

## High Performance Sensorless Motor Control IC

### Features

MCETM (Flexible Motion Control Engine) - Dedicated computation engine for high efficiency sinusoidal sensorless motor control

Built-in hardware peripheral for single or two shunt current feedback reconstruction and analog circuits

Supports induction machine and both interior and surface permanent magnet motor sensorless control

Loss minimization Space Vector PWM

Two-channel analog output (PWM)

Embedded 8-bit high speed microcontroller (8051) for flexible I/O and man-machine control

JTAG programming port for emulation/debugger

Serial communication interface (UART)

I2C/SPI serial interface

Three general purpose timers/counters

Two special timers: analog watchdog timer, periodic timer, capture timer

Internal 32Kbyte OTP ROM

5V tolerant I/O

3.3V single supply

### Product Summary

Maximum clock input ( $f_{crystal}$ )	60 MHz
Maximum Internal clock (SYSCLK)	128MHz
Maximum 8051 clock (8051CLK)	32MHz
Sensorless control computation time (max.)	48 $\mu$ sec
MCE™ computation data range	16 bit signed
8051 OTP Program ROM (min.)	20KB
805/MCE Data RAM	2KB
MCE Program RAM	12KB
PWM carrier frequency	20 bits/ SYSCLK
A/D input channels	4
A/D converter resolution	12 bits
A/D converter conversion speed	2 $\mu$ sec
Analog output (PWM) resolution	8 bits
UART baud rate (typ)	57.6K bps
Number of I/O (max)	7
Package	QFN 5x5 32L
Maximum 3.3V operating current	60mA

### Description

IRMCK182 is a high performance One Time Programmable ROM based motion control IC designed primarily for appliance applications. IRMCK182 is designed to achieve low cost yet high performance control solutions for advanced inverterized appliance motor control. IRMCK182 contains two computation engines. One is the Flexible Motion Control Engine (MCE™) for sensorless control of permanent magnet motors or induction motors; the other is an 8-bit high-speed microcontroller (8051). Both computation engines are integrated into one monolithic chip. The MCE™ contains a collection of control elements implemented in a dedicated computation engine such as Vector rotator, Arc-Tangent, Multiply/Divide, Low loss SVPWM and Motor current sensing. The user can program a motion control algorithm by connecting Control elements using a graphic compiler. Key components of the complex sensorless control algorithms, such as the Angle Estimator, are provided as complete pre-defined control blocks. The MCE and 8051 microcontroller communicate via dual port RAM for signal monitoring and command input. An advanced graphic compiler for the MCE™ is seamlessly integrated into the MATLAB/Simulink environment, while third party JTAG-based emulator tools are supported for 8051 software development including an OTP programmer.

Base Part Number	Package Type	Standard Pack	
		Form	Quantity
IRMCK182MTR	PQFN 5 mm x5 mm	Tape and Reel	3000
IRMCK182M	PQFN 5 mm x5 mm	Tray	624

**Table of Contents**

<b>1</b>	<b>Overview.....</b>	<b>6</b>
<b>2</b>	<b>Pinout .....</b>	<b>7</b>
<b>3</b>	<b>IRMCK182 Block Diagram and Main Functions .....</b>	<b>8</b>
<b>4</b>	<b>Application connection and Pin function .....</b>	<b>11</b>
4.1	<b>8051 Peripheral Interface Group.....</b>	<b>12</b>
4.2	<b>Motion Peripheral Interface Group.....</b>	<b>13</b>
4.3	<b>Analog Interface Group.....</b>	<b>13</b>
4.4	<b>Power Interface Group .....</b>	<b>13</b>
4.5	<b>Test Interface Group.....</b>	<b>14</b>
<b>5</b>	<b>DC Characteristics.....</b>	<b>15</b>
5.1	<b>Absolute Maximum Ratings.....</b>	<b>15</b>
5.2	<b>System Clock Frequency and Power Consumption .....</b>	<b>15</b>
5.3	<b>Digital I/O DC Characteristics .....</b>	<b>16</b>
5.4	<b>PLL and Oscillator DC characteristics.....</b>	<b>17</b>
5.5	<b>Analog I/O (IFBU+,IFBU-,IFBUO, IFBV+,IFBV-,IFBVO) DC Characteristics ....</b>	<b>17</b>
5.6	<b>Under Voltage Lockout DC characteristics .....</b>	<b>18</b>
5.7	<b>Itrip comparator DC characteristics.....</b>	<b>18</b>
<b>6</b>	<b>AC Characteristics.....</b>	<b>19</b>
6.1	<b>Digital PLL AC Characteristics .....</b>	<b>19</b>
6.2	<b>Analog to Digital Converter AC Characteristics .....</b>	<b>20</b>
6.3	<b>Op amp AC Characteristics .....</b>	<b>21</b>
6.4	<b>SYNC to SVPWM and A/D Conversion AC Timing.....</b>	<b>22</b>
6.5	<b>GATEKILL to SVPWM AC Timing .....</b>	<b>23</b>

6.6	Itrip AC Timing.....	23
6.7	UART AC Timing.....	24
6.8	CAPTURE Input AC Timing.....	25
6.9	OTP Programming Timing .....	26
6.10	JTAG AC Timing .....	27
7	I/O Structure.....	28
8	Pin List.....	31
9	Package Dimensions.....	33
10	Part Marking Information .....	33
11	Qualification Information .....	34

## List of Tables

Table 1 Absolute Maximum Ratings .....	15
Table 2 System Clock Frequency .....	15
Table 3 Digital I/O DC Characteristics .....	16
Table 4 PLL DC Characteristics .....	17
Table 5 Analog I/O DC Characteristics .....	17
Table 6 UVcc DC Characteristics .....	18
Table 7 Itrip DC Characteristics .....	18
Table 8 PLL AC Characteristics .....	19
Table 9 A/D Converter AC Characteristics .....	20
Table 10 Current Sensing OP Amp AC Characteristics .....	21
Table 11 SYNC AC Characteristics .....	22
Table 12 GATEKILL to SVPWM AC Timing .....	23
Table 13 Itrip AC Timing .....	23
Table 14 UART AC Timing .....	24
Table 15 CAPTURE AC Timing .....	25
Table 16 OTP Programming Timing .....	26
Table 17 JTAG AC Timing .....	27
Table 18 Pin List .....	32

