International
IOR Rectifier

Data Sheet No. PD60224

IRMCK201

High Performance Configurable Digital AC Servo Control IC

Features

- **Complete closed loop current control (Synchronously Rotating Frame Field Orientation)**
- **Versatile Space Vector PWM**
- **Direct interface to IR2175 current sensing high voltage IC**
- **Direct Encoder interface with multiplexed/non-multiplexed Hall A/B/C signals**
- **Direct interface to IR213x 3 -phase gate driver IC**
- **Closed loop velocity control**
- **Configurable architecture**
  - **Supports AC PM motor or Induction motor**
  - **Closed loop or open loop control**
- **Asynchronous serial communication interface (RS232C, RS422, RS485)**
- **Fast SPI interface**
- **4 channel 12bit A/D interface with simultaneous sample/hold**
- **8-bit parallel bus interface for microcontroller expansion (support most 8bit uP)**
- **Integrated brake IGBT control**
- **ServoDesigner™ (Configuration Tool) available**

Product Summary

Max. Clock Input	33.3 MHz
Max. PLL clock for current feedback	133.3 MHz
Closed loop current control computation time	6 usec max
Closed loop current loop bandwidth (-3dB)	5.5 kHz
Closed loop velocity loop update rate	5 / 10 kHz
PWM carrier frequency	12bit / Sysclk
IR2175 Current feedback sampling latency	7.6 usec
Current feedback temp drift/offset	calibrated
Current feedback data resolution	1023 count/Sysclk * 4
Max SPI clock	8 MHz

Package: QFP100

Description

IRMCK201 is a complete AC servo motor control IC. It contains closed loop current control for sinusoidal AC current, and closed loop velocity control based on encoder position feedback interface. A standard communication port is provided for RS232C or RS422, in addition to a fast SPI communication interface. Unlike a traditional DSP or a microcontroller, the IRMCK201 does not require any programming effort to complete the complex control algorithm. It allows users to configure algorithm for specific application needs. Permanent magnet motor or AC induction motor are supported. IRMCK201 facilitates high performance servo design together with the IR2175 current sensing IC and IR213x high voltage 3-phase gate driver IC, which simplifies the hardware design while minimizing the cost. For multi-axis applications, IRMCK201 can be used as a multi-drop slave drive based on the SPI protocol. The package is available in a 100-pin QFP.

Overview

IRMCK201 is a new International Rectifier integrated circuit device designed for one-chip solution for complete closed loop current control and velocity control for a high performance servo drive system. Unlike a traditional microcontroller or DSP, IRMCK201 does not require any programming to complete complex AC servo algorithm development. Combined with International Rectifier's high voltage gate drive and current sensing IC, the user can implement a complete AC servo control with minimum component count and virtually no design effort. Although IRMCK201 contains dedicated logic to perform closed loop control of AC current and velocity, it has wide range of application coverage through flexible configuration ability. The drive can be easily configured induction machine closed loop vector control or permanent magnet motor servo drive. Rich motion peripherals, analog and digital I/O can also be configured. Host communication logic contains Asynchronous Communication Interface for RS232C or RS422 or RS485 communication interface, a fast slave SPI interface and a 8 bit wide Host Parallel Interface. All communication ports have same access capability to the host register set. The user can write to, and read from the predefined registers to configure and monitor the drive through these communication ports.

IRMCK201 Main functions

IRMCK201 contains the following functions for AC servo motor control applications:

- Complete closed loop current control based on Synchronously Rotating Frame Field Orientation.
- Configurable update rate with PWM carrier frequency.
- Configurable parameters (all PI controller gains, PI output limit range, current feedback scaling, encoder feedback scaling)
- Configurable control structure for induction machine or AC permanent magnet machine (Disable/enable slip gain)
- Closed loop velocity control with configurable update rate
- Enable/disable velocity loop
- Selectable reference input for torque and speed input
- Analog reference input
- RS232C/RS422 reference input
- Dynamic braking control for excess DC bus voltage
- Cycle-by-cycle on/off Control for Brake IGBT
- DC bus voltage feedback
- Flexible Encoder Interface
- A/B quadrature signal input up to 1MHz
- Choice of separate or multiplexed Hall A/B/C signal input
- Auto-initialization with Hall A/B/C plus Z pulse input

- Adaptable for any line count encoder from 200PPR to 10,000PPR
- 1/T counter (2MHz) for low speed performance improvement
- Space Vector PWM with deadtime insertion
- IR2175 current sensing IC interface
- IR213x high voltage gate driver IC interface
- Low cost serial 12bit A/D interface with multiplexer and sample/hold circuit
- 4 channel analog output by PWM
  0-5 V output, 16kHz cut-off frequency with 2-pole butter-worth filter
  One channel analog output for Resolver reference (10kHz sinusoidal)
- Local EEPROM for startup initialization of internal data/parameters through host register interface
  AT24C01A, 128X8
- Versatile host communication interface
  RS232C or RS422 host interface
  Fast SPI slave host interface with multi-drop capability
  Parallel Host interface (total 12 pins)
- Multiplexed data/address bus
  Address Enable
  RD/WR
- Discrete I/O
  Start (Input)
  Stop (Input)
  IFBCAL (Input)
  Fault Clear (Input)
  Fault (Output)
  SYNC (Output)
  PWM Enable (Output)
- LED
  Two bit bi-color

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IRMCK201 Block Diagrams

Basic Block Diagram

Figure 1: Basic Block Diagram shows the basic block diagram of the IRMCK201 surrounded by various Accelerator ICs. Host communications are provided over SPI, RS-232C or Host parallel ports. Two current sensing ICs (IR2175) and a three phase high voltage gate drive typically implement the high voltage / current interface between the IRMCK201 IC and motor.

The IRMCK201 can operate in a "stand-alone" mode without the host controller. A serial EEPROM would be utilized to load motor-specific parameters into the IC.

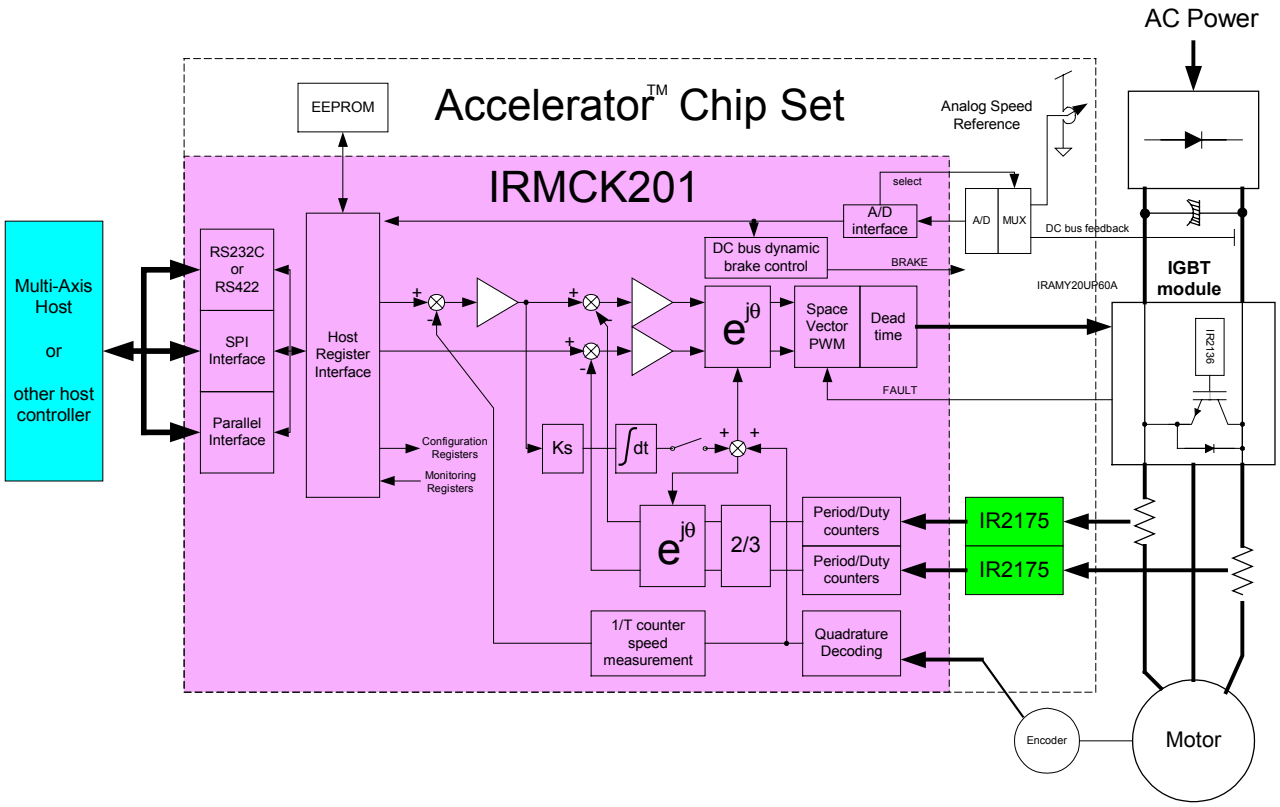


Figure 1: Basic Block Diagram

Detailed Block Diagram

Figure 2: Detailed Block Diagram of IRMCK201 shows the detailed block diagram or the IRMCK201. All logic and algorithms are pre-programmed, and the user does not need to make any effort to develop code, alleviating the tedious design process. If needed, the user can configure the drive to tailor the control per specific needs to meet the required specification. This configuration can be easily done by accessing the host register interface through the communication interface.

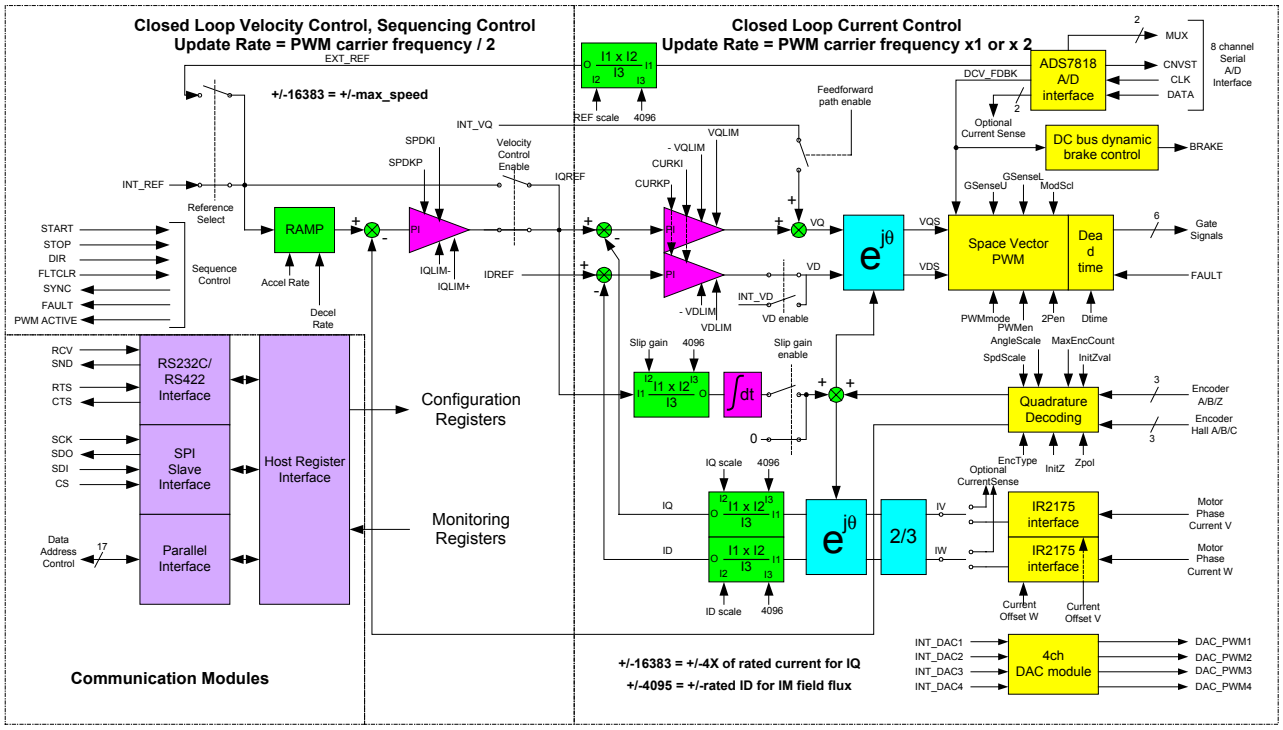


Figure 2: Detailed Block Diagram of IRMCK201

Input/Output of IRMCK201

Figure 3: Input/Output of IRMCK201 shows the interface signals divided into sub-groups. For detailed pin assignment, please refer to the Pin section of this data sheet.

