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Data Sheet

iMOTION™ motor control IC for single motor drive

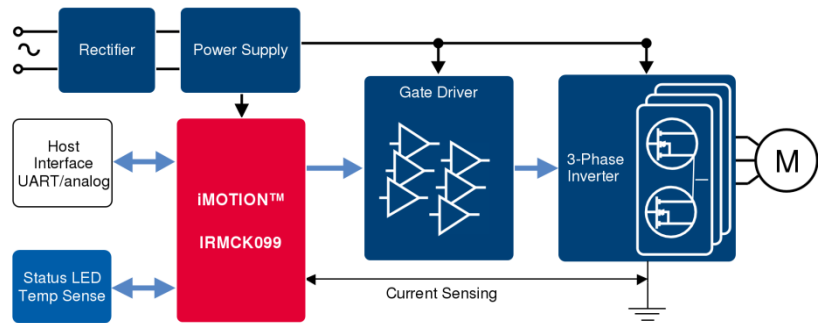
Quality Requirement Category: Industry

Features

- Ready-to-use solution for high efficiency variable speed drives
- Pre-programmed motion control engine (MCE)
- Sensor less field oriented control (FOC) of permanent magnet synchronous motors (PMSM)
- Support for up to 31 sets of motor parameters
- Current measurement based on single or leg shunt
- Integrated oscillator, A/D converter, OP amps & comparators
- Integrated protection features
- Package: 5x5mm² QFN-32

Applications

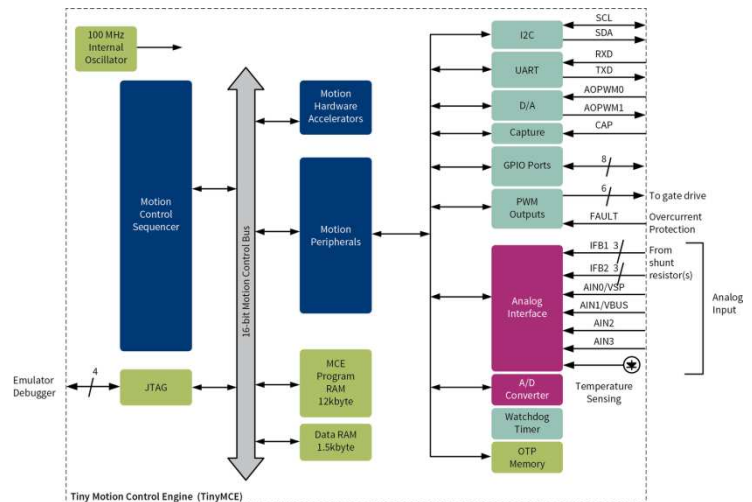
- Pumps & fans
- Drones, multicopters
- Home appliances
- Any other PMSM drive



Description

The IRMCK099 combines the iMOTION™ motor control engine (MCE) with all peripherals required to realize a complete variable speed drive. The IRMCK099 does not require algorithm programming and can be used in combination with a μ IPM™ or a discrete power stage.

The MCE implements sensor less field oriented control using single or leg shunt current feedback and uses space vector PWM with sinusoidal signals to provide highest energy efficiency.





High Performance Sensorless Motor Control IC

Description

IRMCK099 is a low cost, high performance OTP memory based motion control ASIC designed primarily for appliance applications. IRMCK099 is designed to implement high performance control solutions for advanced inverterized appliance motor control. IRMCK099 contains the flexible Tiny Motion Control Engine (TinyMCE) for sensorless control of permanent magnet motors over the full speed range. The TinyMCE implements sensorless Field Oriented Control using single or leg shunt current feedback by a combination of hardware and IR-supplied firmware elements. Key components of the complex sensorless control algorithms, such as the Angle Estimator, are provided as complete pre-defined control blocks. The ASIC is designed to eliminate external components and reduce cost by including an A/D converter, analog amplifiers, an overcurrent comparator, watchdog timer and internal oscillator. Strong startup and configuration tools get the motor running quickly without any programming. A standby power mode can help to increase overall system efficiency. IRMCK099 comes in a 5mmx5mm, 32 pin QFN package.

Features

- TinyMCE (Tiny Motion Control Engine) - Dedicated computation engine for high efficiency sinusoidal sensorless motor control
- Internal Oscillator – no clock required
- Built-in hardware peripheral for single or two shunt current feedback reconstruction and analog circuits
- Supports both interior and surface permanent magnet motor sensorless control
- Loss minimization Space Vector PWM
- Internal ITRIP comparator
- Two-channel analog output (Sigma Delta D/A)
- JTAG programming port for debugging
- UART and I2C serial interface
- Factory Calibrated Analog Inputs
- Capture input
- Watchdog timer with independent internal clock
- Standby low power mode
- Internal 16 Kbyte OTP memory
- CRC Memory Check
- 3.3V single supply

Product Summary

Internal clock frequency (SYSCLK)	100MHz
MCE™ computation time	1 SYSCLK
MCE™ computation data range	16 bit signed
OTP Memory	16KB
MCE Data RAM	1.5KB
MCE Program RAM	12KB
FAULT latency (digital filtered)	2 µsec
PWM carrier frequency	1 – 20kHz
A/D input channels	6
A/D converter resolution	12 bits
A/D converter conversion speed	2 µsec
Analog output (PWM) resolution	8 bits
UART baud rate (typ)	57.6 Kbps
Number of digital I/O (max)	8
Package (lead free)	QFN 5x5 32L
Typical 3.3V operating current	< 30mA
Standby mode power consumption	3.5mW
Integrated Temperature Sensor(typ)	±5degC

Base Part Number	Package Type	Standard Pack		Orderable Part Number
		Form	Quantity	
IRMCK099M	QFN32	Tape and Reel	3000	IRMCK099MTR
		Tray	2450	IRMCK099M

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1 Overview

IRMCK099 is a new generation International Rectifier integrated circuit device primarily designed as a one-chip solution for inverterized appliance motor control applications. Unlike a traditional microcontroller or DSP, the IRMCK099 provides a built-in closed loop sensorless control algorithm using the unique flexible Tiny Motion Control Engine (TinyMCE) for permanent magnet motors. The MCE™ consists of a collection of control elements, motion peripherals, a dedicated motion control sequencer and internal memory to map internal signal nodes. IRMCK099 also employs a unique single shunt current reconstruction circuit in addition to two leg shunt current sensing circuit to eliminate additional analog/digital circuitry. Integrated op-amps and A/D converter enable a direct shunt resistor interface to the IC. Four analog inputs and up to eight digital I/O provide resources for application specific functions. Figure 1 shows a typical application schematic using the IRMCK099.