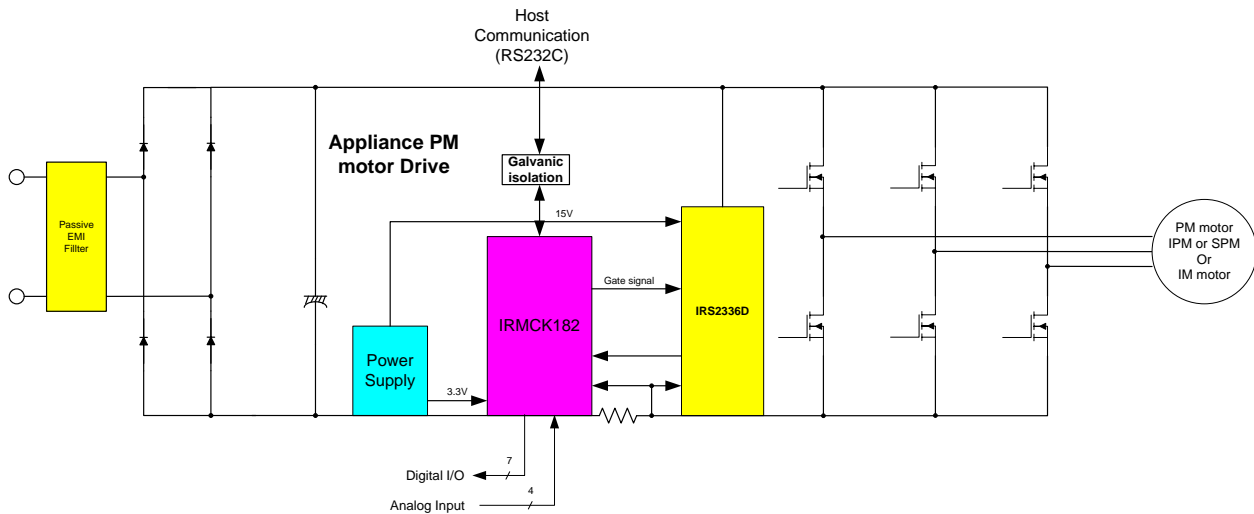
## List of Figures

Figure 1 Typical Application Block Diagram Using IRMCK182.....	6
Figure 2 Pinout of IRMCK182.....	7
Figure 3 Crystal circuit example .....	19
Figure 4 Voltage droop and S/H hold time.....	20
Figure 5 A capacitor of 47pF is recommended at the output pin of all op amps. ....	21
Figure 6 SYNC timing.....	22
Figure 7 Gatekill timing.....	23
Figure 8 ITRIP timing.....	23
Figure 9 UART timing .....	24
Figure 10 CAPTURE timing.....	25
Figure 11 OTP programming timing .....	26
Figure 12 JTAG timing.....	27
Figure 13 PWMUL/PWMUH/PWMVL/PWMVH/PWMWL/PMMWH output.....	28
Figure 14 All digital I/O except motor PWM output.....	28
Figure 15 RESET, GATEKILL I/O.....	29
Figure 16 Analog input.....	29
Figure 17 Analog operational amplifier output and AREF I/O structure .....	29
Figure 18 VPP programming pin I/O structure.....	30
Figure 19 VSS and AVSS pin structure .....	30
Figure 20 VDD1 and VDDCAP pin structure .....	30
Figure 21 XTAL0/XTAL1 pins structure .....	30

## 1 Overview

IRMCK182 is a new generation International Rectifier integrated circuit device primarily designed as a one-chip solution for complete inverter controlled appliance motor control applications. Unlike a traditional microcontroller or DSP, the IRMCK182 provides a built-in closed loop sensorless control algorithm using the unique flexible Motion Control Engine (MCE™) for permanent magnet motors as well as induction motors. The MCE™ consists of a collection of control elements, motion peripherals, a dedicated motion control sequencer and dual port RAM to map internal signal nodes. IRMCK182 also employs a unique single shunt current reconstruction circuit in addition to two leg shunt current sensing circuit to eliminate additional analog/digital circuitry and enables a direct shunt resistor interface to the IC. Motion control programming is achieved using a dedicated graphical compiler integrated into the MATLAB/Simulink™ development environment. Sequencing, user interface, host communication, and upper layer control tasks can be implemented in the 8051 high-speed 8-bit microcontroller. The 8051 microcontroller is equipped with a JTAG port to facilitate emulation and debugging tools. Figure 1 shows a typical application schematic using the IRMCK182.

IRMCK182 contains 32K bytes of OTP program ROM, and comes in a 32-pin QFN package.



**Figure 1 Typical Application Block Diagram Using IRMCK182**

## 2 Pinout

Pin out shown is based on QFN 5x5 32 pin package.

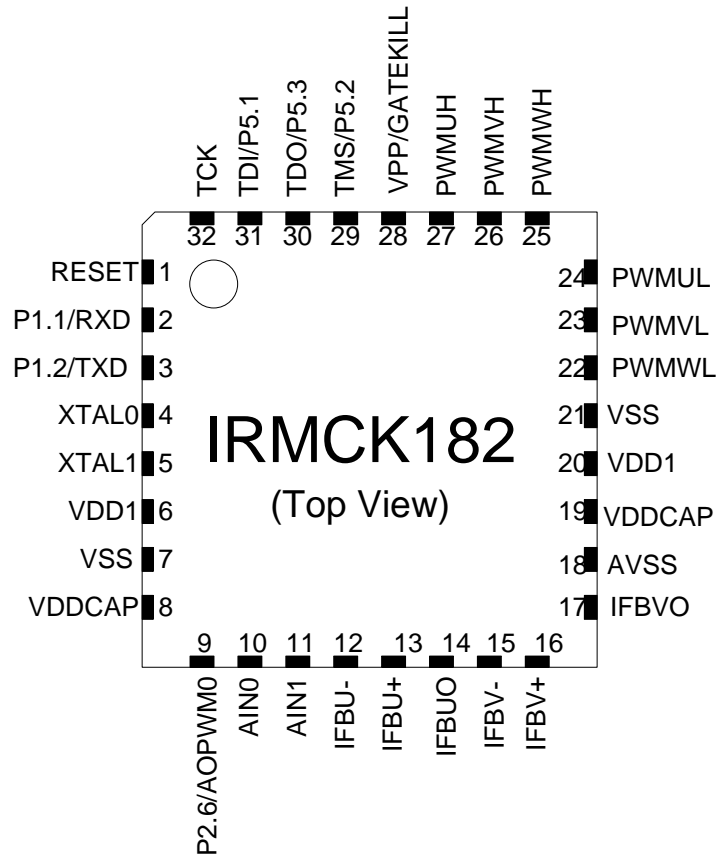
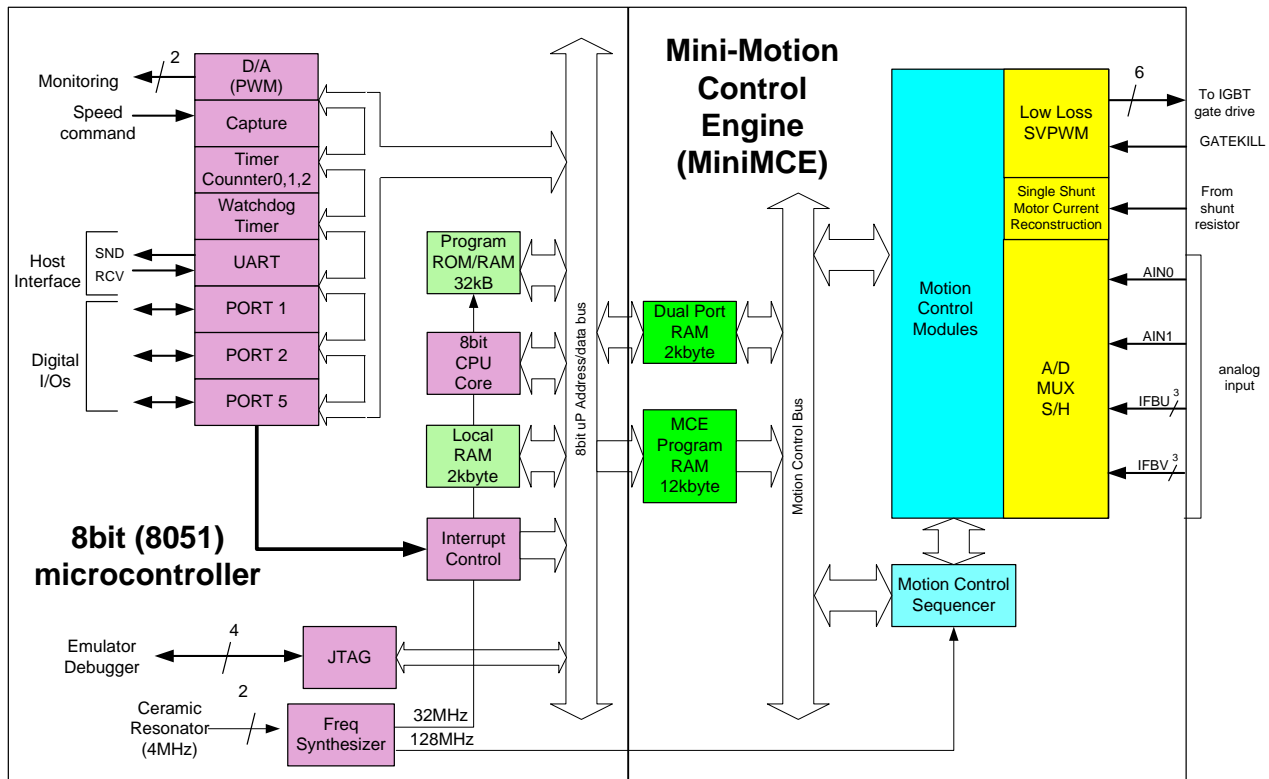