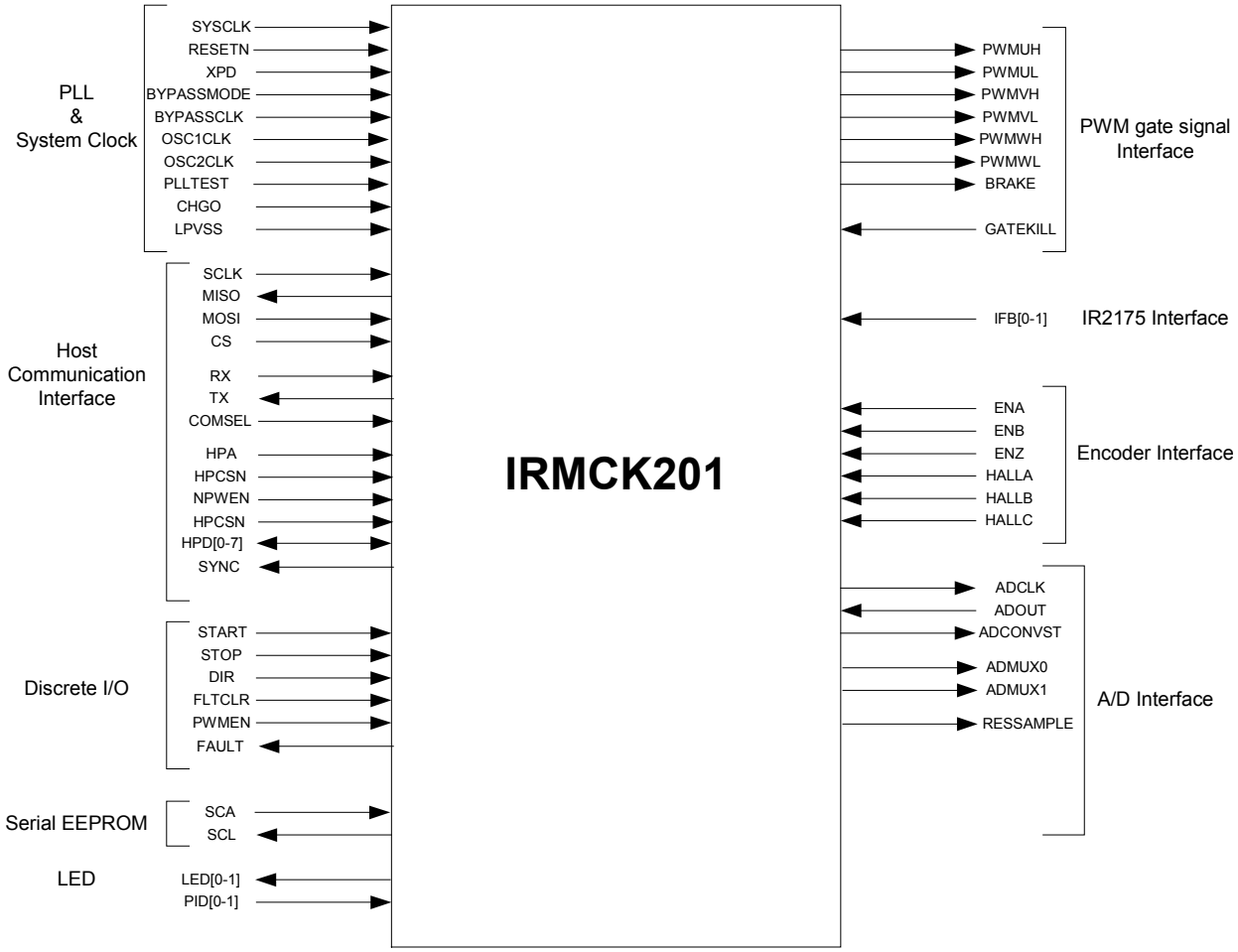


Figure 3: Input/Output of IRMCK201

HOST INTERFACE GROUP			
SIGNAL	**INPUT (I) OUTPUT (O)**	**LOW (L) HIGH (H) TRUE / ASSERTED**	**FUNCTION**
SCLK	I	POSITIVE EDGE SENSITIVE	SPI CLOCK
MISO	O	-	MASTER INPUT AND SLAVE OUTPUT
MOSI	I	-	MASTER OUTPUT AND SLAVE INPUT
CS	I	L	SPI CHIP SELECT
HPOEN	I	L	PARALLEL DATA OUTPUT ENABLE
HPWEN	I	L	PARALLEL DATA WRITE CYCLE IDENTIFICATION
HPD[7:0]	I/O	-	PARALLEL DATA
HPA	I	H	PARALLED DATA ADDRESS CYCLE IDENTIFICATION
HPCSN	I	L	CHIP SELECT
TX	O	-	RS-232 DATA OUT
RX	I	-	RS-232 DATA IN
BAUDSEL	I	H	RS-232 BAUD RATE
SYNC	O	L	START OF PWM CYCLE
DISCRETE I/O GROUP			
SIGNAL	**INPUT (I) OUTPUT (O)**	**LOW (L) HIGH (H) TRUE / ASSERTED**	**FUNCTION**
FBCAL	I	H	CURRENT OFFSET CALIBRATION SIGNAL
START	I	H	START COMMAND
STOP	I	H	STOP COMMAND
FLTCLR	I	H	FAULT CLEAR COMMAND
PWMEN	O	H	PWM ENABLE/DISABLE
FAULT	O	H	FAULT STATE
MOTION PERIPHERAL GROUP			
SIGNAL	**INPUT (I) OUTPUT (O)**	**LOW (L) HIGH (H) TRUE / ASSERTED**	**FUNCTION**
PWMUH	O	-	PWM PHASE U HIGH SIDE
PWMUL	O	-	PWM PHASE U LOWE SIDE
PWMVH	O	-	PWM PHASE V HIGHT SIDE
PWHVL	O	-	PWM PHASE V LOW SIDE
PWMWH	O	-	PWM PHASE W HIGH SIDE
PWMWL	O	-	PWM PHASE W LOW SIDE
BRAKE	O	L	IBGT GATE
GATEKILL	I	Varies, Based on Write Register 0x0C Bit 7	WHEN ASSERTED, NEGATES ALL SIX PWM SIGNALS, HOST WRITEABLE
IFB0	I	-	CHANNEL 0 (PHASE V)
IFB1	I	-	CHANNEL 1 (PHASE W)
ENA	I	-	PHASE A

ENB	I	-	PHASE B
ENZ	I	-	PHASE Z
HALLA	I	-	HALL A
HALLB	I	-	HALL B
HALLC	I	-	HALL C
ANALOG INTERFACE GROUP			
SIGNAL	**INPUT (I) OUTPUT (O)**	**LOW (L) HIGH (H) TRUE / ASSERTED**	**FUNCTION**
ADCLK	O	Negative Edge Sensitive	CLOCK TO ADS7818
ADOUT	I	-	SERIAL DATA FROM ADS7818
DAC[3:0]	O	-	DIAGNOSTIC DAC
ADCONVST	O	L	CONVERT START TO ADS7818
ADMUX0	O	H	ANALOG INPUT MUX SELECT
ADMUX1	O	H	ANALOG INPUT MUX SELECT
PLL INTERFACE GROUP			
SIGNAL	**INPUT (I) OUTPUT (O)**	**LOW (L) HIGH (H) TRUE / ASSERTED**	**FUNCTION**
XPD	I	L	PLL RESET
RESETN	I	L	DIGITAL LOGIC RESET
BYPASSCLK	I	H	INTERNAL TEST PIN – FORCE TO LOGIC LOW
BYPASSMODE	I	H	INTERNAL TEST PIN – FORCE TO LOGIC LOW
OSC1CLK	I	-	33.33 MHz CRYSTAL INPUT
OSC2CLK	I	-	33.33 MHz CRYSTAL INPUT
PLLTEST	I	H	INTERNAL TEST PIN – FORCE TO LOGIC LOW
CHGO	I/O	-	LOW PASS FILTER
LPVSS	I/O	-	LOW PASS FILTER GROUND
MISCELLANEOUS GROUP			
SIGNAL	**INPUT (I) OUTPUT (O)**	**LOW (L) HIGH (H) TRUE / ASSERTED**	**FUNCTION**
SD	O	Varies, Based on Write Register 0x0C Bit 1	SHUT DOWN, HOST WRITEABLE
SCA	I/O	-	EEPROM DATA
SCL	O	Positive Edge Sensitive	EEPROM CLOCK
PID[0:1]	I	-	POWER ID TO SYSTEM STATUS REGISTER, HOST READABLE
GREENLED	O	H	LED SIGNAL
REDLED	O	H	LED SIGNAL

Table 1: IRMCK 201 Signal Descriptions

Application Connections

Typical application connection is shown in Figure 4: Application Connection of IRMCK201. In order to complete a high performance servo drive control, all necessary components are shown in connection to IRMCK201.

Although this is a typical hardware configuration, the user can customize the design. While IRMCK201 provides direct interface to IR2175 high voltage current sensing ICs, the user can still interface to other current sensing devices such as Hall Effect sensing device and/or low side shunt resistors.

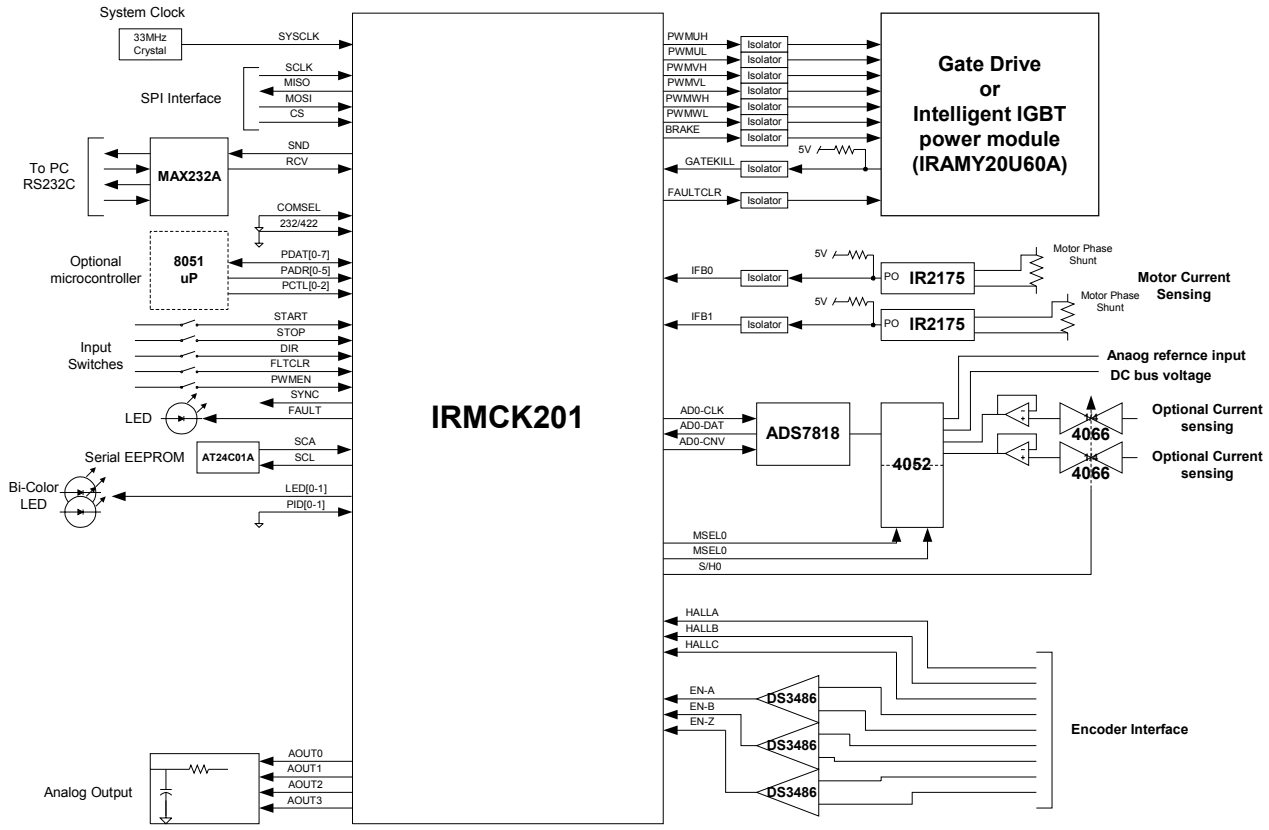


Figure 4: Application Connection of IRMCK201

IC Crystal Clock Circuitry

The clock input to the IC is a 33.33 MHz crystal oscillator. Two shunt capacitors and a possibly a series resistor is required to terminate the crystal to the IC.

The values of the R/C will vary based on actual PCB attributes, and some empirical analysis may be required to get the PLL to start oscillating. Once oscillating, verify that the signal waveform at the OSC1CLK and OSC2CLK pins are sinusoidal rather than trapezoidal. Refer to Table 2: Common Values for the Clock Circuit for suggested R/C values. Most low-cost crystals can be used in this application. An example is a Citizen Part number CM309B33.333MABJT available from Digi-Key under part number 300-4160-1-ND.

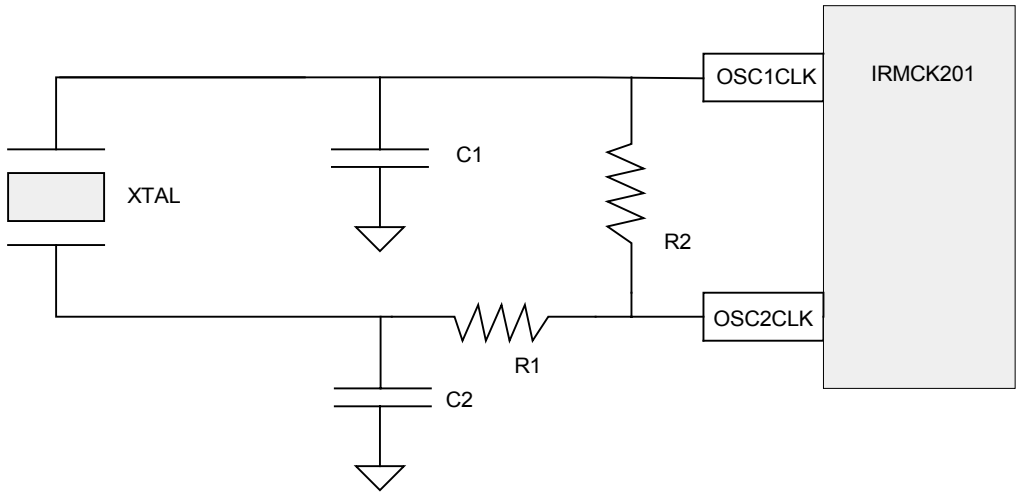


Figure 5: Oscillator Circuit

COMPONENT	VALUE	UNITS
XTAL	33.33	MHz
C1	5	pf
C2	5	pf
R1	0	OHM
R2	3.9K	OHM

Table 2: Common Values for the Clock Circuit

PLL Clock Circuitry

The IRACK201 contains a PLL that creates a 2X and 4X clock from the input 33.33 MHz input clock pin. There are a number of pins on the IC allocated for factory testing purposes, and need to be left unconnected. Table 3: PLL Test Pin Assignments shows required PCB signal connections for these pins.