IRMCK099 contains 16 Kbytes of OTP program memory and comes in a compact 5mm x 5mm 32-pin QFN package.

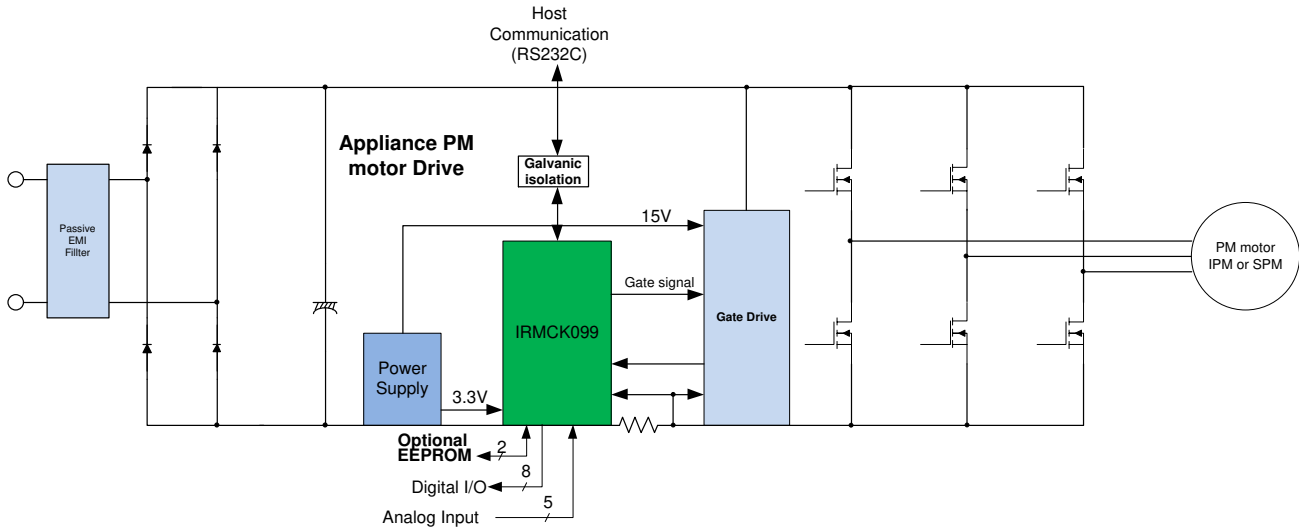


Figure 1. Typical Application Block Diagram Using IRMCK099

2 Pinout

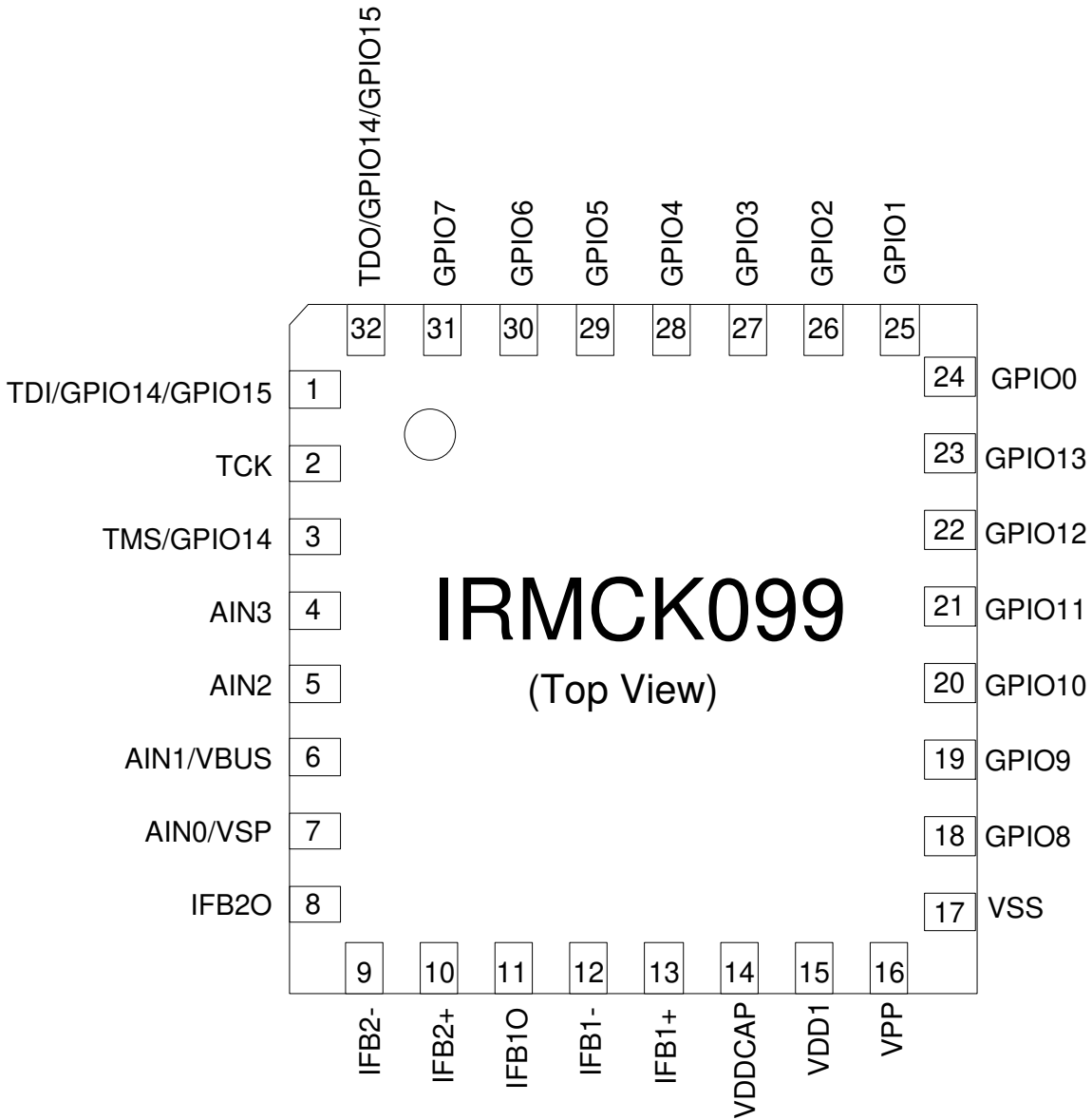


Figure 2. Pinout of IRMCK099

Pin Number	Pin Name	Main Function (After Reset) ⁽¹⁾	Remap ^{(1) (2)}	
1	TDI/GPIO14/GPIO15	TDI	GATEKILL PWMUL PWMUH PWMVL PWMVH PWMWL PWMWH AOPWM0 AOPWM1 RXD TXD SDA SCL CAPTURE	
3	TMS/GPIO14	TMS		
18	GPIO8	(1)		
19	GPIO9			
20	GPIO10			
21	GPIO11			
22	GPIO12			
23	GPIO13			
24	GPIO0			
25	GPIO1			
26	GPIO2			
27	GPIO3			
28	GPIO4			
29	GPIO5			
30	GPIO6			
31	GPIO7			
32	TDO/GPIO14/GPIO15			TDO

Table 1 Remap functions available on GPIO

Note (1)-Function availability depends on the provided firmware and for more information refer to the Application pin out section of the IRMCK099 application guide.

Note (2)-Only one pin can be remapped to one of the provided functions at the same time, for more information refer to the Application pin out section of the IRMCK099 application guide.

3 IRMCK099 Block Diagram and Main Functions

IRMCK099 block diagram for leg shunt mode is shown in Figure 3.