Figure 2 Pinout of IRMCK182

### 3 IRMCK182 Block Diagram and Main Functions

IRMCK182 block diagram is shown in Figure 3.



**Figure 3 IRMCK182 Block Diagram**

IRMCK182 contains the following functions for sensorless AC motor control applications:

- Motion Control Engine (MCE™)
  - Sensorless FOC (complete sensorless field oriented control)
  - Proportional plus Integral block
  - Low pass filter
  - Differentiator and lag (high pass filter)
  - Ramp
  - Limit



- Angle estimate (sensorless control)
- Inverse Clark transformation
- Vector rotator
- Bit latch
- Peak detect
- Transition
- Multiply-divide (signed and unsigned)
- Divide (signed and unsigned)
- Adder
- Subtractor
- Comparator
- Counter
- Accumulator
- Switch
- Shift
- ATAN (arc tangent)
- Function block (any curve fitting, nonlinear function)
- 16 bit wide Logic operations (AND, OR, XOR, NOT, NEGATE)
- MCE™ program memory and dual port RAM (max 12K+2k byte)
- MCE™ control sequencer
- 8051 microcontroller
  - Two 16 bit timer/counters
  - One 16 bit periodic timer
  - One 16 bit watchdog timer
  - One 16 bit capture timer
  - Up to 7 discrete I/Os
  - 4 channel 12 bit A/D

- Buffered (current sensing) two channels (0 – 1.2V input)
- Unbuffered two channels (0 – 1.2V input)
- JTAG port (4 pins)
- Up to three channels of analog output (8 bit PWM)
- UART
- 32K byte OTP program ROM
- 2K byte data RAM

## 4 Application connection and Pin function

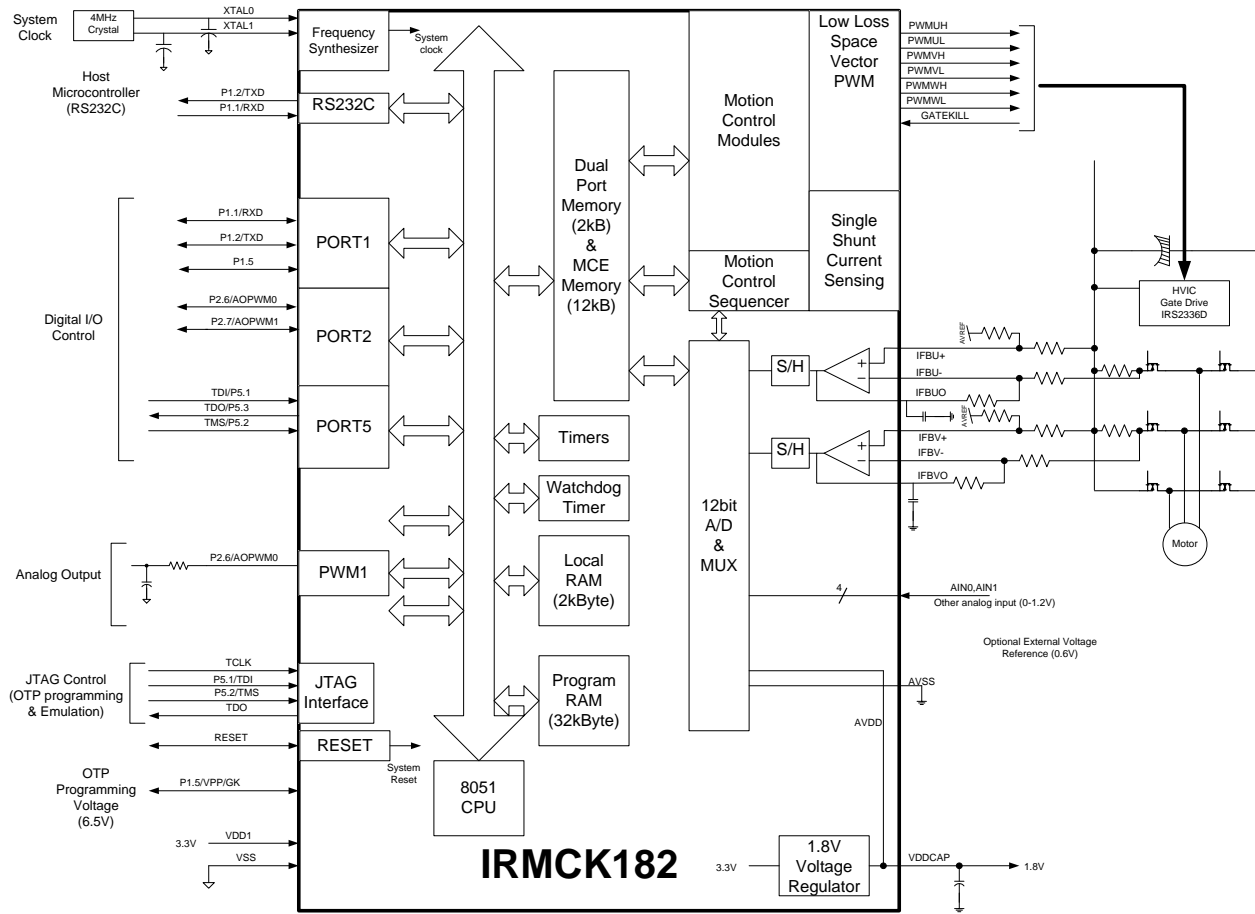


Figure 4 IRMCK182 Connection Diagram

## 4.1 8051 Peripheral Interface Group

### UART Interface

P1.2/TXD	Output, Transmit data from IRMCK182
P1.1/RXD	Input, Receive data to IRMCK182