PIN NUMBER	PCB CONNECTION
1	VSS
2	VSS
7	VSS
15	N/C
16	N/C
17	N/C
18	N/C
23	N/C
24	N/C
25	N/C
41	N/C
45	N/C
56	N/C
89	N/C

Table 3: PLL Test Pin Assignments

Low Pass Filter

The low pass filter for this PLL resides between the CHGO and LPVSS pins. Three passive components are required to implement this filter: Cp, Rp and Cs. Figure 6: PLL Low Pass Filter Shielding shows how to place these components around the IC.

A shield should be placed below Rp, Cp and Cs made out of copper etch.

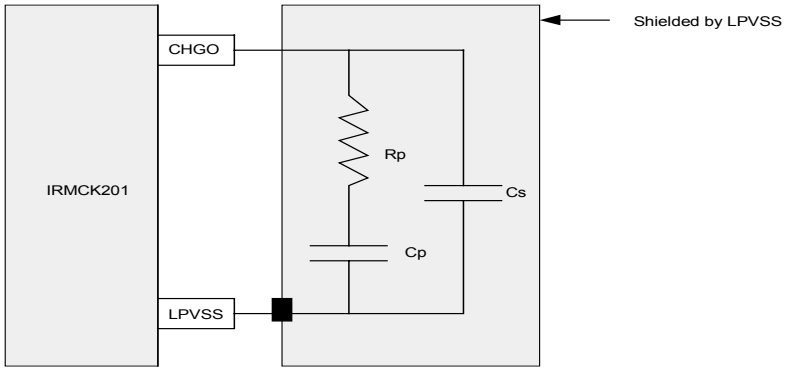


Figure 6: PLL Low Pass Filter Shielding

Implementing the Low Pass Filter Shield

Make all connections between CHGO, Rp, Cp, Cs and LPVSS as short as possible. Create the underlining shield by "copper filling" a larger area in the signal plane of the PCB. Connect this shield to the LPVSS pin of the IC. Do not connect this shield to signal ground (VSS).

Cp Rp and Cs Component Values

For a typical FR4 PCB, the values of the passive components are shown in Figure 7: PLL Low Pass Filter Values.

COMPONENT	VALUE	UNITS
Rp	3.9K	OHM
Cp	1000	pf
Cs	Not Installed	-

Figure 7: PLL Low Pass Filter Values

PLL Reset

There are two reset pins on the IC, XPD and RESETN both low true. XPD holds the PLL circuitry in reset when low. Upon XPD going high, the PLL circuitry begins to lock onto the 33.33 MHz clock input. The PLL circuit may take up to 1 ms to become stable. RESETN asserted low holds the internal DSP logic in reset. Upon RESETN going high, the IC digital logic becomes active.

RESET should be held low during and at least 1 ms after XPD goes high false to hold the internal DSP logic in reset while the PLL becomes stable.

DC Electrical Characteristics and Operating Conditions

Absolute Maximum Ratings

Note: VSS = 0 Volt

PARAMETER	SYMBOL	LIMITS	UNITS	NOTE
Power Supply Voltage	VDD	VSS-0.3 to 4.0	V	
Input Voltage	VI	VSS-0.3 to VDD+0.5	V	Non 5 Volt Tolerant Pins (Note 1)
Input Voltage	VI	VSS-0.3 to 7	V	Only on 5 Volt Tolerant Pins (Note 1)
Output Voltage	VO	VSS-0.3 to VDD+0.5	V	
Output Current per Pin	IOUT	+/- 30	mA	
Storage Temperature	Tstg	-65 to 150	°C	

Table 4: Absolute Maximum Ratings

Recommended Operating Conditions

Note: VSS = 0 Volt

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTE
Power Supply Voltage	VDD	3.0	3.3	3.6	V	
Input Voltage	VI	VSS	-	VDD	V	Non 5 Volt Tolerant Pins (Note 1)
Input Voltage	VI	VSS	-	5.5	V	Only on 5 Volt Tolerant Pins (Note 1)
Ambient Temperature	Ta	-40	-	85	°C	Note 2

Table 5: Recommended Operating Conditions

Notes:
2. The ambient temperature range is recommended for Tj= -40 to 125 °C

DC Characteristics

Common Quiescent and Leakage Current

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Quiescent Current	IDDS	VI=VDD or VSS VDD=MAX IOH=IOL=0 Ta=Tj=85°C	-	-	.35	uA
Input Leakage Current	ILI	VDD=MAX VIH=VDD VIL=VSS	-1	-	1	uA

Table 6: DC Characteristics

Input Characteristics – Non Schmitt Inputs

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
High Level Input Voltage	VIH1	VDD=MAX	2.0	-	-	V
Low Level Input Voltage	VIL1	VDD=MIN	-	-	0.8	V

Table 7: Non Schmitt Input Characteristics

Input Characteristics – Schmitt Inputs

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
High Level Input Voltage	VT1+	VDD=MAX	1.1	-	2.4	V
Low Level Input Voltage	VT1-	VDD=MIN	0.6	-	1.8	V
Hysteresis Voltage	VH1	VDD=MIN	0.1	-	-	V

Table 8: Schmitt Input Characteristics

Output Characteristics

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
High Level Output Voltage	VOH3	VDD=MIN IOH=-12mA	VDD - 0.4	-	-	V
Low Level Output Voltage	VOL3	VDD=MIN IOH = 12mA	-	-	VSS + 0.4	V

Table 9: Output Characteristics

Pin and I/O Characteristic Table

Pin Number	Pin Name	INTERNAL IC RESISTOR TERMINATION	Pin Type	5.50 VOLT TOLERANT INPUT	INPUT DC CHARACTERISTIC TABLE	OUTPUT DC CHARACTERISTIC TABLE
1	BYPASSMODE	40K-240K Pull Down	I	-	Table 8: Schmitt Input Characteristics	-
2	BYPASSCLK	40K-240K Pull Down	I	-	Table 8: Schmitt Input Characteristics	-
3	OSC1CLK		I	-		
4	LVDD		P	-	-	-
5	OSC2CLK		O	-		
6	VSS		P	-	-	-
7	PLLTEST	20K-120K Pull Down	I	-	Table 7: Non Schmitt Input Characteristics	-
8	XPD		I	-	Table 7: Non Schmitt Input Characteristics	-
9	VSSHC		P	-	-	-
10	MVDD		P	-	-	-
11	VSSHC		P	-	-	-
12	AVDD		P	-	-	-
13	CHGO		O	-	-	-
14	LPVSS		P	-	-	-
15	N.C. (CLKI)		I	-	Table 8: Schmitt Input Characteristics	-
16	N.C. (CLKSEL)		I	-	Table 8: Schmitt Input Characteristics	-
17	N.C. (CPT0)		I	-	Table 8: Schmitt Input Characteristics	-
18	N.C. (CPT1)		I	-	Table 8: Schmitt Input Characteristics	-
19	LVDD		P	-	-	-
20	REDLED		O	-	-	Table 9: Output Characteristics
21	GREENLED		O	-	-	Table 9: Output Characteristics
22	VSS		P	-	-	-
23	N.C. (TSTCLK)		I	-	Table 8: Schmitt Input Characteristics	-
24	N.C. (TSTSEL)		I	-	Table 8: Schmitt Input Characteristics	-
25	N.C. (OLAP)		I	-	Table 8: Schmitt Input Characteristics	-
26	PWMWL		O	-	-	Table 9: Output Characteristics
27	PWMWH		O	-	-	Table 9: Output Characteristics
28	PWMVL		O	-	-	Table 9: Output Characteristics
29	LVDD		P	-	-	-

Pin Number	Pin Name	INTERNAL IC RESISTOR TERMINATION	Pin Type	5.50 VOLT TOLERANT INPUT	INPUT DC CHARACTERISTIC TABLE	OUTPUT DC CHARACTERISTIC TABLE
30	PWMVH		O	-	-	Table 9: Output Characteristics
31	PWMUL		O	-	-	Table 9: Output Characteristics
32	VSS		P	-	-	-
33	PWMUH		O	-		Table 9: Output Characteristics
34	BRAKE		O	-	-	Table 9: Output Characteristics
35	RESETN	20K -120K Pull Up	I	-	Table 8: Schmitt Input Characteristics	-
36	FLTCLR		O	-	-	Table 9: Output Characteristics
37	GATEKILL	20K -120K Pull Up	I	-	Table 8: Schmitt Input Characteristics	-
38	IFB0		I	YES	Table 8: Schmitt Input Characteristics	-
39	IFB1		I	YES	Table 8: Schmitt Input Characteristics	-
40	SD		O	-	-	Table 9: Output Characteristics
41	N.C. (D0)		I	-	Table 8: Schmitt Input Characteristics	-
42	PID0	20K -120K Pull Up	I	-	Table 8: Schmitt Input Characteristics	-
43	PID1	20K -120K Pull Up	I	-	Table 8: Schmitt Input Characteristics	-
44	LVDD		P	-	-	-
45	N.C. (D3)		I	-	Table 8: Schmitt Input Characteristics	-
46	CS		I	YES	Table 8: Schmitt Input Characteristics	-
47	VSS		P	-		
48	MOSI		I	YES	Table 8: Schmitt Input Characteristics	
49	MISO		O	-	-	Table 9: Output Characteristics
50	SCLK		I	YES	Table 8: Schmitt Input Characteristics	-
51	TX		O	-	-	Table 9: Output Characteristics
52	RX		I	YES	Table 8: Schmitt Input Characteristics	-
53	BAUDSEL	20K -120K Pull Down	I	YES	Table 7: Non Schmitt Input Characteristics	-
54	LVDD		P	-	-	-
55	ADMUX0		O	-	-	Table 9: Output Characteristics

Pin Number	Pin Name	INTERNAL IC RESISTOR TERMINATION	Pin Type	5.50 VOLT TOLERANT INPUT	INPUT DC CHARACTERISTIC TABLE	OUTPUT DC CHARACTERISTIC TABLE
56	N.C. (N2)		I	-	Table 8: Schmitt Input Characteristics	-
57	VSS		P	-	-	-
58	ADMUX1		O	-	-	Table 9: Output Characteristics
59	RESSAMPLE		O	-	-	Table 9: Output Characteristics
60	ADCONVST		O	-	-	Table 9: Output Characteristics
61	ADCLK		O	-	-	Table 9: Output Characteristics
62	ADOUT		I	YES	Table 8: Schmitt Input Characteristics	-
63	SYNC		O	-	-	Table 9: Output Characteristics
64	FAULT		O	-	-	Table 9: Output Characteristics
65	START	20K -120K Pull Down	I	YES	Table 8: Schmitt Input Characteristics	-
66	STOP	20K -120K Pull Down	I	YES	Table 8: Schmitt Input Characteristics	-
67	FBCAL	20K -120K Pull Down	I	YES	Table 8: Schmitt Input Characteristics	-
68	FLTCLR	20K -120K Pull Down	I	YES	Table 8: Schmitt Input Characteristics	-
69	LVDD		P	-	-	-
70	PWMEN		O	-	-	Table 9: Output Characteristics
71	DAC[3]		O	-	-	Table 9: Output Characteristics
72	VSS		P	-	-	-
73	DAC[2]		O	-	-	Table 9: Output Characteristics
74	DAC[1]		O	-	-	Table 9: Output Characteristics
75	DAC[0]		O	-	-	Table 9: Output Characteristics
76	HPD[0]	20K -120K Pull Down	B	-	Table 7: Non Schmitt Input Characteristics	Table 9: Output Characteristics
77	HPD[1]	20K -120K Pull Down	B	-	Table 7: Non Schmitt Input Characteristics	Table 9: Output Characteristics
78	HPD[2]	20K -120K Pull Down	B	-	Table 7: Non Schmitt Input Characteristics	Table 9: Output Characteristics
79	VDD		P	-	-	-
80	HPD[3]	20K -120K Pull Down	B	-	Table 7: Non Schmitt Input Characteristics	Table 9: Output Characteristics
81	HPD[4]	20K -120K Pull Down	B	-	Table 7: Non Schmitt Input Characteristics	Table 9: Output Characteristics
82	VSS		P	-	-	-