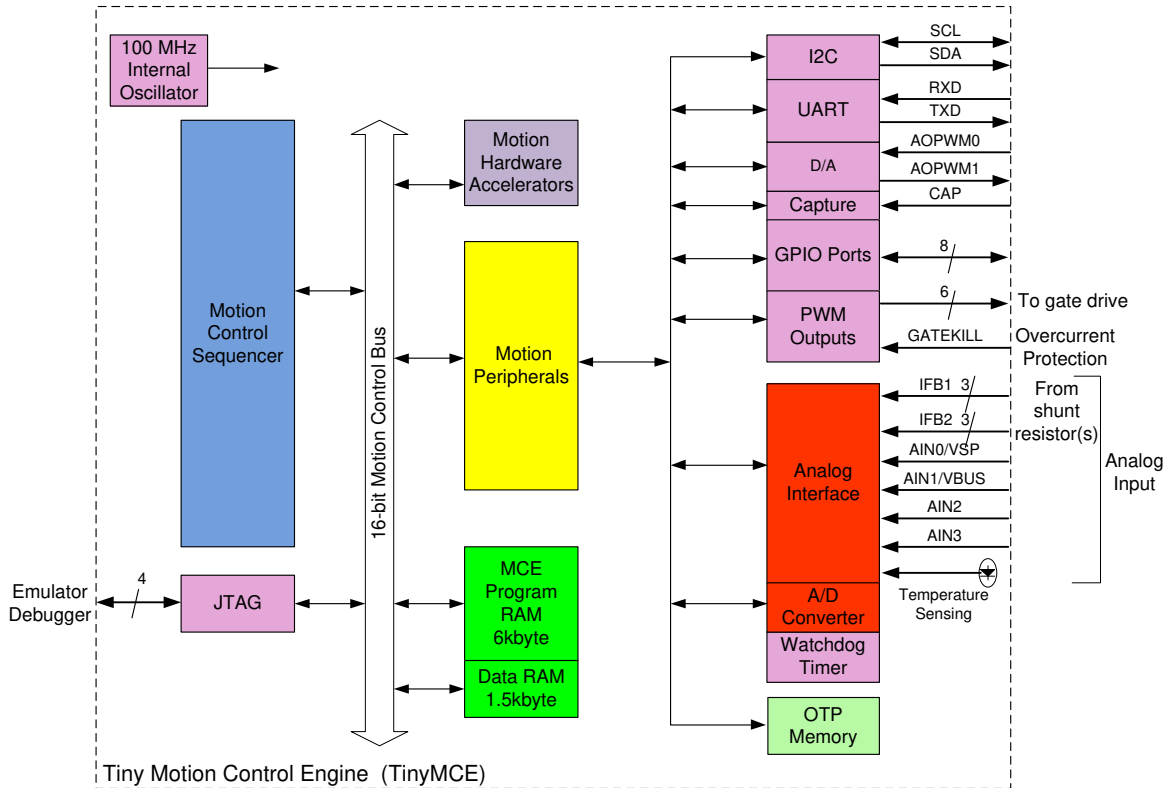


Figure 3. IRMCK099 Block Diagram

IRMCK099 contains the following functions for sensorless permanent magnet motor control applications:

Tiny Motion Control Engine (TinyMCE)

- Sensorless FOC (complete sensorless field oriented control)
 - PI Speed Regulator
 - 2-channel PI Current regulators (q & d quadratures)
 - Angle estimator (sensorless control)
 - Clark/Inverse Clark transformation
 - Vector rotator
 - No parking
 - Torque at low to zero speed
 - Multiply-divide (signed and unsigned)
 - Divide (signed and unsigned)
 - ATAN (arc tangent)
- Hardware PWM shutdown pin (GK)
- Up to 20kHz PWM Frequency
- One 16 bit watchdog timer
- One 16 bit capture timer
- Up to 8 discrete digital I/Os
- Six-channel 12 bit A/D
 - Buffered (current sensing) two channels (0 – 1.2V input)
 - Unbuffered four channels (0 – 1.2V input)
- JTAG port (4 pins)
- Two channels analog output (8 bit PWM)
- UART
- I²C port
- Standby Low Power Mode
- 1.5K byte data RAM
- 12K byte program RAM
- 16K byte OTP memory

4 Application connection and Pin function

Figure 4 shows the application connections in leg shunt mode.