### Discrete I/O Interface

P1.1/RXD	Input/output port 1.1, can be configured as RXD input
P1.2/TXD	Input/output port 1.2, can be configured as TXD output
VPP/GK	OTP programming voltage, or GATEKILL input
P2.6/AOPWM0	Input/output port 2.6, can be configured as AOPWM0 output
P2.7/AOPWM1	Input/output port 2.7, can be configured as AOPWM1 output
P5.1/TDI	Input port 5.1, configured as JTAG port by default
P5.2/TMS	Input port 5.2, configured as JTAG port by default

### Analog Output Interface

P2.6/AOPWM0	Input/output, can be configured as 8-bit PWM output 0 with programmable carrier frequency
P2.7/AOPWM1	Input/output, can be configured as 8-bit PWM output 1 with programmable carrier frequency

### Crystal Interface

XTAL0	Input, connected to crystal
XTAL1	Output, connected to crystal

### Reset Interface

RESET	Input and Output, system reset, doesn't require external RC time constant
-------	---

## 4.2 Motion Peripheral Interface Group

### PWM

PWMUH	Output, PWM phase U high side gate signal, internally pulled down by 58k $\Omega$
PWMUL	Output, PWM phase U low side gate signal, internally pulled down by 58k $\Omega$
PWMVH	Output, PWM phase V high side gate signal, internally pulled down by 58k $\Omega$
PWMVL	Output, PWM phase V low side gate signal, internally pulled down by 58k $\Omega$
PWMWH	Output, PWM phase W high side gate signal, internally pulled down by 58k $\Omega$
PWMWL	Output, PWM phase W low side gate signal, internally pulled down by 58k $\Omega$

### Fault

GATEKILL	Input, upon assertion, this negates all six PWM signals, active low, internally pulled up by 70k $\Omega$
----------	---

## 4.3 Analog Interface Group

AVSS	Analog power return, (analog internal 1.8V power is shared with VDDCAP)
IFBU+	Input, Operational amplifier positive input for single or U-phase leg shunt resistor current sensing
IFBU-	Input, Operational amplifier negative input for single or U-phase leg shunt resistor current sensing
IFBUO	Output, Operational amplifier output for single or U-phase leg shunt resistor current sensing
IFBV+	Input, Operational amplifier positive input for V-phase leg shunt resistor current sensing
IFBV-	Input, Operational amplifier negative input for V-phase leg shunt resistor current sensing
IFBVO	Output, Operational amplifier output for V-phase leg shunt resistor current sensing
AIN0	Input, Analog input channel 0 (0 – 1.2V), typically configured for DC bus voltage input
AIN1	Input, Analog input channel 1 (0 – 1.2V), needs to be pulled down to AVSS if unused

## 4.4 Power Interface Group

VDD1	Digital power (3.3V)
VDDCAP	Internal 1.8V output, requires capacitors to the pin. Shared with analog power pad internally <b>Note:</b> 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 common

## 4.5 Test Interface Group

P5.2/TMS	JTAG test mode input or input/output digital port
TDO	JTAG data output
P5.1/TDI	JTAG data input, or input/output digital port
TCK	JTAG test clock

## 5 DC Characteristics

### 5.1 Absolute Maximum Ratings

Symbol	Parameter	Min	Typ	Max	Condition
V <sub>DD1</sub>	Supply Voltage	-0.3 V	-	3.6 V	Respect to VSS
V <sub>IA</sub>	Analog Input Voltage	-0.3 V	-	1.98 V	Respect to AVSS
V <sub>ID</sub>	Digital Input Voltage	-0.3 V	-	6.0 V	Respect to VSS
V <sub>PP</sub>	OTP Programming voltage	-0.3V	-	7.0V	Respect to VSS
T <sub>A</sub>	Ambient Temperature	-40 °C	-	85 °C	
T <sub>S</sub>	Storage Temperature	-65 °C	-	150 °C	

Table 1 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

C<sub>AREF</sub> = 1nF, C<sub>MEXT</sub> = 100nF. VDD1=3.3V, Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Unit
SYCLK	System Clock	32	-	128	MHz
P <sub>D</sub>	Power consumption		160 <sup>1)</sup>	200	mW

Table 2 System Clock Frequency

Note 1) The value is based on the condition of MCE clock=126MHz, 8051 clock 31.5MHz with a actual motor running by a typical MCE application program and 8051 code.

### 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
$V_{PP}$	OTP Programming voltage	6.70V	6.75V	6.80V	Recommended
$V_{IL}$	Input Low Voltage	-0.3 V	-	0.8 V	Recommended
$V_{IH}$	Input High Voltage	2.0 V		3.6 V	Recommended
$C_{IN}$	Input capacitance	-	3.6 pF	-	<sup>(1)</sup>
$I_L$	Input leakage current		$\pm 10$ nA	$\pm 1$ $\mu$ A	$V_O = 3.3$ V or 0 V
$I_{OL2}^{(2)}$	Low level output current	17.9 mA	26.3 mA	33.4 mA	$V_{OL} = 0.4$ V <sup>(1)</sup>
$I_{OH2}^{(2)}$	High level output current	24.6 mA	49.5 mA	81 mA	$V_{OH} = 2.4$ V <sup>(1)</sup>

Table 3 Digital I/O DC Characteristics

Note:

- (1) Data guaranteed by design.
- (2) Applied to all digital I/O pins.



## 5.4 PLL and Oscillator DC characteristics

$C_{AREF} = 1nF$ ,  $C_{MEXT} = 100nF$ .  $V_{DD1} = 3.3V$ , Unless specified,  $T_a = 25^\circ C$ .

Symbol	Parameter	Min	Typ	Max	Condition
$V_{IL\ OSC}$	Oscillator (XTAL0,1) Input Low Voltage	0	-	$0.2 * V_{DDCAP}$	$V_{DDCAP}$ = voltage at VDDCAP pin
$V_{IH\ OSC}$	Oscillator (XTAL0,1) Input High Voltage	$0.8 * V_{DDCAP}$	-	$V_{DDCAP}$	$V_{DDCAP}$ = voltage at VDDCAP pin

Table 4 PLL DC Characteristics

## 5.5 Analog I/O (IFBU+,IFBU-,IFBUO, IFBV+,IFBV-,IFBVO) DC Characteristics

$C_{AREF} = 1nF$ ,  $C_{MEXT} = 100nF$ .  $V_{DD1} = 3.3V$ , Unless specified,  $T_a = 25^\circ C$ .

Symbol	Parameter	Min	Typ	Max	Condition
$V_{OFFSET}$	Input Offset Voltage	-	-	26 mV	
$V_I$	Input Voltage Range	0 V		1.2 V	Recommended
$V_{OUTSW}$	OP amp output operating range	50 mV (1)	-	1.2 V	
$C_{IN}$	Input capacitance	-	3.6 pF	-	(1)
$R_{FDBK}$	OP amp feedback resistor	5 k $\Omega$	-	20 k $\Omega$	Requested between IFBO and IFB-
$OP_{GAINCL}$	Operating Close loop Gain	80 db	-	-	(1)
CMRR	Common Mode Rejection Ratio	-	80 db	-	(1)
$I_{SRC}$	Op amp output source current	-	1 mA	-	$V_{OUT} = 0.6 V$ (1)
$I_{SNK}$	Op amp output sink current	-	100 $\mu A$	-	$V_{OUT} = 0.6 V$ (1)

Table 5 Analog I/O DC Characteristics

Note:

(1) Data guaranteed by design.