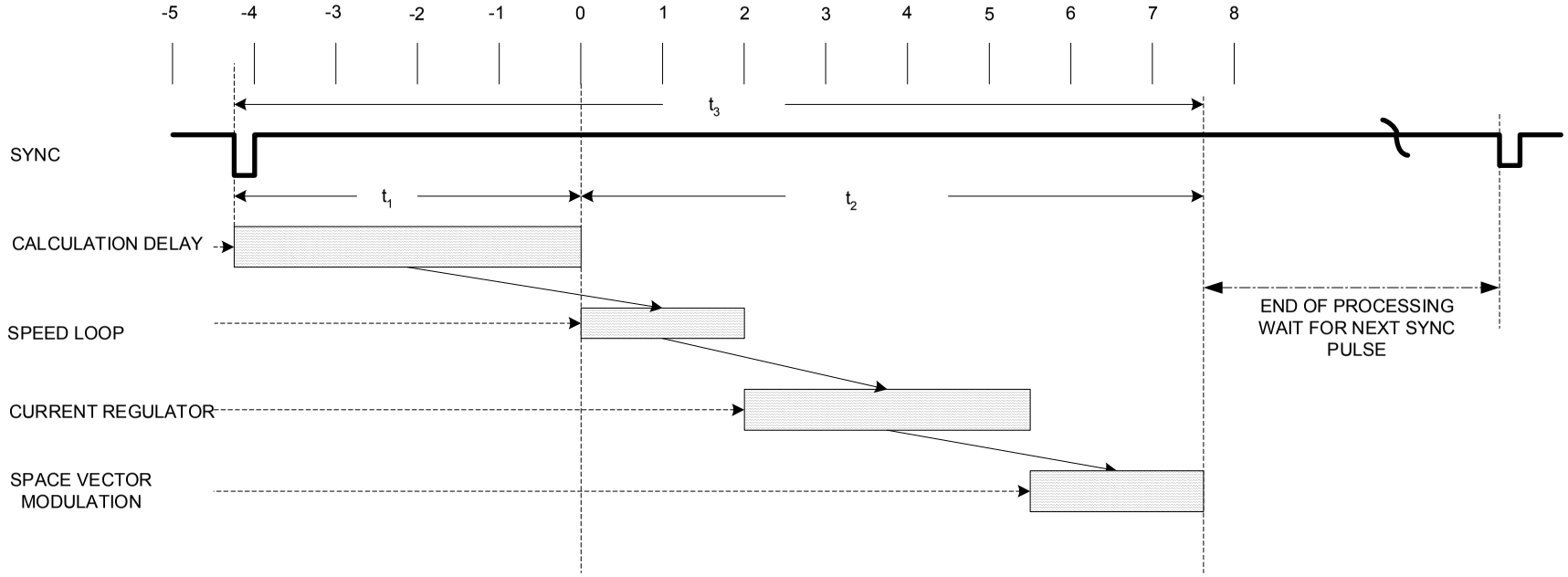
Pin Number	Pin Name	INTERNAL IC RESISTOR TERMINATION	Pin Type	5.50 VOLT TOLERANT INPUT	INPUT DC CHARACTERISTIC TABLE	OUTPUT DC CHARACTERISTIC TABLE
83	HPD[5]	20K -120K Pull Down	B	-	Table 7: Non Schmitt Input Characteristics	Table 9: Output Characteristics
84	HPD[6]	20K -120K Pull Down	B	-	Table 7: Non Schmitt Input Characteristics	Table 9: Output Characteristics
85	HPD[7]	20K -120K Pull Down	B	-	Table 7: Non Schmitt Input Characteristics	Table 9: Output Characteristics
86	HPOEN		I	YES	Table 8: Schmitt Input Characteristics	-
87	HPWEN		I	YES	Table 8: Schmitt Input Characteristics	
88	HPA		I	YES	Table 8: Schmitt Input Characteristics	-
89	N.C. (N11)		I	-	Table 8: Schmitt Input Characteristics	-
90	HPCSN		I	YES	Table 8: Schmitt Input Characteristics	-
91	ENCZ		I	YES	Table 8: Schmitt Input Characteristics	-
92	ENCB		I	YES	Table 8: Schmitt Input Characteristics	-
93	ENCA		I	YES	Table 8: Schmitt Input Characteristics	-
94	LVDD		P	-	-	-
95	HALLC		I	YES	Table 8: Schmitt Input Characteristics	-
96	HALLB		I	YES	Table 8: Schmitt Input Characteristics	-
97	VSS		P	-	-	
98	HALLA		I	YES	Table 8: Schmitt Input Characteristics	-
99	SCL		O	-	-	Table 9: Output Characteristics
100	SDA	20K -120K Pull Up	B	-	Table 7: Non Schmitt Input Characteristics	Table 9: Output Characteristics

Table 10: Pin and I/O Characteristics

AC Electrical Characteristics and Operating Conditions

System Level AC Characteristics

Sync Pulse to Sync Pulse Timing



Critical Path Timing Including PWM Calculation Time

Figure 8: System Level SYNC To SYNC Timing

SYMBOL	DESCRIPTION	TIME	UNITS
t_1	Current Feedback Sample Delay from SYNC Pulse Falling Edge	4.32	us
t_2	Closed Loop Computation Time (current control only including PWM computation)	6.33	us
	Closed Loop Computation Time (current and velocity control including PWM calculation time)	7.68	
t_3	Minimum SYNC-to-SYNC time (current control only including PWM calculation time)	10.65	us
	Minimum SYNC-to-SYNC time (current and velocity control including PWM calculation time)	12.0	

Table 11: System Level SYNC to SYNC Timing

FAULT and REDLED Response to GATEKILL

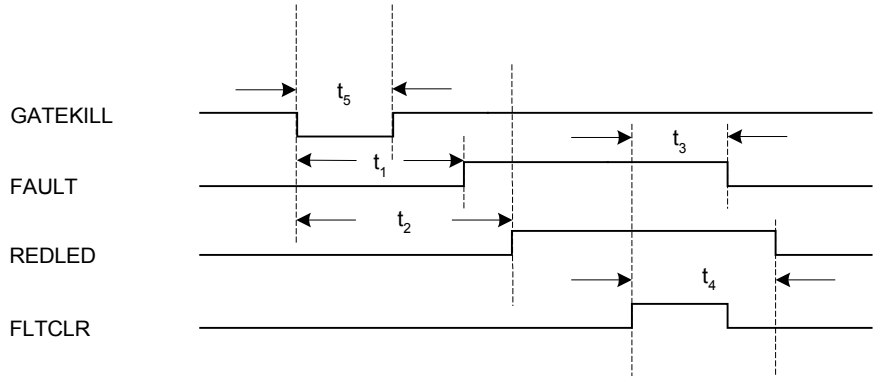


Figure 9: FAULT and REDLED Response to GATEKILL

SYMBOL	DESCRIPTION	MIN	TYP	UNITS
t_1	FAULT Response to GATEKILL		685	ns
t_2	REDLED Response to GATEKILL		715	ns
t_3	FAULT Response to FLTCLR		145	ns
t_4	REDLED Response to FLTCLR		175	ns
t_5	GATEKILL Pulse Width	490		ns

Table 12: FAULT and REDLED Response to GATEKILL

Host Interface AC Characteristics
SPI Timing

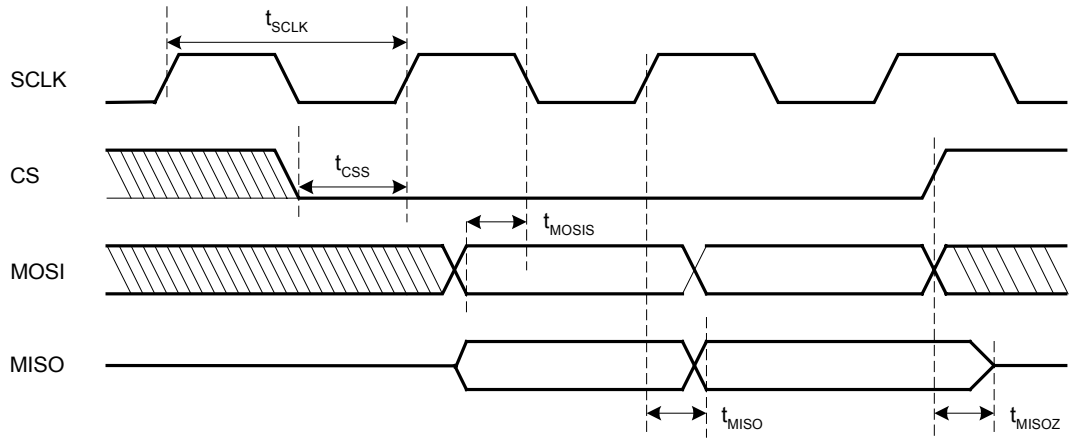


Figure 10 SPI Timing

SYMBOL	DESCRIPTION	MIN	MAX	UNITS
f_{SCLK}	SPI Clock Frequency		8	MHz
t_{SCLK}	SPI Clock Period	125		ns
t_{CSS}	CS to SCLK high Setup	20		ns
t_{MOSIS}	MOSI to SCLK low Setup	20		ns
t_{MISO}	SCLK to MISO Valid	30		ns
t_{MIOZ}	CS to MOSI High Impedance	15	35	ns

Table 13: SPI Timing

Host Parallel Timing

Host Parallel Read Cycle

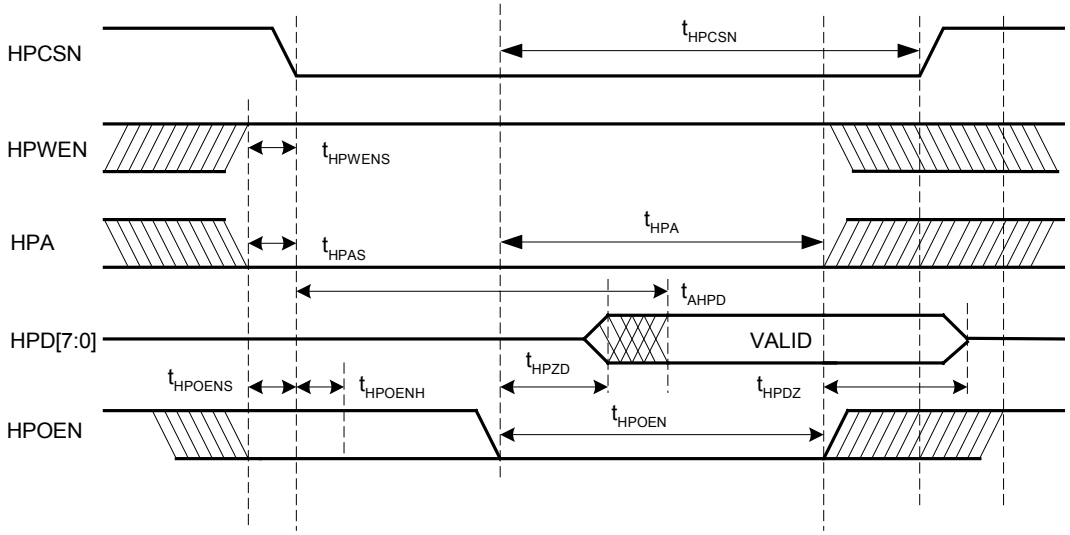


Figure 11: Host Parallel Read Cycle

SYMBOL	DESCRIPTION	MIN	MAX	UNITS	NOTE
t_{HPCSN}	HPCSN Period	70		ns	
t_{HPWENS}	HPWENS Setup	10		ns	
t_{HPAS}	HPA Setup	10		ns	
t_{AHPD}	HPD[7:0] Access	60	105	ns	
T_{HPZD}	HPD[7:0] Active	0	9	ns	
t_{HPDZ}	HPD[7:0] High Impedance	0	6	ns	
t_{HPOENH}	HPOEN Hold	10		ns	Note 3
t_{HPOENS}	HPOEN Setup	10		ns	Note 3
t_{HPOEN}	HPOEN Period	70		ns	

Table 14: Host Parallel Read Cycle Timing

Note:
3. HPOEN must be stable before and after the high to low transition of HPCNS.