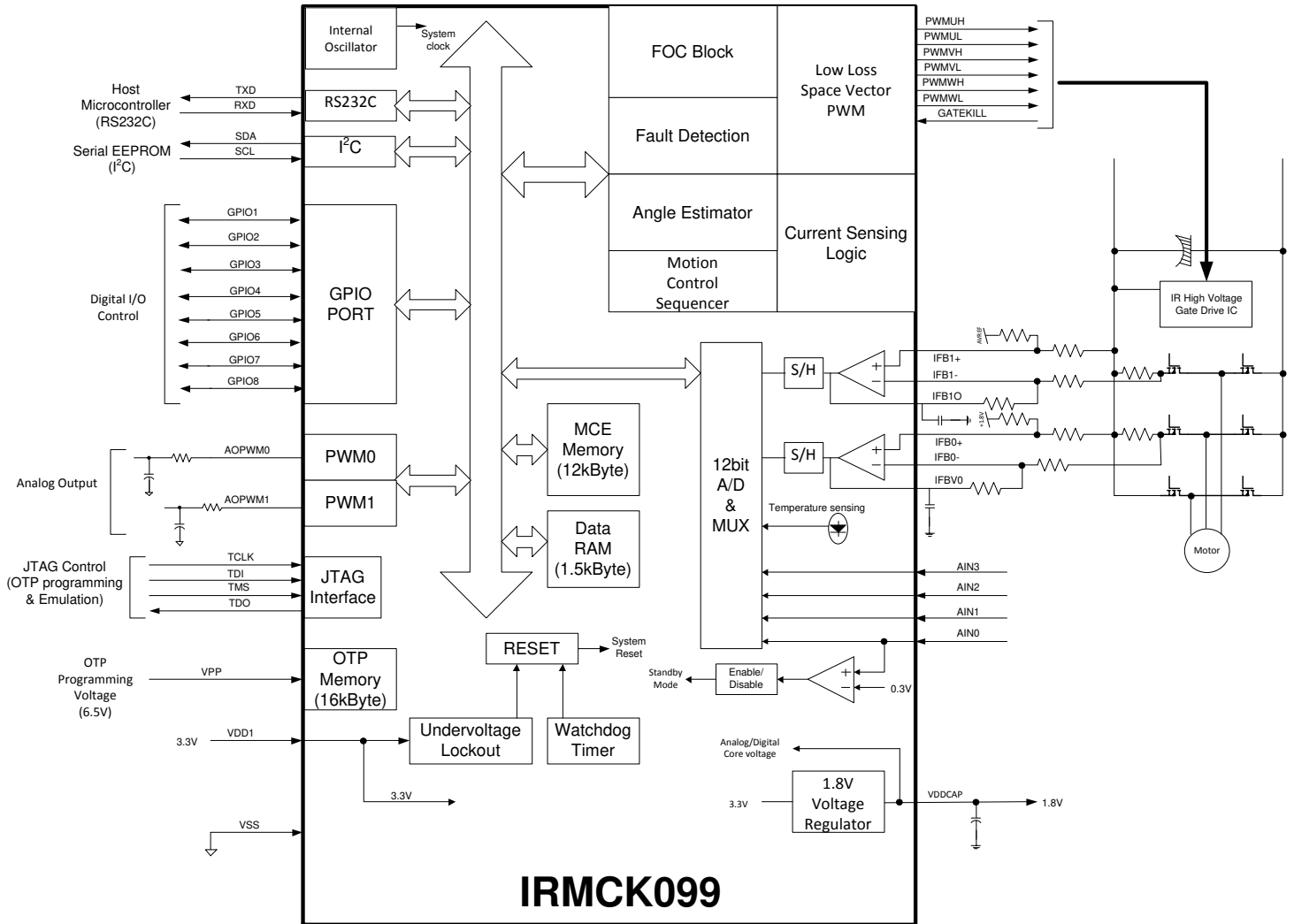


Figure 4. IRMCK099 Leg Shunt Connection Diagram

4.1 MCE Peripheral Interface Group

UART Interface

TXD Output, Transmit data from IRMCK099, can be configured to GPIO pins
 RXD Input, Receive data to IRMCK099, can be configured to GPIO pins

Discrete I/O Interface

GPIO0 - GPIO15 Digital Input/Output Ports

Analog Output Interface

AOPWM1	Input/output, can be configured as 8-bit PWM output 1 with programmable carrier frequency
AOPWM2	Input/output, can be configured as 8-bit PWM output 2 with programmable carrier frequency

I²C Interface

SCL	Output, I ² C clock output, can be configured to GPIO pins
SDA	Input/output, I ² C Data line, can be configured to GPIO pins

Capture Interface

CAP	Capture Input, can be configured to GPIO pins
-----	---

4.2 Motion Peripheral Interface Group
PWM

PWMUH	Output, PWM phase U high side gate signal, tri-state at power up until configured by firmware
PWMUL	Output, PWM phase U low side gate signal, tri-state at power up until configured by firmware
PWMVH	Output, PWM phase V high side gate signal, tri-state at power up until configured by firmware
PWMVL	Output, PWM phase V low side gate signal, tri-state at power up until configured by firmware
PWMWH	Output, PWM phase W high side gate signal, tri-state at power up until configured by firmware
PWMWL	Output, PWM phase W low side gate signal, tri-state at power up until configured by firmware

GATEKILL

GK	Input, upon assertion this sets all six PWM signals to off state according to setting of active_pol register, pulled up by 49kOhm internal resistor
----	---