## 5.6 Under Voltage Lockout DC characteristics

Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Condition
UV <sub>CC+</sub>	UV <sub>CC</sub> positive going Threshold	2.78 V	3.04 V	3.23 V	(1)
UV <sub>CC-</sub>	UV <sub>CC</sub> negative going Threshold	2.78 V	2.97 V	3.23 V	
UV <sub>CCH</sub>	UV <sub>CC</sub> Hysteresys	-	73 mV	-	(1)

**Table 6 UV<sub>CC</sub> 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 <sub>+</sub>	Itrip positive going Threshold	-	1.22V	-	
Itrip <sub>-</sub>	Itrip negative going Threshold	-	1.10V	-	
ItripH	Itrip Hysteresys	-	120mV	-	

**Table 7 Itrip DC Characteristics**

## 6 AC Characteristics

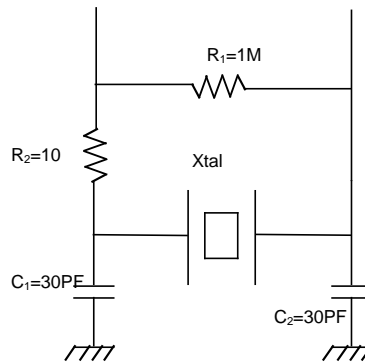
### 6.1 Digital PLL AC Characteristics

Symbol	Parameter	Min	Typ	Max	Condition
F <sub>CLKIN</sub>	Crystal input frequency	3.2 MHz	4 MHz	60 MHz	<sup>(1)</sup> (see figure below)
F <sub>PLL</sub>	Internal clock frequency	32 MHz	50 MHz	128 MHz	<sup>(1)</sup>
F <sub>LWPPW</sub>	Sleep mode output frequency	F <sub>CLKIN</sub> ÷ 256	-	-	<sup>(1)</sup>
J <sub>S</sub>	Short time jitter	-	200 psec	-	<sup>(1)</sup>
D	Duty cycle	-	50 %	-	<sup>(1)</sup>
T <sub>LOCK</sub>	PLL lock time	-	-	500 μsec	<sup>(1)</sup>

**Table 8 PLL AC Characteristics**

Note:

(1) Data guaranteed by design.



**Figure 3 Crystal circuit example**

## 6.2 Analog to Digital Converter AC Characteristics

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

Symbol	Parameter	Min	Typ	Max	Condition
$T_{\text{CONV}}$	Conversion time	-	-	2.05 $\mu\text{sec}$	(1)
$T_{\text{HOLD}}$	Sample/Hold maximum hold time	-	-	10 $\mu\text{sec}$	Voltage droop $\leq 15$ LSB (see figure below)

Table 9 A/D Converter AC Characteristics

Note:

(1) Data guaranteed by design.

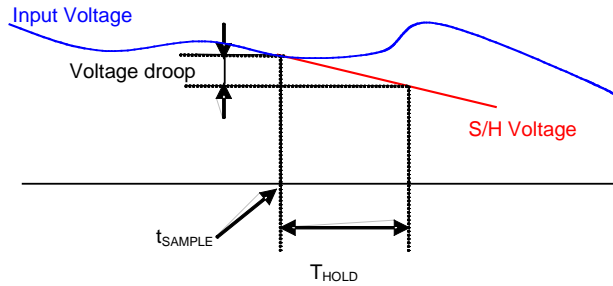


Figure 4 Voltage droop and S/H hold time

### 6.3 Op amp AC Characteristics

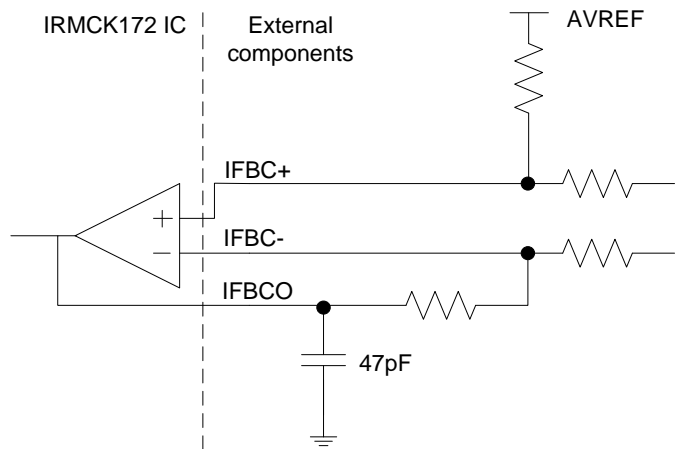
Unless specified, Ta = 25°C.

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

**Table 10 Current Sensing OP Amp AC Characteristics**

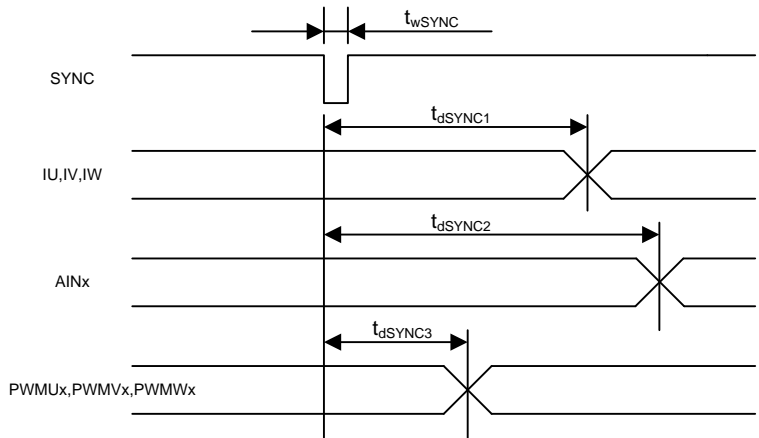
Note:

- (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 47pF, see Figure 5. Here only the single shunt current amplifier is show but all op amp outputs should be loaded with this capacitor.



**Figure 5 A capacitor of 47pF is recommended at the output pin of all op amps.**

### 6.4 SYNC to SVPWM and A/D Conversion AC Timing



**Figure 6 SYNC timing**

Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Unit
$t_{wSYNC}$	SYNC pulse width	-	32	-	SYSClk
$t_{dSYNC1}$	SYNC to current feedback conversion time	-	-	100	SYSClk
$t_{dSYNC2}$	SYNC to AIN0-5 analog input conversion time	-	-	200	SYSClk <sup>(1)</sup>
$t_{dSYNC3}$	SYNC to PWM output delay time	-	-	2	SYSClk

**Table 11 SYNC AC Characteristics**

Note:

(1) AIN1 through AIN5 channels are converted once every 6 SYNC events

### 6.5 GATEKILL to SVPWM AC Timing

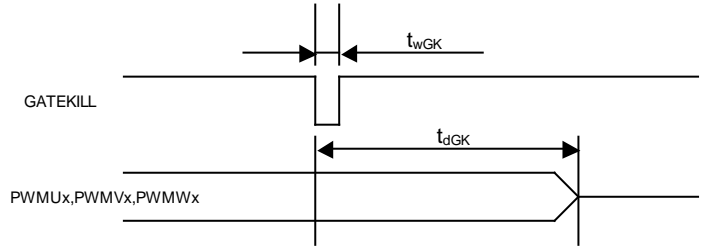


Figure 7 Gatekill timing

Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Unit
t <sub>wGK</sub>	GATEKILL pulse width	32	-	-	SYSClk
t <sub>dGK</sub>	GATEKILL to PWM output delay	-	-	100	SYSClk