Host Parallel Write Cycle

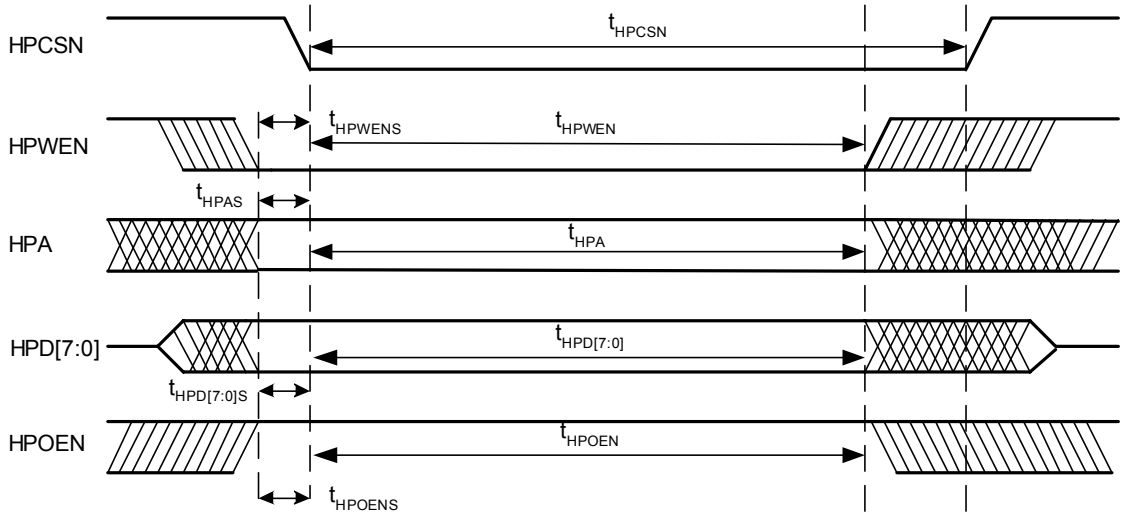


Figure 12: Host Parallel Write Cycle

SYMBOL	DESCRIPTION	MIN	MAX	UNITS	NOTE
t_{HPCSN}	HPCSN Period	70		ns	
t_{HPWENS}	HPWENS Setup	10		ns	
t_{HPWEN}	HPWEN Period	70		ns	
t_{HPAS}	HPA Setup	-10		ns	
t_{HPA}	HPA Period	70		ns	
$t_{HPD[7:0]}$	HPD[7:0] Setup	-10		ns	
t_{HPOENS}	HPOEN Setup	10		ns	
t_{HPOEN}	HPOEN Period	70		ns	Note 4

Table 15: Host Parallel Write Cycle Timing

Note:

4. HPOEN must be asserted high while HPCSN low during a Host Parallel Write Cycle.

Discrete I/O Electrical Characteristics

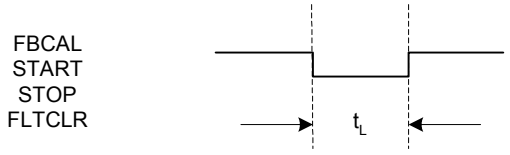


Figure 13: Discrete I/O Timing

SYMBOL	DESCRIPTION	MIN	MAX	UNITS
t_L	Pulse Width FBCAL	100		ms
	Pulse Width START	100		ns
	Pulse Width STOP	100		ns
	Pulse Width FLTCLR	1		us

Table 16: Discrete I/O Timing

Motion Peripheral Electrical Characteristics

PWM Electrical Characteristics

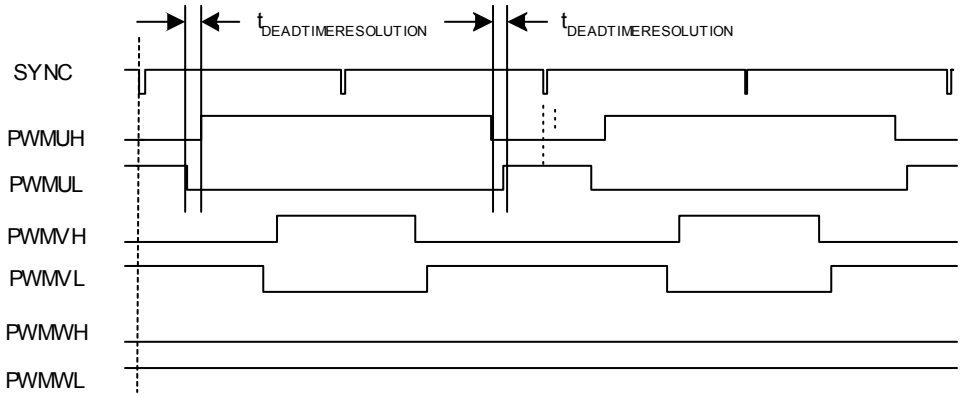


Figure 14: PWM Timing

SYMBOL	DESCRIPTION		UNITS
$t_{DEADTIMERESOLUTION}$	Deadtime Insertion Logic Resolution	30	ns

Table 17: PWM Timing

IR2175 Interface

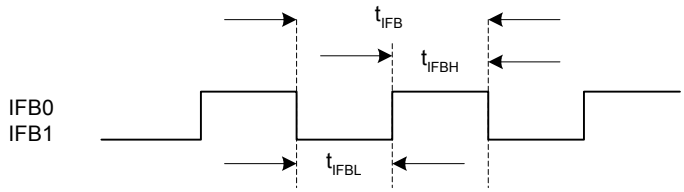


Figure 15: IR2175 Interface

SYMBOL	DESCRIPTION	MIN	MAX	UNITS
f_{IFB}	Current Feedback Input Frequency	95	165	kHz
t_{IFB}	Current Feedback Period	10.52	6.06	us
t_{IBH}	Current Feedback High Pulse Width	500 ns	10 us	
t_{IFBH}	Current Feedback Low Pulse Width	500 ns	10 us	

Figure 16: IR2176 Interface

Encoder Electrical Characteristics

Figure 17: Encoder Timing shows the input timing characteristics of the encoder inputs. Please refer to the IRMCK201 Applications Developer's Guide for an example encoder input circuit that drives the IRMCK201.

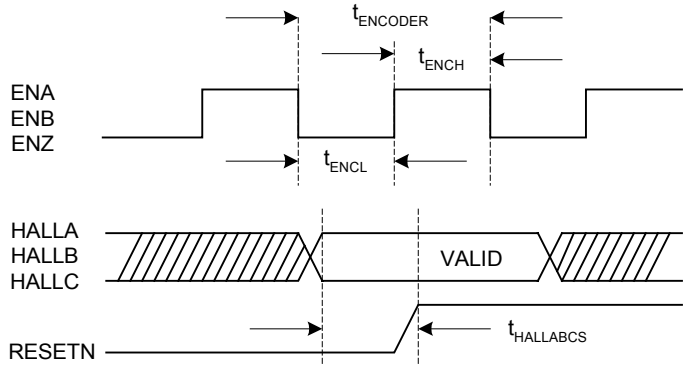


Figure 17: Encoder Timing

SYMBOL	DESCRIPTION	MIN	TYP	MAX	UNITS
$f_{ENCODER}$	Encoder Input Frequency			1	MHz
$t_{ENCODER}$	ENA ENB ENZ Period	1			us
t_{ENCL}	ENA ENB ENZ Pulse Width	500			ns
t_{ENCH}	ENA ENB ENZ Pulse Width	500			ns
$t_{HALLABCS}$	HALLA HALLB HALLC Setup to RESETN	1			us

Table 18: Encoder Timing

Analog Interface Electrical Characteristics

ADC Timing

System Level Timing

The IRMCK201 contains logic to drive an ADC Converter, Analog MUX and associated Sample and Hold circuits. Figure 18: Top Level ADC Timing shows the system level timing of these elements. Figure 19: ADC Specific Timing shows specific timing parameters associated with the ADC Converter. Refer to the Application Developers Guide for a detailed description of ADC, MUX and Sample and Hold signal system level protocol.

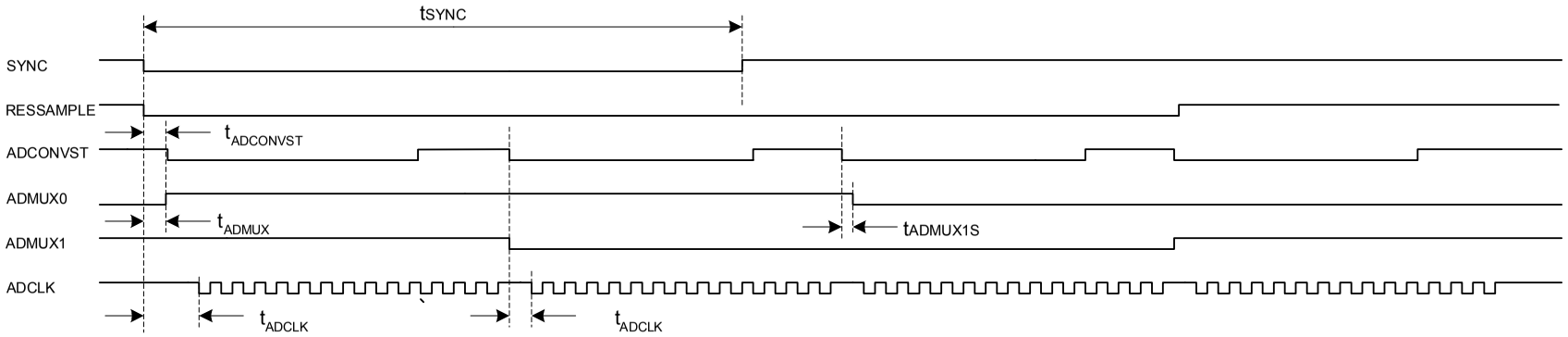


Figure 18: Top Level ADC Timing

SYMBOL	DESCRIPTION	MIN	TYP	MAX	UNITS
t_{SYNC}	SYNC Pulse Width		3		us
$t_{RESSAMPLES}$	SYNC Falling Edge to RESSAMPLE Valid	-10		10	ns
$t_{ADMUX0S}$	ADCONVST to ADMUX0 Valid	40		61	ns
$t_{ADMUX1S}$	ADCONVST to ADMUX1 Valid	40		61	ns
$t_{ADCONVSTS}$	ADCONVST to ADCLK	71		91	ns

Table 19: Top Level ADC Timing

Converter Level Timing

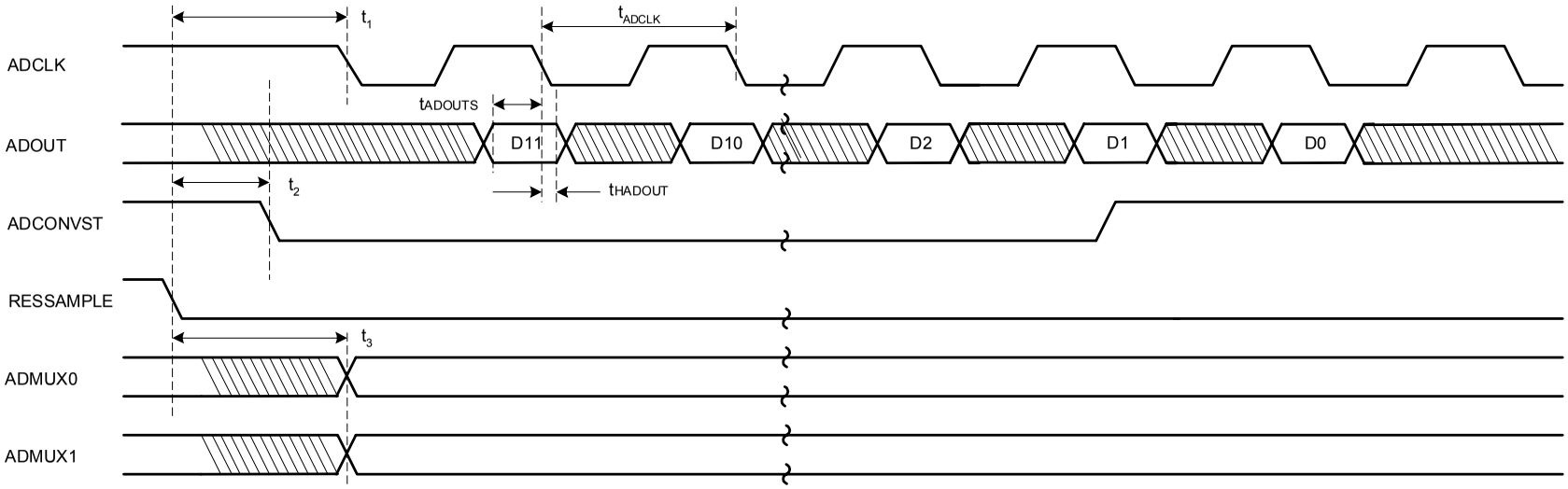


Figure 19: ADC Specific Timing

SYMBOL	DESCRIPTION		MIN	MAX	UNITS
f_{ADCLK}	ADC Clock Frequency	8.33			MHz
t_{ADCLK}	ADC Clock Period	120			ns
t_1	RESSAMPLE to ADCLK			91	ns
t_2	RESSAMPLE to ADCONVST			40	ns
t_3	RESSAMPLE to ADMUX0, ADMUX1			64	ns
t_{HADOUT}	ADOUT to ADCLK Setup		19.7		
t_{ADOUTS}	ADOUT to ADCLK Hold		2		ns

Table 20: ADC Specific Timing

PLL Interface Electrical Characteristics

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Current Consumption	IDDS	Static	-	-	170	uA
Current Consumption	IDD	Dynamic	-	5	-	MA
Peak jitter	Tpj	-	-	-	1000	ps
Cycle jitter	Tcj	-	-500	-	+500	ps
Lock-up Time	Tlock	-	-	-	1	ms
PLL Reset Period	Trst	Recommended operating condition	10	-	-	ns

Table 21: PLL Electrical Characteristics

Appendix A Host Register Map

A host computer controls the IRMCK201 using either its slave-mode Full-Duplex SPI port, a standard RS-232 port or a 8-bit parallel port for connection to a microprocessor. All interfaces are always active and can be used interchangeably, although not simultaneously. Control/status registers are mapped into a 128-byte address space.

Host Parallel Access

The IRMCK201 contains an address register that is updated with the Host Register address that all subsequent data transfers are to access. This address register is updated during Host Parallel write cycles where the HPA signal is asserted to a logical high. The diagram below shows that Data Bytes 0 to N would access the register location specified by the Address Byte. The Address Bye with the HPA signal can be asserted at any time.

Address Byte HPA = 1	Data Byte 0 HPA = 0	..... HPA = 0	Data Byte N HPA = 0

Host Parallel Data Transfer Format

SPI Register Access

When configured as an SPI device read only and read/write operations are performed using the following transfer format:

Command Byte	Data Byte 0	.....	Data Byte N

Data Transfer Format

Bit Position							
7	6	5	4	3	2	1	0
Read Only	Register Map Starting Address						

Command Byte Format

Data transfers begin at the address specified in the command byte and proceed sequentially until the SPI transfer completes. Note that accesses are read/write unless the “read only” bit is set.

RS-232 Register Access

The IRMCK201 includes an RS-232 interface channel that allows operation using a direct connection to the host PC. This interface implements a simple protocol that checks the validity of data prior to being written into a register. The protocol is explained below.