4.3 Analog Interface Group

IFB1+	Input, Operational amplifier positive input for single or leg shunt resistor current sensing
IFB1-	Input, Operational amplifier negative input for single or leg shunt resistor current sensing
IFB1O	Output, Operational amplifier output for single or leg shunt resistor current sensing
IFB2+	Input, Operational amplifier positive input for 2 nd leg shunt resistor current sensing
IFB2-	Input, Operational amplifier negative input for 2 nd leg shunt resistor current sensing
IFB2O	Output, Operational amplifier output for 2 nd leg shunt resistor current sensing
AIN0/VSP	Input, Analog input channel 0 (0 – 1.2 V), also used for Standby Mode wake-up
AIN1/VBUS	Input, Analog input channel 1 (0 – 1.2 V), typically configured for DC bus voltage input
AIN2	Input, Analog input channel 2 (0 – 1.2 V), needs to be pulled down to VSS if unused
AIN3	Input, Analog input channel 3 (0 – 1.2 V), needs to be pulled down to VSS if unused

4.4 Power Interface Group

VDD1	Digital and analog power (3.3V)
VDDCAP	Internal 1.8V output, require capacitors connected to the pin. Note: The internal 1.8V supply is not designed to power any external circuits or devices. Only capacitors should be connected to this pin.
VSS	Digital and Analog common

4.5 Test Interface Group

TMS	JTAG test mode input or input digital port
TDO	JTAG data output
TDI	JTAG data input, or input digital port
TCK	JTAG test clock

5 DC Characteristics

5.1 Absolute Maximum Ratings

Symbol	Parameter	Min	Typ	Max	Condition
V _{DD1}	Supply Voltage	-0.3 V	-	3.6 V	Respect to VSS
V _{IA}	Analog Input Voltage	-0.3 V	-	1.98 V	Respect to VSS
V _{ID}	Digital Input Voltage	-0.3 V	-	3.6 V	Respect to VSS
T _A	Ambient Temperature	-40 °C	-	125 °C	
T _S	Storage Temperature	-65 °C	-	150 °C	

Table 2. Absolute Maximum Ratings

Caution: Stresses beyond those listed in “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only and function of the device at these or any other conditions beyond those indicated in the operational sections of the specifications are not implied.

5.2 System Clock Frequency and Power Consumption

V_{DD1}=3.3V, Unless specified, T_a = 25°C.

Symbol	Parameter	Min	Typ	Max	Unit
SYCLK	System Clock	-	100	-	MHz
P _D	Power Consumption		100 ¹⁾	-	mW
P _{STBY}	Standby Power Consumption		3.5		mW

Table 3. System Clock Frequency and Power Consumption

Note

1) The value is based on the condition of MCE clock=100MHz with an actual motor running by a typical TinyMCE application program.

5.3 Digital I/O DC Characteristics

Symbol	Parameter	Min	Typ	Max	Condition
V_{DD1}	Supply Voltage	3.0 V	3.3 V	3.6 V	Recommended
V_{IL}	Input Low Voltage	-	-	0.8 V	Recommended
V_{IH}	Input High Voltage	2.0 V		-	Recommended
C_{IN}	Input capacitance	-	1.6 pF	-	(1)
I_L	Input leakage current		± 10 nA	± 1 μ A	$V_O = 3.3$ V or 0 V
I_{OL}	Low level output current	14.1mA	22.9mA	31.8mA	$V_{OL} = 0.4$ V (1)
I_{OH}	High level output current	21.8mA	44.2mA	73.5mA	$V_{OH} = 2.4$ V (1)

Table 4. Digital I/O DC Characteristics

Note:

(1) Data guaranteed by design.

5.4 Analog I/O DC Characteristics

- OP amps for current sensing (IFB1+,IFB1-,IFB1O, IFB2+,IFB2-,IFB2O)

VDD1=3.3V, Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Condition
V _{OFFSET}	Input Offset Voltage	-20mV	3mV	20mV	V _{VDD1} = 3.3 V
V _I	Input Voltage Range	0 V		1.25 V	Recommended
V _{OUTSW}	OP amp output operating range	50 mV ⁽¹⁾	-	1.7 V	V _{VDD1} = 3.3 V
C _{IN}	Input capacitance	-	3.6 pF	-	
R _{FDBK}	OP amp feedback resistor	5 kΩ	-	20 kΩ	Requested between IFBO and IFB-
OP _{GAINCL}	Operating Open loop Gain	-	80 db	-	⁽¹⁾
CMRR	Common Mode Rejection Ratio	-	80 db	-	⁽¹⁾
I _{SRC}	Op amp output source current	-	1 mA	-	V _{OUT} = 0.6 V
I _{SNK}	Op amp output sink current	-	100 μA	-	V _{OUT} = 0.6 V

Table 5. Analog I/O DC Characteristics

Note:

(1) Data guaranteed by design.

5.5 A/D Accuracy and Linearity

Unless specified, Ta = 25°C.

A/D accuracy for current sensing (IFB1+,IFB1-,IFB1O, IFB2+,IFB2-,IFB2O), Vdc (AIN1) sensing and analog input channels (AIN0,AIN2, AIN3)

Symbol	Parameter	Min	Typ	Max	Condition
ADC _{error}	Error is the difference between ideal counts and compensated counts for any applied voltage in 0-1.2V range	0	±10Counts	±20counts	⁽¹⁾
ADCINL	Integral Non Linearity			±4 counts	⁽¹⁾ ⁽²⁾ Full 12bit range
ADCDNL	Differential Non Linearity			±1.4 counts	⁽¹⁾ ⁽²⁾ Full 12bit range

Table 5. A/D Accuracy

Note:

(1) Characterization only

(2) The value is based on the condition of MCE clock=100MHz with an actual motor running by a typical TinyMCE application program.

5.6 Under Voltage Lockout DC characteristics

Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Condition
UV _{CC3.3+}	UVcc positive going Threshold	2.55V	2.78V	3.00V	
UV _{CC3.3-}	UVcc negative going Threshold	2.40V	2.65V	2.85V	
UV _{CC3.3H}	UVcc Hysteresys	-	100mV	-	(1)

Table 6. UVcc 3.3V DC Characteristics

Note:

- (1) Data guaranteed by design.