Table 12 GATEKILL to SVPWM AC Timing

### 6.6 Itrip AC Timing

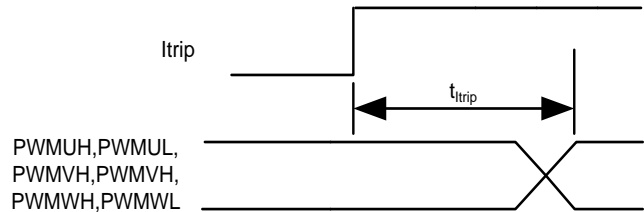


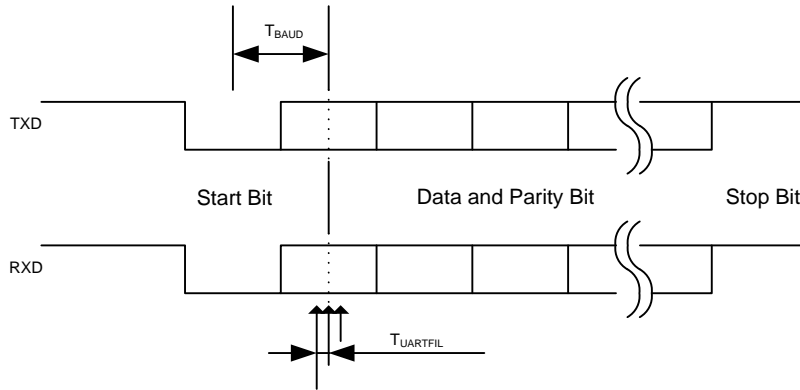
Figure 8 ITRIP timing

Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Unit
t <sub>TRIP</sub>	Itrip propagation delay	-	-	100(sysclk)+1.0usec	SYSClk+usec

Table 13 Itrip AC Timing

## 6.7 UART AC Timing



**Figure 9 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 <sup>(1)</sup>	-	1/16	-	$T_{BAUD}$

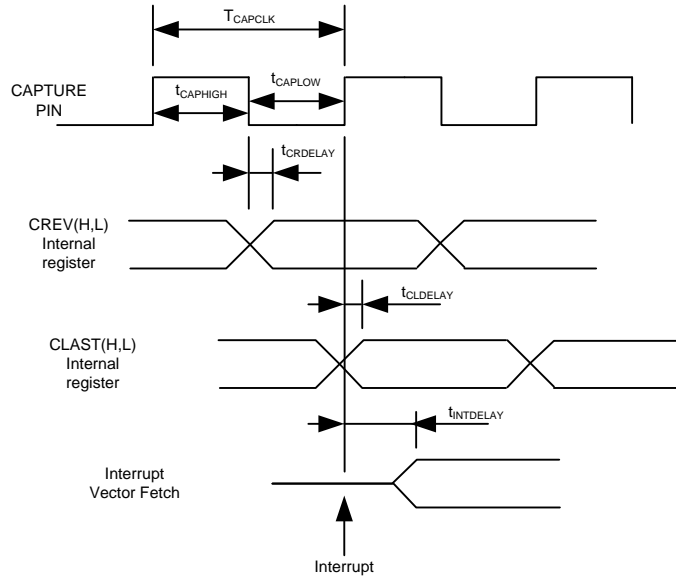
**Table 14 UART AC Timing**

Note:

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



### 6.8 CAPTURE Input AC Timing



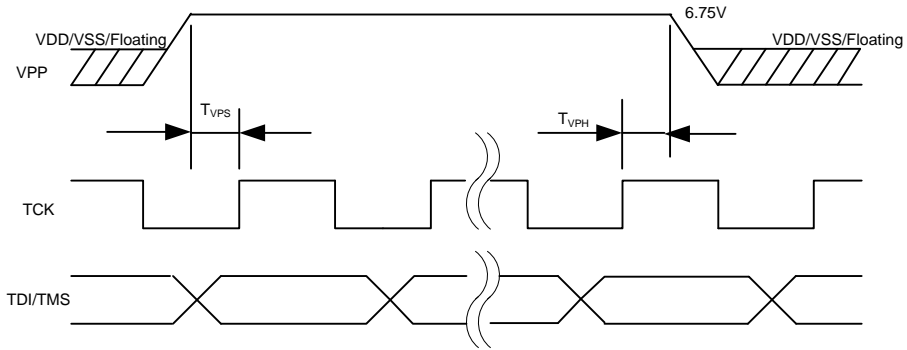
**Figure 10 CAPTURE timing**

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 15 CAPTURE AC Timing**

## 6.9 OTP Programming Timing



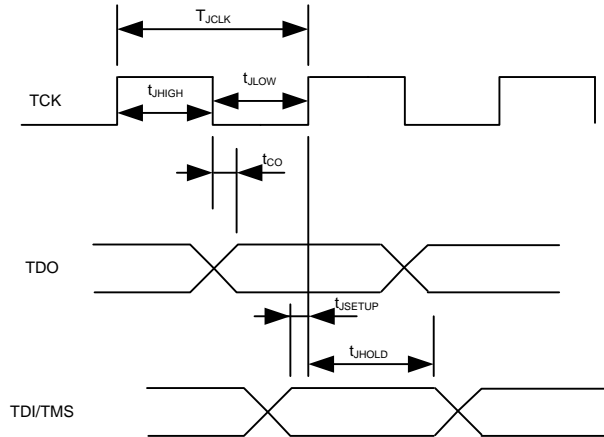
**Figure 11 OTP programming timing**

Unless specified, Ta = 25°C.

Symbol	Parameter	Min	Typ	Max	Unit
T <sub>VPS</sub>	VPP Setup Time	10	-	-	nsec
T <sub>VPH</sub>	VPP Hold Time	15	-	-	nsec

**Table 16 OTP Programming Timing**

### 6.10 JTAG AC Timing



**Figure 12 JTAG timing**

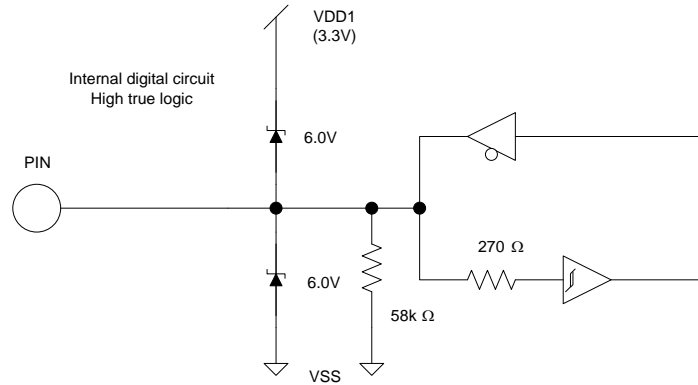
Unless specified,  $T_a = 25^\circ\text{C}$ .