RS-232 Register Write Access

A Register write operation consists of a command/address byte, byte count, register data and checksum. When the IRMCK201 receives the register data, it validates the checksum, writes the register data, and transmits and acknowledgement to the host.

Command / Address Byte	Byte Count	1-6 bytes of register data	Checksum

Register Write Operation

Command Acknowledgement Byte	Checksum

Register Write Acknowledgement

Bit Position							
7	6	5	4	3	2	1	0
1=Read/ 0=Write	Register Map Starting Address						

Command/Address Byte Format

Bit Position							
7	6	5	4	3	2	1	0
1=Error/ 0=OK	Register Map Starting Address						

Command Acknowledgement Byte Format

The following example shows a command sequence sent from the host to the IRMCO201 requesting a two-byte register write operation:

0x2F	Write operation beginning at offset 0x2F
0x02	Byte count of register data is 2
0x00	Data byte 1
0x04	Data byte 2
0x35	Checksum (sum of preceding bytes, overflow discarded)

A good reply from the IRMCK201 would appear as follows:

0x2F	Write completed OK at offset 0x2F
0x2F	Checksum

An error reply to the command would have the following format:

0xAF	Write at offset 0x2F completed in error
0xAF	Checksum

RS-232 Register Read Access

A register read operation consists of a command/address byte, byte count and checksum. When the IRMCK201 receives the command, it validates the checksum and transmits the register data to the host.

Command / Address Byte	Byte Count	Checksum

Register Read Operation

Command Acknowledgement Byte	Register Data (Byte Count bytes)	Checksum

Register Read Acknowledgement (transfer OK)

Command Acknowledgement Byte	Checksum

Register Read Acknowledgement (error)

The following example shows a command sequence sent from the host to the IRMCK201 requesting four bytes of read register data:

0xA0	Read operation beginning at offset 0x20 (high-order bit selects read operation)
0x04	Requested data byte count is 4
0xA4	Checksum

A good reply from the IRMCK201 might appear as follows:

0x20	Read completed OK at offset 0x20
0x11	Data byte 1
0x22	Data byte 2
0x33	Data byte 3
0x44	Data byte 4
0xCA	Checksum

An error reply to the command would have the following format:

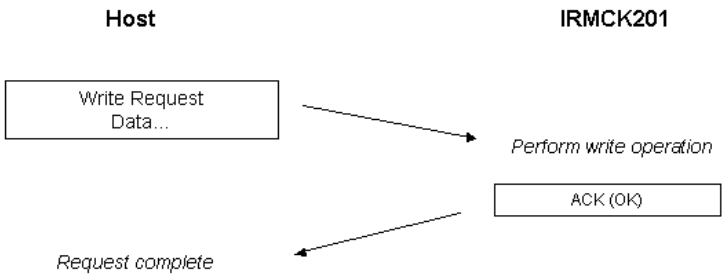
0xA0	Read at offset 0x20 completed in error
0xA0	Checksum

RS-232 Timeout

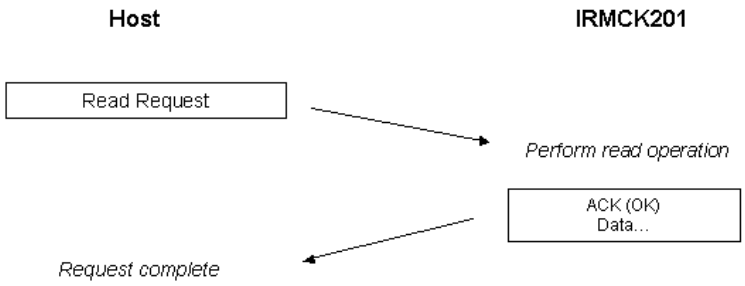
The IRMCK201 receiver includes a timer that automatically terminates transfers from the host to the IRMCK201 after a period of 32 msec.

RS-232 Transfer Examples

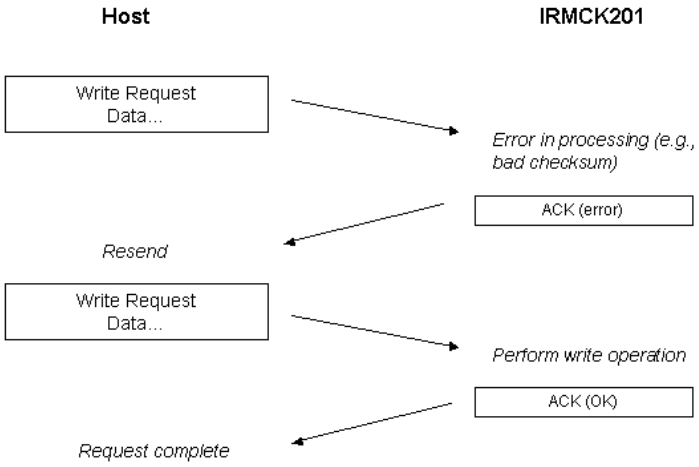
The following example shows a normal exchange executing a register write access.



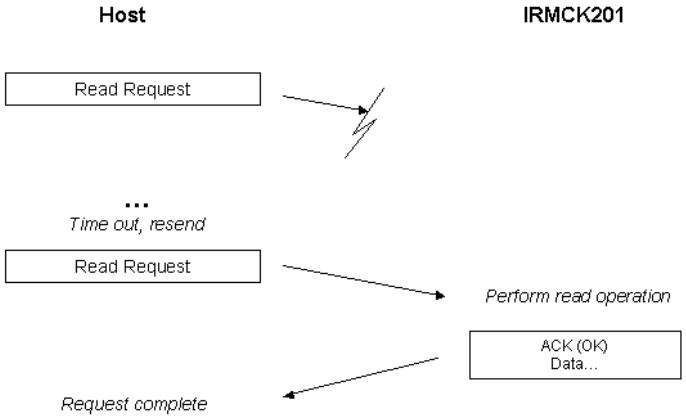
The example below shows a normal register read access exchange.



The following example shows a register write request that is repeated by the host due to a negative acknowledgement from the IRMCK201.



In the final example, the host repeats a register read access request when it receives no response to its first attempt.



Write Register Definitions

QuadratureDecode Register Group (Write Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x0	EncCntW (LSBs) (W)							
0x1	EncCntW (MSBs) (W)							
0x3	MaxEncCnt (LSBs) (W)							
0x4	MaxEncCnt (MSBs) (W)							
0x6	ZEncCnt (LSBs) (W)							
0x7	ZEncCnt (MSBs) (W)							
0x9	EncAngScl (LSBs) (W)							
0xA	EncAngScl (MSBs) (W)							
0xB	SPARE			RedSig (W)	PwrOn RedSig (W)	ZPulse Enb (W)	ZPulsePol (W)	CntEnb (W)

QuadratureDecode Write Register Map

Field Name	Access (R/W)	Field Description
EncCntW	W	New value for 16-bit Quadrature Decoder counter.
MaxEncCnt	W	Maximum value of 16-bit Quadrature Decoder counter. The encoder count is reset to 0 after this count has been reached. This maximum should be set to correspond to a 360-degree physical angle.
ZEncCnt	W	Encoder count value when the Z-pulse occurs. This value is loaded automatically in hardware when the Z-pulse occurs. (See ZPulseEnb and ZPulsePol fields below.)

Field Name	Access (R/W)	Field Description
EncAngScl	W	This value should be set to ((MtrPoles / 2) * (4096 * 4096) / (MaxEncCnt + 1), where MtrPoles is the number of motor poles. The value is used to convert the encoder count to an angle ranging from 0 - 4095 using the equation: Angle = ((MtrPoles / 2) * 4096 * (encoder count) / (MaxEncCnt + 1)) MOD 4096. (The current encoder count can be read from the EncCntR feld of the QuadratureDecodeStatus read register group.)
CntEnb	W	Encoder counter enable.
ZPulsePol	W	ZPULSE polarity. 1= load ZEncCnt on rising Z-pulse edge. 0= load ZEncCnt on falling Z-pulse edge.
ZPulseEnb	W	ZPULSE count initialization enable. When this bit is set, the encoder count is set to the ZEncCnt value at each Z-pulse edge as determined by the ZPulsePol field.
PwrOnRedSig	W	PowerOn Reduced signal enable. Set this bit in the EEPROM to enable EEPROM standalone initialization for a wire-saving encoder. When this bit is set, the EEPROM initialization uses the PwrOnHallA, PwrOnHallB, PwrOnHallC bits instead of the HallA, HallB, HallC bits to determine initial motor angle. (The Hall bits can be read from the QuadratureDecodeStatus read register group.)
RedSig	W	Reduced signal encoder enable. 1 = read Hall A/B/C fields from encoder A/B/Z wires.

QuadratureDecode Write Register Field Definitions

PwmConfig Register Group (Write Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0xC	Gatekill Sns (W)	SPARE	Gate SnsL (W)	Gate SnsU (W)	SPARE		SD (W)	SPARE
0xD	PwmPeriod (LSBs) (W)							
0xE	SPARE		PwmConfig (W)		PwmPeriod (MSBs) (W)			
0xF	PwmDeadTm (W)							

PwmConfig Write Register Map

Field Name	Access (R/W)	Field Description
SD	W	Shutdown control output to IR2137.
GateSnsU	W	Upper IGBT gate sense. 1 = active high gate control, 0 = active low gate control.
GateSnsL	W	Lower IGBT gate sense. 1 = active high gate control, 0 = active low gate control.
GatekillSns	W	GATEKILL signal sense. 1 = active high GATEKILL, 0 = active low GATEKILL.
PwmPeriod	W	This field is used to set the desired PWM frequency using the following equation: PwmPeriod = 33,333,333 / (2 * (PWM frequency)) – 1, where 33,333,333 is the system clock frequency (33.333Mhz). Note that while "PwmPeriod" is the name of this field, the actual PWM carrier period is 2 * (PwmPeriod + 1) * (System Clock Period = 30ns).
PwmConfig	W	PWM Configuration. 0 = Asymmetrical center aligned PWM, 1 = Symmetrical Center aligned PWM.
PwmDeadTm	W	Gate drive dead time in units of system clock cycles (e.g., 30 ns with 33 MHz clock).

PwmConfig Write Register Field Definitions

CurrentFeedbackConfig Register Group (Write Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x10	IfbOffsV (LSBs) (W)							
0x11	IfbOffsW (LSBs) (W)				IfbOffsV (MSBs) (W)			
0x12	IfbOffsW (MSBs) (W)							
0x13	IdScl (LSB) (W)							
0x14	IdScl (MSB) (W)							
0x15	IqScl (LSB) (W)							
0x16	IqScl (MSB) (W)							

CurrentFeedbackConfig Write Register Map

Field Name	Access (R/W)	Field Description
IfbOffsV	W	12-bit signed value for V phase current feedback offset. When the IfbOffsEnb bit in the SystemControl write register group is "0" this value is automatically added to each current measurement in hardware.
IfbOffsW	W	12-bit signed value for W phase current feedback offset. When the IfbOffsEnb bit in the SystemControl write register group is "0" this value is automatically added to each current measurement in hardware.
IdScl	W	Rotating frame Id component current feedback scale factor. Constant used to scale current measurements before they are used in the field orientation calculation. This is a 15-bit fixed-point signed number with 10 fractional bits that ranges from –16 to + 16 + 1023 / 1024.
IqScl	W	Rotating frame Iq component current feedback scale factor. Constant used to scale current measurements before they are used in the field orientation calculation. This is a 15-bit fixed-point signed number with 10 fractional bits that ranges from –16 to + 16 + 1023 / 1024.

CurrentFeedbackConfig Write Register Field Definitions

SystemControl Register Group (Write Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x17	DcComp Enb	IfbOffs Enb	SPARE			Reserved	Foc EnbW	Pwm EnbW

SystemControl Write Register Map

Field Name	Access (R/W)	Field Description
PwmEnbW	W	PWM Enable bit. Setting this bit to 1 or 0 sets the IGBT gate control signals to their active or inactive states. At power up the gate control output signals remain in a high-Z state. After PwmEnbW is set for the first time, the gate controls are driven to their active or inactive states according to the value of PwmEnbW. A fault condition clears this bit automatically in hardware.
FocEnbW	W	Field Orientated Control Enable bit. Setting this bit to 1 enables the FOC algorithm. Setting this bit to 0 resets the FOC algorithm and causes zero output voltage to be applied to the motor. A fault condition clears this bit automatically in hardware.
Reserved	W	This field should is reserved and should be set to 0.

Field Name	Access (R/W)	Field Description
IfbOffsEnb	W	When IFB PwmEnbW = 1, and FocEnbW = 0, the Current feedback offset is calculated and saved in the CurrentFeedbackOffset read register group. When IfbOffsEnb = 1, the Current feedback offset values in the CurrentFeedbackOffset **Read** registers are applied to each current feedback measurement. When IfbOffsEnb = 0, the Current feedback offset values in the CurrentFeedbackConfig **Write** registers are applied to each current feedback measurement.
DcCompEnb	W	DC Bus Compensation enable. When this bit is set to "1", PWM output is compensated for using the following formula: PWM (comp) = PWM * 310 / DCBUSVOLTS where PWM (comp) is the compensated PWM output voltage; PWM is the uncompensated PWM output voltage; 310 is the nominal DC bus voltage; and DCBUSVOLTS is the actual DC bus voltage.