5.7 Itrip comparator DC characteristics

Unless specified, VDD1=3.3V, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Condition
Itrip ₊	Itrip positive going Threshold	1.282V	1.342V	1.402V	V _{DD1} = 3.3 V, Ta=0-85C ⁽²⁾
Itrip ₋	Itrip negative going Threshold	1.05V	1.124V	1.25V	V _{DD1} = 3.3 V
ItripH	Itrip Hysteresys	0.05V	0.218V	0.3V	(1)

Table 7. Itrip DC Characteristics

Note:

- (1) Data guaranteed by design.
(2) Characterization only.

5.8 Wake-up threshold DC characteristics

Unless specified, VDD1=3.3V, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Condition
V _{WK}	Exit from Standby Threshold	0.285V	0.315V	0.345V	V _{DD1} = 3.3 V

Table 8. Wake-up threshold DC Characteristics

5.9 Integrated Temperature Sensor

Unless specified, VDD1=3.3V

Symbol	Parameter	Min	Typ	Max	Condition
T _{sense}	Integrated T _{sense} Error	-	±5°C	-	V _{DD1} = 3.3 V Ta = - 40°C, 25°C, 125°C

Table 8. Wake-up threshold DC Characteristics

6 AC Characteristics

6.1 Internal Oscillator AC Characteristics

Unless specified, $T_a = 25^\circ\text{C}$. $V_{DD1} = 3.3\text{V}$

Symbol	Parameter	Min	Typ	Max	Condition
F_{CLK}	Clock Frequency	99MHz	100.0MHz	101MHz	$T_a = -40\text{C} - 125\text{C}$
		95.8MHz ⁽¹⁾		104.4MHz ⁽¹⁾	

Note:

(1) Characterization only

Table 9. Internal Oscillator AC Characteristics

6.2 Analog to Digital Converter AC Characteristics

Unless specified, $T_a = 25^\circ\text{C}$.

Symbol	Parameter	Min	Typ	Max	Condition
T_{CONV}	Conversion time	-	-	2.05 μsec	⁽¹⁾
T_{HOLD}	Sample/Hold maximum hold time	-	-	10 μsec	Voltage droop ≤ 15 LSB (see figure below)

Table 10.A/D Converter AC Characteristics

Note:

(1) Data guaranteed by design.

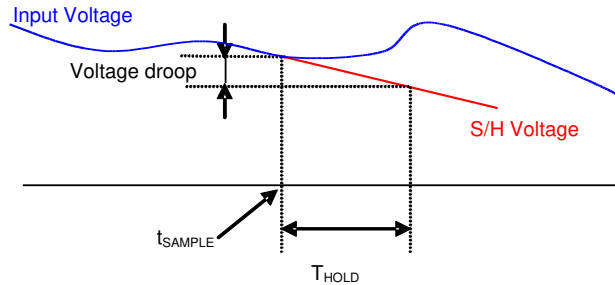


Figure 5. Voltage droop and S/H hold time

6.3 Op amp AC Characteristics

Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Condition
OP _{SR}	OP amp slew rate	-	10 V/μsec	-	VDD1 = 3.3 V, CL = 33 pF ⁽¹⁾
OP _{IMP}	OP input impedance	-	10 ⁸ Ω	-	⁽¹⁾ ⁽²⁾
T _{SET}	Settling time	-	400 ns	-	VDD1 = 3.3 V, CL = 33 pF ⁽¹⁾

Table 11 Current Sensing OP Amp AC Characteristics

Note:

- (1) Data guaranteed by design.
- (2) To guarantee stability of the operational amplifier, it is recommended to load the output pin by a capacitor of 100pF, see Figure 6. Here only the single shunt current amplifier is shown but all op amp outputs should be loaded with this capacitor value.

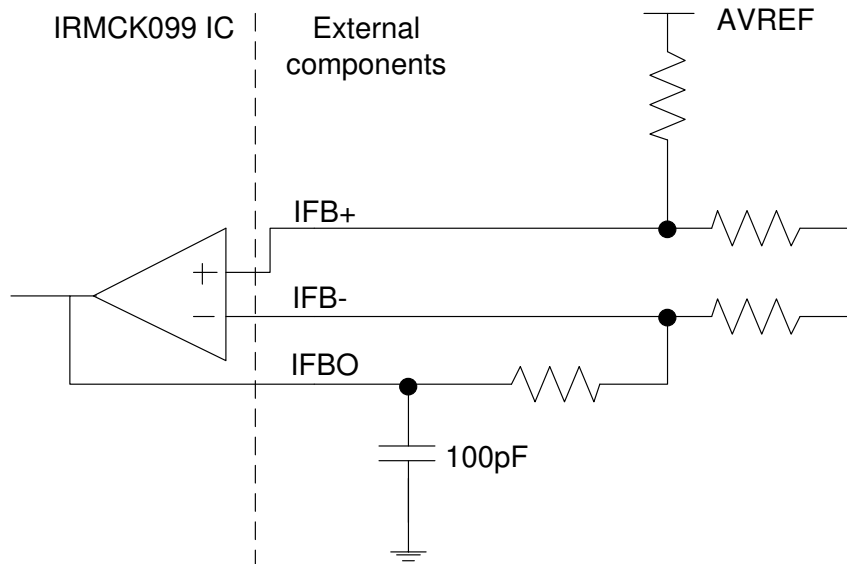


Figure 6. Op amp output capacitor

6.4 SYNC to SVPWM and A/D Conversion AC Timing

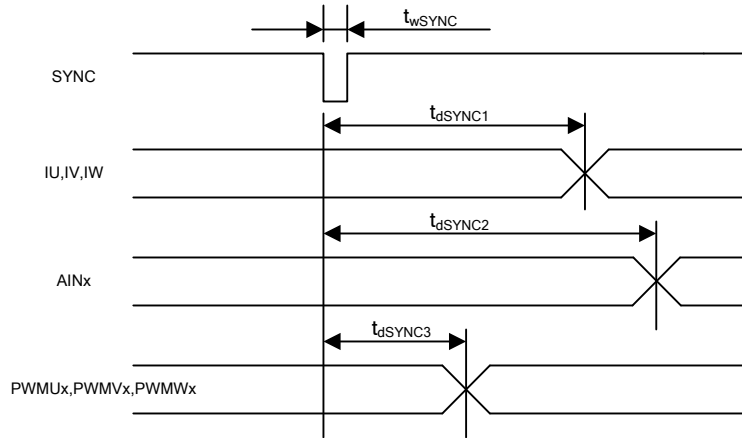


Figure 7. SYNC timing

Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Unit
t_{wSYNC}	SYNC pulse width	-	32	-	SYSCLK (1)
t_{dSYNC1}	SYNC to current feedback conversion time	-	-	100	
t_{dSYNC2}	SYNC to AIN0-3	-	-	200	
t_{dSYNC3}	SYNC to PWM output time	-	-	2	