Symbol	Parameter	Min	Typ	Max	Unit
$T_{JCLK}$	TCK Period	-	-	50	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 17 JTAG AC Timing**

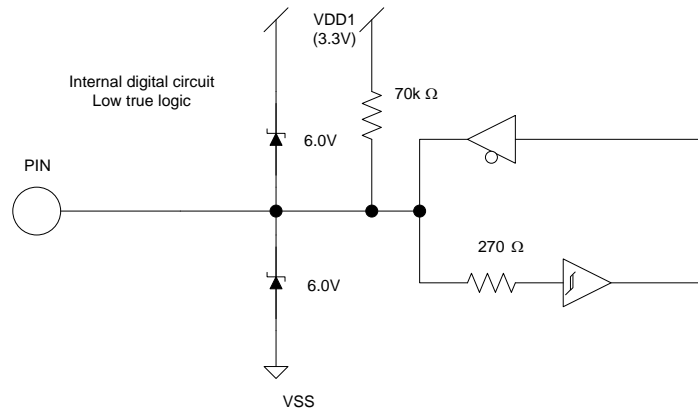
## 7 I/O Structure

The following figure shows the motor PWM output (PWMUH/PWMUL/PWMVH/PWMVL/PWMWH/PWMWL)



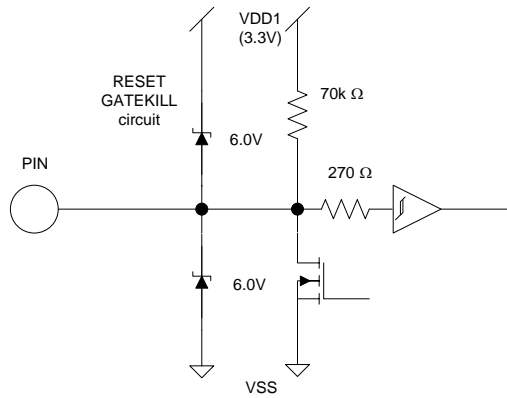
**Figure 13 PWMUL/PWMUH/PWMVL/PWMVH/PWMWL/PWMWH output**

The following figure shows the digital I/O structure except the motor PWM output



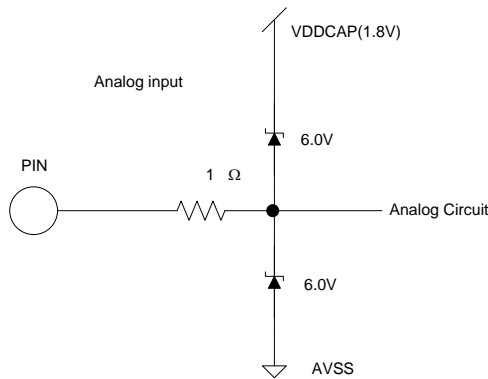
**Figure 14 All digital I/O except motor PWM output**

The following figure shows RESET and GATEKILL I/O structure.



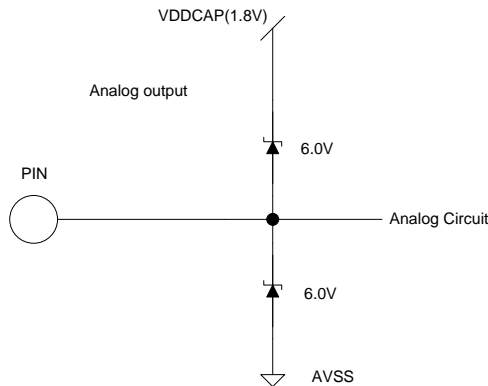
**Figure 15 RESET, GATEKILL I/O**

The following figure shows the analog input structure.



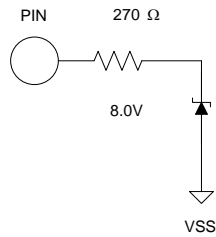
**Figure 16 Analog input**

The following figure shows all analog operational amplifier output pins and AREF pin I/O structure.



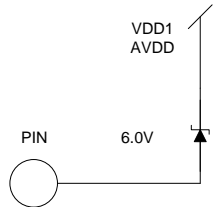
**Figure 17 Analog operational amplifier output and AREF I/O structure**

The following figure shows the VPP pin structure



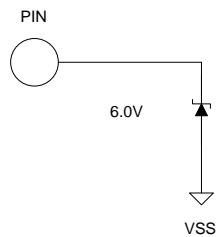
**Figure 18 VPP programming pin I/O structure**

The following figure shows the VSS and AVSS pins structure



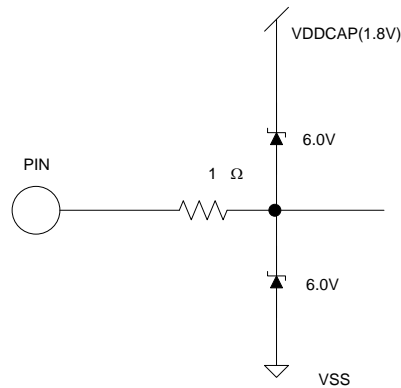
**Figure 19 VSS and AVSS pin structure**