SystemControl Write Register Field Definitions

CurrentLoopConfig Register Group (Write Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x18	IqRefW – Quadrature Reference Current (LSBs) (W)							
0x19	IqRefW – Quadrature Reference Current (MSBs) (W)							
0x1A	KpIreg – Current Loop Proportional Gain (LSBs) (W)							
0x1B	KpIreg – Current Loop Proportional Gain (MSBs) (W)							
0x1C	KxIreg – Current Loop Integral Gain (LSBs) (W)							
0x1D	KxIreg – Current Loop Integral Gain (MSBs) (W)							
0x1E	IdRef – Direct/Magnetizing Reference Current (LSBs) (W)							
0x1F	IdRef – Direct/Magnetizing Reference Current (MSBs) (W)							
0x20	SlipGn (LSBs) (W)							
0x21	SlipGn (MSBs) (W)							
0x22	VqLim – Quadrature Current Output Limit (LSBs) (W)							
0x23	VqLim – Quadrature Current Output Limit (MSBs) (W)							

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x26	VdLim – Direct Current Output Limit (LSBs) (W)							
0x27	VdLim – Direct Current Output Limit (MSBs) (W)							

CurrentLoopConfig Write Register Map

Field Name	Access (R/W)	Field Description
IqRefW	W	15-bit signed quadrature current reference input from velocity loop.
KpIreg	W	15-bit signed current loop PI controller proportional gain. Scaled with 14 fractional bits for an effective range of 0 – 1.
KxIreg	W	15-bit signed current loop PI controller integral gain. Scaled with 19 fractional bits for an effective range of 0 - .03125.
IdRef	W	15-bit signed direct/magnetized current to D-axis current loop PI controller.
SlipGn	W	This parameter controls the slip speed for induction motor applications. SlipGn should be set to 2048 * 2048 * (Rated slip speed in Hz) / (Current loop update frequency). SlipGn MUST be set to 0 if slip is not desired.
VqLim	W	16-bit Quadrature current PI controller voltage output limit.
VdLim	W	16-bit Direct current PI controller voltage output limit.

CurrentLoopConfig Write Register Field Definitions

VelocityControl Register Group (Write Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x31	SPARE				SpdLpRate			SpdLpEnb
0x32	KpSreg – Velocity loop proportional gain (LSBs) (W)							
0x33	KpSreg – Velocity loop proportional gain (MSBs) (W)							
0x34	KxSreg – Velocity loop integral gain (LSBs) (W)							
0x35	KxSreg – Velocity loop integral gain (MSBs) (W)							
0x36	SregLimP – Velocity loop positive Limit (LSBs) (W)							
0x37	SregLimP – Velocity loop positive Limit (MSBs) (W)							

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x38	SregLimN – Velocity loop negative Limit (LSBs) (W)							
0x39	SregLimN – Velocity loop negative Limit (MSBs) (W)							
0x3A	SpdScl – Speed Scale Factor (LSBs)							
0x3B	SpdScl – Speed Scale Factor (MSBs)							
0x3C	TargetSpd – Setpoint/target speed (LSBs)							
0x3D	TargetSpd – Setpoint/target speed (MSBs)							
0x3E	SpdAccRate – Acceleration							
0x3F	SpdDecRate – Deceleration							

VelocityControl Write Register Map

Field Name	Access (R/W)	Field Description
SpdLpEnb	W	Speed loop enable: 1 = enable speed loop PI controller. 0 = Reset Speed loop PI controller.
SpdLpRate	W	Speed loop update rate: 0 = disabled, N = update speed loop immediately before every Nth current loop update.
KpSreg	W	15-bit velocity loop proportional gain, in fixed point with 5 fractional bits. Range = 0 - 512.
KxSreg	W	15-bit velocity loop integral gain, in fixed point with 13 fractional bits. Range = 0 - 2.
SregLimP	W	16-bit speed PI controller output positive limit.
SregLimN	W	16-bit speed PI controller output negative limit (2's complement).
SpdScl	W	Motor Speed Scale factor. The user should set SpdScl = 60 * 16383 * (33.333MHz/32) / (Max RPM * Encoder PPR) / 2, which will result in a Spd value ranging ±16384 corresponding to ± Max RPM.
TargetSpd	W	Velocity loop speed setpoint in SPEED units, which are determined by the user via the SpdScl register setting.
SpdAccRate	W	Velocity loop acceleration in units of SPEED / Velocity loop execution or SPEED / (SpdLpRate / PWM period).
SpdDecRate	W	Velocity loop deceleration in units of SPEED / Velocity loop execution or SPEED / (SpdLpRate / PWM period).

VelocityControl Write Register Field Definitions

FaultControl Register Group (Write Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x42	SPARE						FltClr	DcBusM Enb

FaultControl Write Register Map

Field Name	Access (R/W)	Field Description
DcBusMEnb	W	DC Bus monitor enable. 1 = Monitor DC bus voltage and generate appropriate brake signal control and disable PWM output when voltage fault conditions occur. GatekillFlt and OvrSpdFlt faults cannot be disabled. DC bus voltage thresholds are as follows: Overvoltage – 410V Brake On – 380V Brake Off – 360V Nominal – 310V Undervoltage off – 140V Undervoltage – 120V
FltClr	W	This bit clears all active fault conditions. The user should monitor the FaultStatus read register group to determine fault status and set this bit to “1” to clear any faults that have occurred. A fault condition automatically clears the PwmEnbW and FocEnbW bits in the SystemControl write register group. Note that this bit also directly controls the output 2137 FLTCLR pin. After clearing a fault, the user must explicitly set this bit to “0” to re-enable fault processing.

FaultControl Write Register Field Definitions

SVPWMScaler Register Group (Write Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x44	ModScl (LSBs) (W)							
0x45	ModScl (MSBs) (W)							

SVPWMScaler Write Register Map

Field Name	Access (R/W)	Field Description
ModScl	W	Space vector modulator scale factor. This register, which depends on the PWM carrier frequency, should be set as follows: ModScl = PwmPeriod * sqrt(3) * 4096 / 2355 where PwmPeriod is the value in the PwmConfig write register group's PwmPeriod register.

SVPWMScaler Write Register Field Definitions

DiagnosticPwmControl Register Group (Write Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x4E	PwmData1Sel				PwmData0Sel			
0x4F	PwmData3Sel				PwmData2Sel			

DiagnosticPwmControl Write Register Map

Field Name	Access (R/W)	Field Description
PwmData0Sel, PwmData1Sel, PwmData2Sel, PwmData3Sel	W	Selects diagnostic data items for output on DAC PWM pins 0-3. These pins are intended for use with external RC filters for oscilloscope diagnostic display: 1 = DC Bus Voltage 2 = V phase current 3 = W phase current 5 = Speed PI Reference 6 = Speed PI Feedback 7 = Speed PI Error 8 = IQ Ref 9 = Q axis voltage Qv 10 = D axis voltage Dv 11 = 12-bit electrical angle 12 = Q axis current Qi 13 = D axis current Di 14 = A axis (stationary frame) voltage Av 15 = B axis (stationary frame) voltage Bv

DiagnosticPwmControl Write Register Field Definitions

SystemConfig Register Group (Write Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x50	ExtCtrlW	SpdRefSel		IqRefSel		HostAng Enb	HostVd Enb	RmpRef Sel

SystemConfig Write Register Map

Field Name	Access (R/W)	Field Description
RmpRefSel	W	Speed Ramp reference select. 0= TargetSpd field of the VelocityControl write register group, 1 = External analog reference.
HostVdEnb	W	Host D-Axis current control enable. When this bit is set, the D-Axis PI Controller is disconnected from the forward path vector rotator, which then takes its input from the VdSfwd field of the DirectHostVoltageControl write register group.
HostAngEnb	W	Host electrical angle control enable. When this bit is set, the vector rotator takes its angle input from the ElecAngW field of the DirectHostVoltageControl write register group.
IqRefSel	W	Selects the source for the Q-Axis PI controller IQREF input: 0 = Speed PI controller output 1 = IqRefW field of the CurrentLoopConfig write register group 2 = Reference A/D converter input.
SpdRefSel	W	Selects the source for the Speed PI controller reference input: 0 = Internal Accel/Deccel ramp generator 1 = TargetSpd field of the VelocityControl write register group 2 = Reference A/D converter input.
ExtCtrlW	W	Setting this bit to “1” enables direct control of basic motor operation via the external User Interface pins. When this bit is “1”, the FocEnbW and PwmEnbW bits in the SystemControl write register group are ignored.

SystemConfig Write Register Field Definitions

DirectHostVoltageControl Register Group (Write Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x52	VdSfwd (LSBs) (W)							
0x53	VqSfwd (LSBs) (W)				VdSfwd (MSBs) (W)			

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x54	VqSfwd (MSBs) (W)							
0x55	ElecAngW (LSBs) (W)							
0x56	SPARE				ElecAngW (MSBs) (W)			

DirectHostVoltage Control Write Register Map

Field Name	Access (R/W)	Field Description
VdSfwd	W	12-bit signed value for synchronous frame direct current when host direct current control is enabled. This field is typically used for V/Hz control.
VqSfwd	W	12-bit signed value for synchronous frame quadrature voltage that is added to the Q-Axis PI-controller output. This field is typically used for feedforward or V/Hz control.
ElecAngW	W	12-bit electrical angle used when host electrical angle control is enabled. This field is typically used for V/Hz control.

DirectHostVoltageControl Write Register Field Definitions

32bitQuadDecode Register Group (Write Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x58	EncCnt32bW (bits 0-7) (W)							
0x59	EncCnt32bW (bits 8-15) (W)							
0x5A	EncCnt32bW (bits 16-23) (W)							
0x5B	EncCnt32bW (bits 24-31) (W)							

32bitQuadDecode Write Register Map

Field Name	Access (R/W)	Field Description
EncCnt32bW	W	New value for 32-bit Quadrature Decoder counter.

32bitQuadDecode Write Register Field Definitions

EepromControl Registers (Write Registers)

At power up, the write registers can be optionally initialized with values stored in EEPROM. The EepromControl write register group and EepromStatus read register group are used to read and write these EEPROM values. Since the EeAddrW write register (which selects the EEPROM offset to read or write) does not require initialization at power up, the location corresponding to that register in EEPROM (at offset 0x5D) is used to store a register map version code. At power on, the FPGA initializes the write registers from EEPROM only if the version code stored at this offset in EEPROM matches its internal register map version code (which can be read from the RegMapVer field of the EepromStatus read register group).

To enable write register initialization at power up, write the appropriate register map version code to EEPROM at offset 0x5D. To disable write register initialization at power up, write a zero (or any non-matching version code) to offset 0x5D of the EEPROM.

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x5C	SPARE					EeWrite	EeRead	EeRst
0x5D	EeAddrW / RegMapVersCode (W)							
0x5E	EeDataW (W)							

EepromControl Write Register Map

Field Name	Access (R/W)	Field Description
EeRst	W	Self-clearing EEPROM reset. Writing a "1" to this bit resets the I2C EEPROM interface.
EeRead	W	Self-clearing I2c EEPROM Read. Writing a "1" to this bit initiates an EEPROM read from the byte located at EEPROM address EeAddrW. After setting this bit the user should poll the EeBusy bit in the EepromStatus read register group to determine when the read completes and then read the data from EeDataR in the EepromStatus read register group.
EeWrite	W	Self-clearing EEPROM Write. Writing a "1" to this bit initiates an EEPROM write from the data byte in EeDataW to the EEPROM address EeAddrW.
EeAddrW	W	EEPROM Address Register. Contains the address for the next EEPROM read or write operation.
EeDataW	W	EEPROM Data Register. Contains the data for the next EEPROM write operation.

EepromControl Write Register Field Definitions

HallSensorEncoderInit (Write Registers – EEPROM only)

These values must be set in the EEPROM for initial encoder count/angle initialization in the EEPROM standalone (i.e. operation without a host program). EEPROM initialization logic automatically loads the appropriate value into the encoder counter at power-on based on the HALL A/B/C sensor values. These values are present only in the EEPROM since they serve no purpose after power on.

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x72	HallCBA001(LSBs)							
0x73	HallCBA001(MSBs)							
0x74	HallCBA010 (LSBs)							
0x75	HallCBA010 (MSBs)							
0x76	HallCBA011(LSBs)							
0x77	HallCBA011(MSBs)							
0x78	HallCBA100 (LSBs)							
0x79	HallCBA100 (MSBs)							
0x7A	HallCBA101(LSBs)							
0x7B	HallCBA101(MSBs)							
0x7C	HallCBA110 (LSBs)							
0x7D	HallCBA 110 (MSBs)							

HallSensorEncoderInit Register Map

Field Name	Access (R/W)	Field Description
HallCBA*nnn*	W (EEPROM ONLY)	Initial encoder count for Hall Sensor [C, B, A] value [*n*, *n*, *n*].

HallSensorEncoderInit Field Definitions

Read Register Definitions

QuadratureDecodeStatus Register Group (Read Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x0	EncCntR (LSBs) (R)							
0x1	EncCntR (MSBs) (R)							
0x3	SPARE	PwrOn HallC	PwrOn HallB	PwrOn HallA	SPARE	HallC	HallB	HallA

QuadratureDecodeStatus Read Register Map

Field Name	Access (R/W)	Field Description
EncCntR	R	Current value of 16-bit Quadrature Decoder counter.
HallA, HallB, HallC	R	Hall Sensor A/B/C values.
PwrOnHallA, PwrOnHallB, PwrOnHallC	R	Hall Sensor A/B/C values at power-on for reduced-wire encoder interface.