Table 12. SYNC AC Characteristics

Note:

(1) Characterization only

6.5 FAULT to SVPWM AC Timing

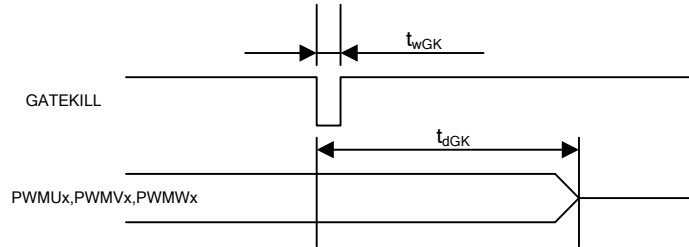


Figure 8. Fault timing

Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Unit
t _{wGK}	FAULT pulse width	32	-	-	SYCLK
t _{dGK}	FAULT to PWM output delay	-	-	100	SYCLK

Table 13. FAULT to SVPWM AC Timing

6.6 ITRIP AC Timing

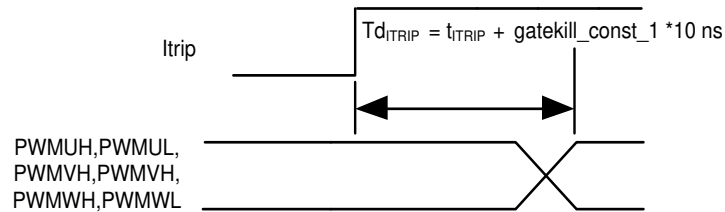


Figure 9. ITRIP timing

Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Unit
t _{ITRIP}	Itrip propagation delay	-	470ns	-	ns ⁽¹⁾

Table 14. Itrip AC Timing

Note:

(1) Characterization only

6.7 I²C AC Timing

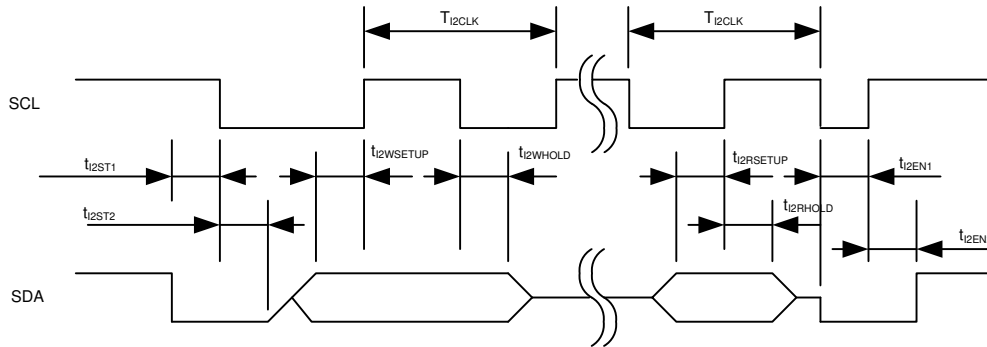


Figure 10. I²C Timing

Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Unit
T _{12CLK}	I ² C clock period	10	-	-	SYCLK
t _{12ST1}	I ² C SDA start time	0.25	-	-	T _{12CLK}
t _{12ST2}	I ² C SCL start time	0.25	-	-	T _{12CLK}
t _{12WSETUP}	I ² C write setup time	0.25	-	-	T _{12CLK}
t _{12WHOLD}	I ² C write hold time	0.25	-	-	T _{12CLK}
t _{12RSETUP}	I ² C read setup time	I ² C filter time ⁽¹⁾	-	-	SYCLK
t _{12RHOLD}	I ² C read hold time	1	-	-	SYCLK

Table 15. I²C AC Timing

Note:

(1) I²C read setup time is determined by the programmable filter time applied to I²C communication.

6.8 UART AC Timing

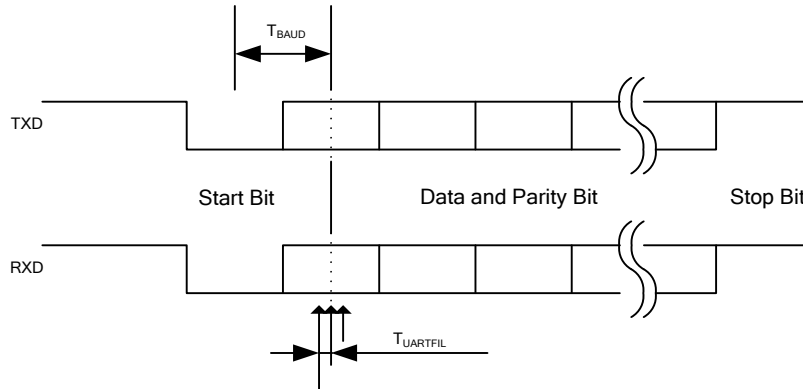


Figure 11. UART timing

Unless specified, $T_a = 25^\circ\text{C}$.

Symbol	Parameter	Min	Typ	Max	Unit
T_{BAUD}	Baud Rate Period	-	57600	-	bit/sec
T_{UARTFIL}	UART sampling filter period ⁽¹⁾	-	1/16	-	T_{BAUD}

Table 16. UART AC Timing

Note:

- (1) Each bit including start and stop bit is sampled three times at center of a bit at an interval of $1/16 T_{\text{BAUD}}$. If three sampled values do not agree, then UART noise error is generated.