The following figure shows the VDD1 and VDDCAP pin structure



**Figure 20 VDD1 and VDDCAP pin structure**

The following figure shows the XTAL0 and XTAL1 pins structure



**Figure 21 XTAL0/XTAL1 pins structure**

## 8 Pin List

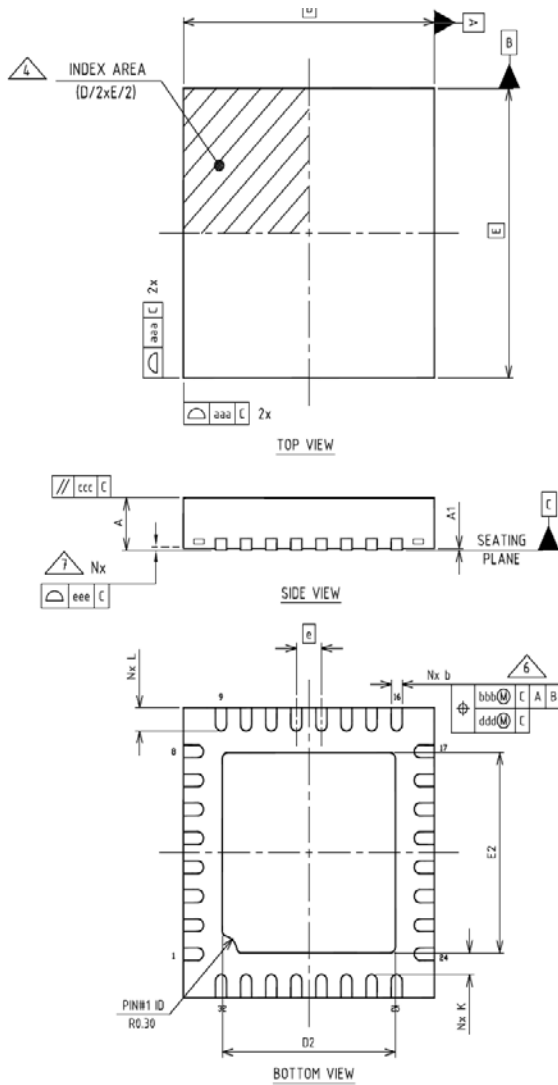
Pin Number	Pin Name	Internal Pull-up /Pull-down	Pin Type	Description
1	RESET		I/O	Reset, low true, Schmitt trigger input
2	P1.1/RXD		I/O	UART receiver input or Discrete programmable I/O
3	P1.2/TXD		I/O	UART transmitter output or Discrete programmable I/O
4	XTAL0		I	Crystal input
5	XTAL1		O	Crystal output
6	VDD1		P	3.3V digital power
7	VSS		P	Digital common
8	VDDCAP		P	Internal 1.8V output, Capacitor(s) to be connected
9	P2.6/AOPWM0		I/O	Discrete programmable I/O or PWM 0 digital output
10	AIN0		I	Analog input channel 0, 0-1.2V range, needs to be pulled down to AVSS if unused
11	AIN1		I	Analog input channel 1, 0-1.2V range, needs to be pulled down to AVSS if unused
12	IFBU-		I	Single or U-phase leg shunt current sensing OP amp input (-)
13	IFBU+		I	Single or U-phase leg shunt current sensing OP amp input (+)
14	IFBUO		O	Single or U-phase leg shunt current sensing OP amp output
15	IFBV-		I	Single or V-phase leg shunt current sensing OP amp input (-)
16	IFBV+		I	Single or V-phase leg shunt current sensing OP amp input (+)
17	IFBVO		O	Single or V-phase leg shunt current sensing OP amp output
18	AVSS		P	Analog ground
19	VDDCAP		P	Internal 1.8V output, Capacitor(s) to be connected
20	VDD1		P	3.3V digital power
21	VSS		P	Digital common
22	PWMWL	58 kΩ Pull down	O	PWM gate drive for phase W low side, configurable either high or low true.
23	PWMVL	58 kΩ Pull down	O	PWM gate drive for phase V low side, configurable either high or low true
24	PWMUL	58 kΩ Pull down	O	PWM gate drive for phase U low side, configurable either high or low true
25	PWMWH	58 kΩ Pull down	O	PWM gate drive for phase W high side, configurable either high or low true

Pin Number	Pin Name	Internal Pull-up /Pull-down	Pin Type	Description
26	PWMVH	58 k $\Omega$ Pull down	O	PWM gate drive for phase V high side, configurable either high or low true
27	PWMUH	58 k $\Omega$ Pull down	O	PWM gate drive for phase U high side, configurable either high or low true
28	VPP/GK		I/O P	OTP programming power (6.5V) and PWM shutdown input
29	TMS/P5.2		I/O	JTAG test mode select or Discrete I/O
30	TDO/P5.3		O	JTAG test data output
31	TDI/P5.1		I/O	JTAG test data input or Discrete I/O
32	TCK		I	JTAG test clock

**Table 18 Pin List**



## 9 Package Dimensions



Dimension Table				
Thickness Symbol	W : Very Very Thin			NOTE
	MINIMUM	NOMINAL	MAXIMUM	
A	0.70	0.75	0.80	
A1	0.00	0.02	0.05	
b	0.18	0.25	0.30	6
D	5.00 BSC			
E	5.00 BSC			
e	0.50 BSC			
D2	3.30	3.45	3.55	
E2	3.30	3.45	3.55	
K	0.20	---	---	
L	0.30	0.40	0.50	
aaa	0.05			
bbb	0.10			
ccc	0.10			
ddd	0.05			
eee	0.08			
N	32			3
ND	8			5
NE	8			5
NOTES	1, 2			
LF PART NO.	437727			
LF DWG. NO.	CARSEM-06257			
REV.	A			

**NOTE:**

1. Dimensioning and tolerancing conform to ASME Y14.5-2009.

2. All dimensions are in millimeters.

3. N is the total number of terminals.

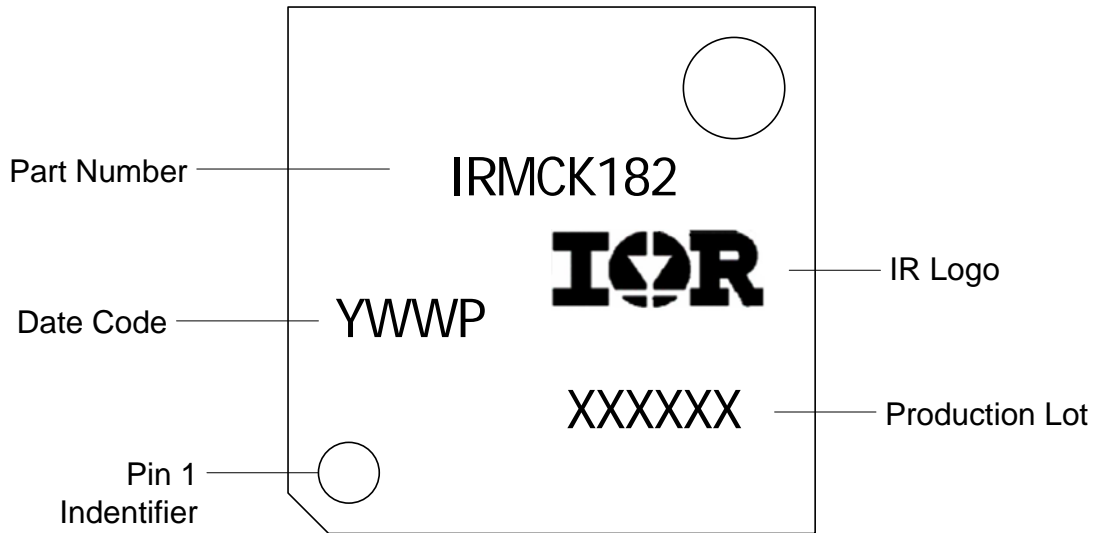
4. The location of the marked terminal #1 identifier is within the hatched area.

5. ND and NE refer to the number of terminals on D and E side respectively.

6. Dimension b applies to the metallized terminal and is measured between 0.15mm and 0.30mm from the terminal tip. If the terminal has a radius on the other end of it, dimension b should not be measured in that radius area.

7. Coplanarity applies to the terminals and all other bottom surface metallization.

## 10 Part Marking Information



## 11 Qualification Information

<b>Qualification Level</b>		Industrial <sup>††</sup> (per JEDEC JESD 47E)
<b>Moisture Sensitivity Level</b>		MSL2 <sup>†††</sup> (per IPC/JEDEC J-STD-020C)
<b>ESD</b>	<b>Machine Model</b>	Class B (per JEDEC standard JESD22-A114D)
	<b>Human Body Model</b>	Class 2 (per EIA/JEDEC standard EIA/JESD22-A115-A)
<b>RoHS Compliant</b>		Yes

† Qualification standards can be found at International Rectifier's web site <http://www.irf.com/>

†† Higher qualification ratings may be available should the user have such requirements. Please contact your International Rectifier sales representative for further information.

††† Higher MSL ratings may be available for the specific package types listed here. Please contact your International Rectifier sales representative for further information.

**Note:** Test condition for Temperature Cycling test is -40C to 125C.



# International Rectifier

IR WORLD HEADQUARTERS: 233 Kansas St., El Segundo, California 90245, Tel: (310) 252-7105  
<http://www.irf.com> *Data and specifications subject to change without notice. 6/16/2006*

*Sales Offices, Agents and Distributors in Major Cities Throughout the World.*