QuadratureDecodeStatus Read Register Field Definitions

SystemStatus Register Group (Read Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x7	Start	Stop	SPARE	PwrID		GateKill	Foc EnbR	Pwm EnbR
0x8	RevCode (LSBs)							
0x9	RevCode (MSBs)							

SystemStatus Read Register Map

Field Name	Access (R/W)	Field Description
PwmEnbR	R	PWM Enable bit status.
FocEnbR	R	FOC Enable bit status.
GateKill	R	GATEKILL status. This bit is set by the Gatekill input from the IR2137. Once set, this bit remains set until it is cleared by writing a “1” to the FaultClr bit in the FaultControl write register group.
PwrID	R	Power ID. 0 = 3 kW, 1 = 2 kW, 2 = 500 W.
Stop	R	User Interface "STOP" digital input status.
Start	R	User Interface "START" digital input status.
RevCode	R	ASIC Revision Code. Revision code format is “XX.XX”, where each “X” is a 4-bit hexadecimal number.

SystemStatus Read Register Field Definitions

DcBusVoltage Register Group (Read Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0xA	DcBusVolts (LSBs)							
0xB	SPARE			Brake	DcBusVolts (MSBs)			

DcBusVoltage Read Register Map

Field Name	Access (R/W)	Field Description
DcBusVolts	R	DC Bus Voltage. Data range is 0 - 4095, which corresponds to a DC bus voltage between 0 and 500 volts.
Brake	R	Brake signal status. 0 = Brake signal active.

DcBusVoltage Read Register Field Definitions

FocDiagnosticData Register Group (Read Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0xC	IvFbk - V Phase IFB Raw Current (LSBs) (R)							
0xD	IwFbk - W Phase IFB Raw Current (LSBs) (R)				IvFbk - V Phase IFB Raw Current (MSBs) (R)			

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0xE	IwFbk - W Phase IFB Raw Current (MSBs) (R)							
0xF	Id – Synchronous Frame Direct Current (LSBs) (R)							
0x10	Id – Synchronous Frame Direct Current (MSBs) (R)							
0x11	Iq – Synchronous Frame Quadrature Current (LSBs) (R)							
0x12	Iq – Synchronous Frame Quadrature Current (MSBs) (R)							
0x13	Ud – Synchronous Frame Direct Voltage (LSBs) (R)							
0x14	Ud – Synchronous Frame Direct Voltage (MSBs) (R)							
0x15	Uq – Synchronous Frame Quadrature Voltage (LSBs) (R)							
0x16	Uq – Synchronous Frame Quadrature Voltage (MSBs) (R)							
0x17	UAlpha – Stationary Frame Alpha Voltage (LSBs) (R)							
0x18	UBeta – Stationary Frame Beta Voltage (LSBs) (R)						UAlpha – Stationary Frame Alpha Voltage (MSBs) (R)	
0x19	UBeta – Stationary Frame Beta Voltage (MSBs) (R)							

FocDiagnosticData Read Register Map

Field Name	Access (R/W)	Field Description
IvFbk, IwFbk	R	Offset-corrected V and W phase raw current from the IR2175 current sensor. Values range from 0 - 4096, where 2048 corresponds to 0 current. The current feedback scale factors IdScl and IqScl in the CurrentFeedbackConfig write register group and the current sense resistor value determine the full scale current value.
Id, Iq	R	Synchronous or rotating frame direct and quadrature current values in 2's complement representation. The full scale current values range from –16384 to 16383.
Ud, Uq	R	Synchronous or rotating frame direct and quadrature voltage values in 2's complement representation. Data ranges are ± VdLim for Ud and ± VqLim for Uq as specified in the CurrentLoopConfig write register group.

UAlpha, UBeta	R	Stationary frame Alpha and Beta voltage output component values. Data range is ± VdLim or ± VqLim (as specified in the CurrentLoopConfig write register group), whichever is larger.

FocDiagnosticData Read Register Field Definitions

FaultStatus Register Group (Read Registers)

The Fault Status register records fault conditions that occur during drive operation. When any of these fault conditions occur, the PWM output is automatically disabled. The user should monitor this register continuously for fault conditions. A fault condition can be cleared by writing a "1" to the FaultClr bit in the FaultControl write register group. (This does not automatically re-enable PWM output.)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x1E	SPARE			ExecTm Flt	OvrSpdFlt	OvFlt	LvFlt	GatekillFlt

FaultStatus Read Register Map

Field Name	Access (R/W)	Field Description
GatekillFlt	R	Filtered and latched version of IR2137 FAULT output.
LvFlt	R	DC bus low voltage fault. This fault occurs if the DC bus drops below 120V.
OvFlt	R	DC bus overvoltage fault. This fault occurs if the DC bus voltage exceeds 410V.
OvrSpdFlt	R	Over speed fault. This fault occurs whenever the motor reaches the positive or negative limits. The user should use the scale factor in the SpdScl field of the VelocityControl write register group to scale the motor speed so that it falls between -16384 and +16383 with these limits as the over speed condition.
ExecTmFlt	R	Execution time fault.

FaultStatus Read Register Field Definitions

VelocityStatus Register Group (Read Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x26	Spd (LSBs)							
0x27	Spd (MSBs)							

VelocityStatus Read Register Map

Field Name	Access (R/W)	Field Description
Spd	R	Current motor speed in SPEED units. (See the description of SpdScl in the VelocityControl write register group.)

VelocityStatus Read Register Field Definitions

CurrentFeedbackOffset Register Group (Read Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x30	IfbVOffs (LSBs) (R)							
0x31	IfbWOffs (LSBs) (R)				IfbVOffs (MSBs) (R)			
0x32	IfbWOffs (MSBs) (R)							

CurrentFeedbackOffset Read Register Map

Field Name	Access (R/W)	Field Description
IfbVOffs, IfbWOffs	R	Current feedback offset values from the last IFB Offset calculation. These values are automatically applied to each current feedback measurement value whenever the IfbOffsEnb bit in the SystemControl write register group is set.

CurrentFeedbackOffset Read Register Field Definitions

32bitQuadDecodeStatus Register Group (Read Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x34	EncCnt32bR (bits 0-7) (R)							
0x35	EncCnt32bR (bits 8-15) (R)							
0x36	EncCnt32bR (bits 16-23) (R)							
0x37	EncCnt32bR (bits 24-31) (R)							

32bitQuadDecodeStatus Read Register Map

Field Name	Access (R/W)	Field Description
EncCnt32bR	R	Current value of 32-bit Quadrature Decoder counter.

32bitQuadDecodeStatus Read Register Field Definitions

EepromStatus Registers (Read Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x38	SPARE							EeBusy
0x39	EeDataR (R)							
0x3A	EeAddrR (R)							
0x3B	RegMapVer (R)							

EepromStatus Read Register Map

Field Name	Access (R/W)	Field Description
EeBusy	R	I2C EEPROM Interface busy bit. The user should wait for this bit to clear before initiating EEPROM read or write operations.
EeDataR	R	EEPROM Data Register. Contains the data from the last EEPROM read operation. Note that writing to the EeRst field in the EepromControl write register group invalidates this register.
EeAddrR	R	EEPROM Address read register shows the value stored in EEPROM at the offset of the EeAddrW write register (0x5D). Since this address in the EEPROM contains the BPFPGA register map version, the user can read this field to determine whether or not the write registers were initialized at power on.
RegMapVer	R	Current register map version code.

EepromStatus Read Register Field Definitions

FOCDiagnosticDataSupplement Register Group (Read Registers)

Byte Offset	Bit Position							
	7	6	5	4	3	2	1	0
0x3C	ElecAngR (LSBs) (R)							
0x3D	SPARE				ElecAngR (MSBs) (R)			
0x3E	SpdRef (LSBs) (R)							
0x3F	SpdRef (MSBs) (R)							
0x40	SpdErr (LSBs) (R)							
0x41	SpdErr (MSBs) (R)							
0x42	IqRefR (LSBs) (R)							
0x43	IqRefR (MSBs) (R)							

FOCDiagnosticDataSupplement Read Register Map

Field Name	Access (R/W)	Field Description
ElecAngR	R	Electrical angle.
SpdRef	R	Speed PI controller reference input.
SpdErr	R	Speed PI controller error.
IqRefR	R	Speed PI controller output.

FOCDiagnosticDataSupplement Read Register Field Definitions

Appendix B Package

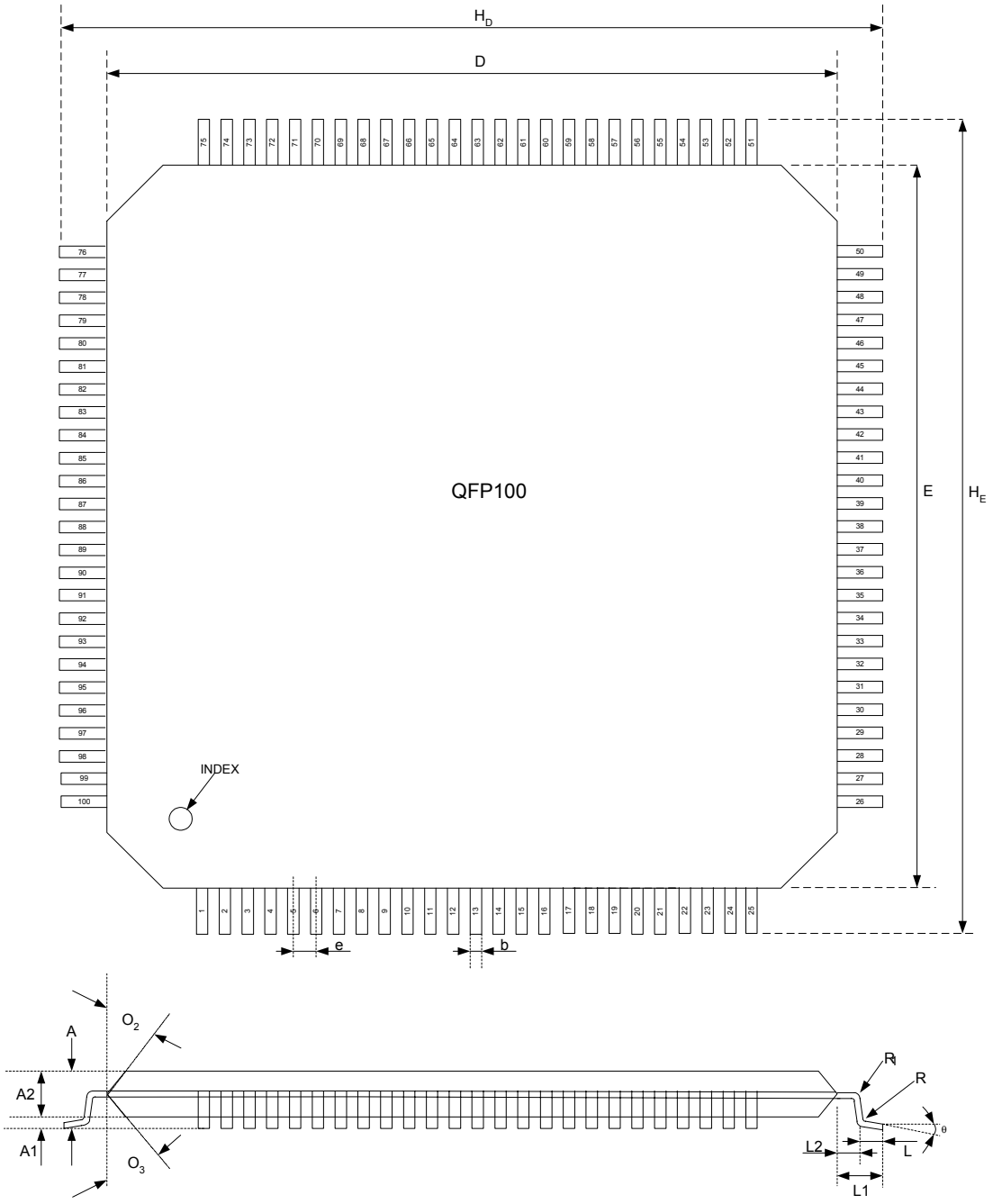


Figure 20: QFP100 Package

SYMBOL	DIMENSION IN MILIMETERS			DIMENSION IN INCHES*		
	Min.	Nom.	Max.	Min.	Nom.	Max.
E	13.9	14	14.1	(0.548)	(0.551)	(0.555)
D	13.9	14	14.1	(0.548)	(0.551)	(0.555)
A			1.7			(0.066)
A1		0.1			(0.004)	
A2	1.3	1.4	1.5	(0.052)	(0.055)	(0.059)
e		0.5			(0.020)	
b	0.13	0.18	0.28	(0.006)	(0.007)	(0.011)
C	0.1	0.125	0.175	(0.004)	(0.005)	(0.006)
□	0º		10º	(0º)		(10º)
L	0.3	0.5	0.7	(0.012)	(0.20)	(0.027)
L1		1			(0.039)	
L2		0.5			(0.020)	
H_E	15.6	16	16.4	(0.615)	(0.630)	(0.645)
H_D	15.6	16	16.4	(0.615)	(0.630)	(0.645)
□2		12º			(12º)	
□3		12º			(12º)	
R		0.2			(0.008)	
R1		0.2			(0.008)	

Table 22: QFP100 Dimensions

* For reference

Appendix C Errata

1. When using the ADS7818 A/D converter interface as the current feedback source (instead of the IR2175) the current offset is not calculated.

2. The scaling is too large by a factor of 16 for the following Diagnostic DAC PWM selections: Reference Speed (#5) Motor Speed (#6) IQREF (#8). The scaling too large by a factor of 8 for the following Diagnostic DAC PWM selections: IQ (#C) DQ (#D)

The scaling is too large by a factor of 4 for the following Diagnostic DAC PWM selections: Av (#E) Bv (#F) These values will work at small data ranges, but overflow otherwise. To extract the correct data for these items, use the parallel port and diagnostic data registers.

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