6.9 CAPTURE Input AC Timing

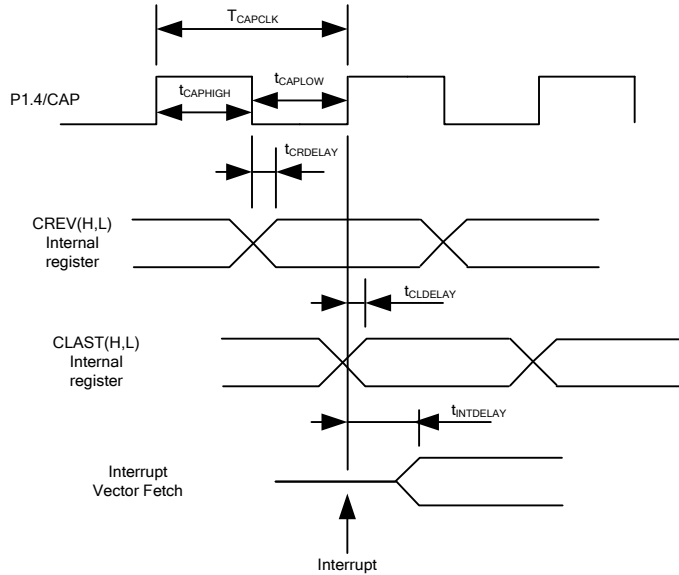


Figure 12. CAPTURE timing

Unless specified, $T_a = 25^\circ\text{C}$.

Symbol	Parameter	Min	Typ	Max	Unit
T_{CAPCLK}	CAPTURE input period	8	-	-	SYCLK
$t_{CAPHIGH}$	CAPTURE input high time	4	-	-	SYCLK
t_{CAPLOW}	CAPTURE input low time	4	-	-	SYCLK
$t_{CRDELAY}$	CAPTURE falling edge to capture register latch time	-	-	4	SYCLK
$t_{CLDELAY}$	CAPTURE rising edge to capture register latch time	-	-	4	SYCLK
$t_{INTDELAY}$	CAPTURE input interrupt latency time	-	-	4	SYCLK

Table 17. CAPTURE AC Timing

6.10 JTAG AC Timing

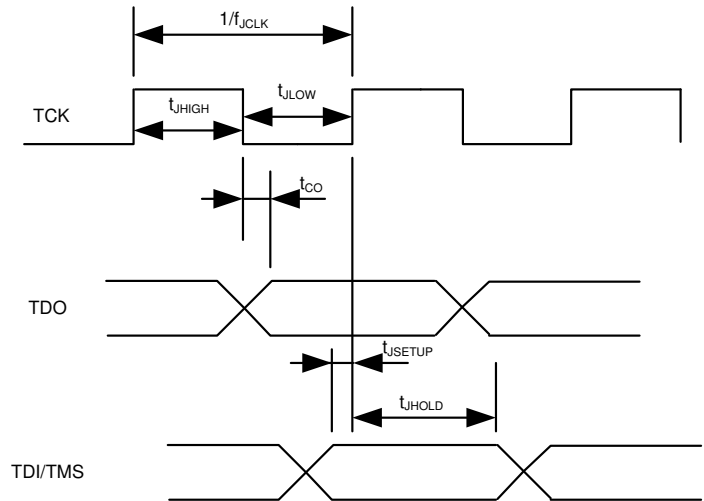


Figure 13. JTAG timing

Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Unit
f _{JCLK}	TCK Frequency	-	-	10	MHz
t _{JHIGH}	TCK High Period	10	-	-	nsec
t _{JLOW}	TCK Low Period	10	-	-	nsec
t _{CO}	TCK to TDO propagation delay time	0	-	5	nsec
t _{JSETUP}	TDI/TMS setup time	4	-	-	nsec
t _{JHOLD}	TDI/TMS hold time	0	-	-	nsec

Table 18. JTAG AC Timing

7 I/O Structure

The following figure shows the I/O structure for all digital pins. At power up, the programmable pull up transistor is off.

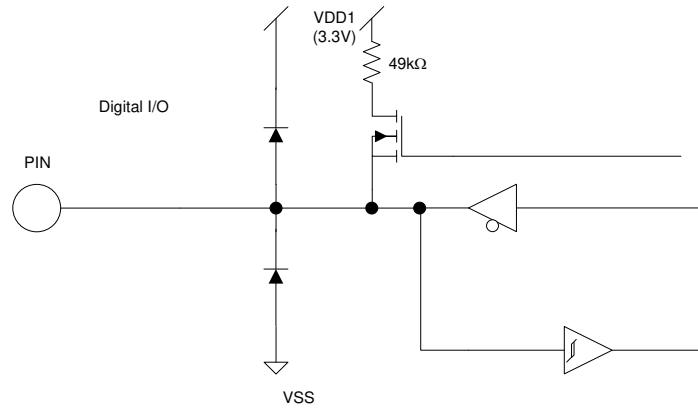


Figure 14. Digital I/O Structure

The following figure shows the analog input/output structure, except for AIN0/STBY.

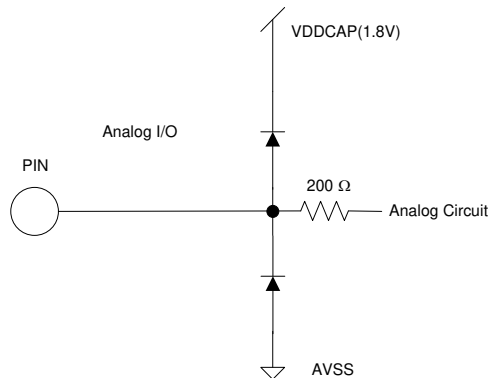


Figure 15. Analog I/O Structure

The following figure shows all the input structure for AIN0/STBY pin.

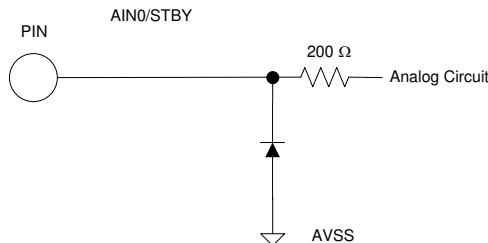


Figure 16 Analog Analog Input Structure for AIN0/STBY