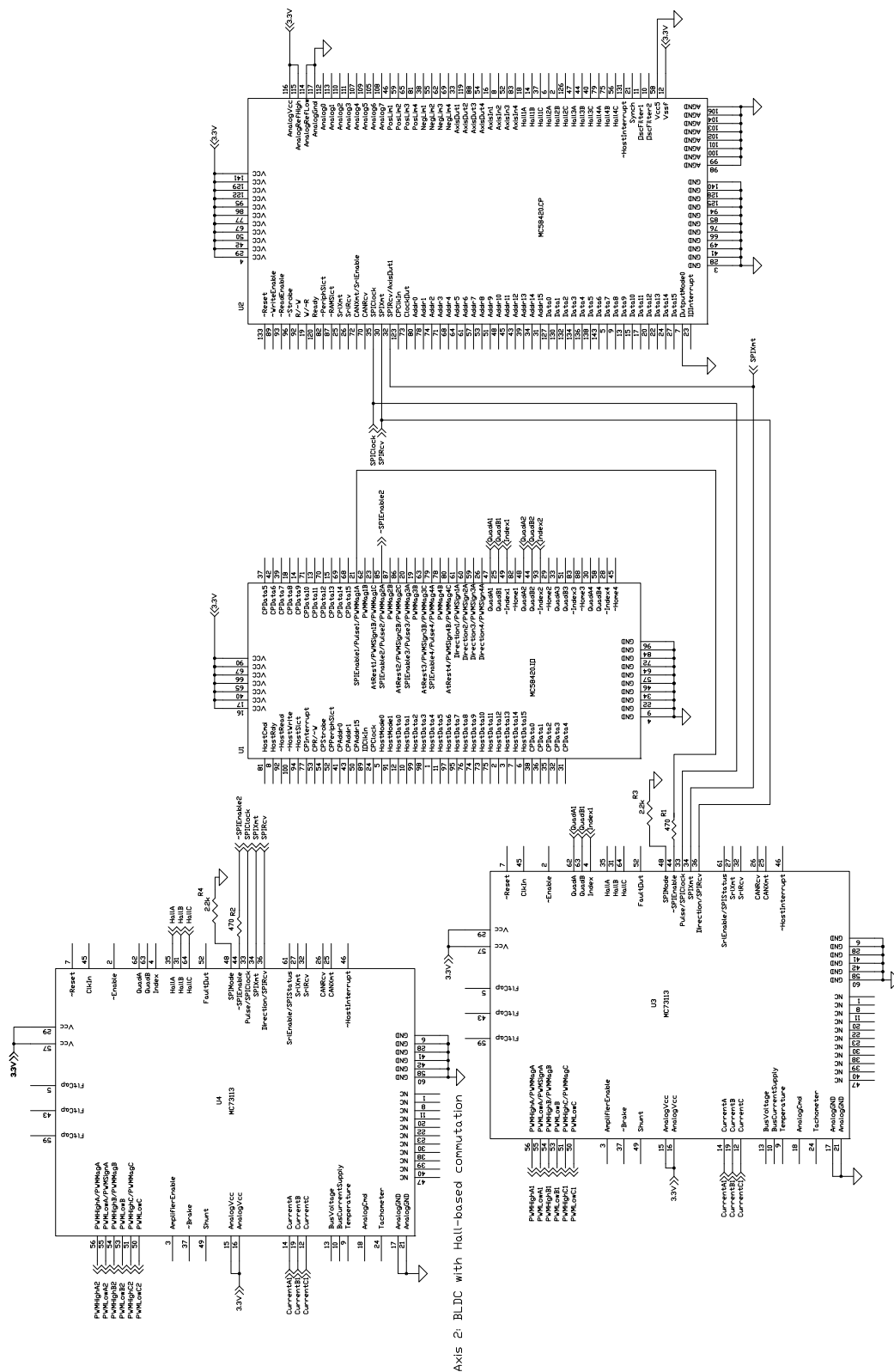


Figure 7-17: Two-Axis BLDC Motor Drive With Multi-Axis Magellan

Performance Motion Devices, Inc.			
Title	Two Axis BLDC Motor Amplifiers with Multi-Axis Magellan	Rev	A
Doc #	PM1000	Document Number	
Page	1	of	2

Figure 7-17: Two-Axis BLDC Motor Drive With Multi-Axis Magellan

This page intentionally left blank.