IMM100T - iMOTION™ IPM for motor control

Fully integrated high-performance turnkey motor control system

IMM100T

Features

- Motion Control Engine (MCE) as a ready-to-use control solution for variable speed drives
- Integrated script engine for application control customization
- Integrated drive and system protection features
- Field oriented control (FOC) for permanent magnet synchronous motor (PMSM)
- Flexible space vector PWM for sinusoidal voltage control
- Current sensing via single or leg shunt
- Sensorless operation
- Hall sensor operation using analog or digital Hall
- Integrated analog comparators for over-current protection
- Built-in temperature sensor
- Power factor correction (PFC) control (optional)
- Flexible control input options: UART, Frequency, duty cycle or analog signal
- Certified drive safety functions according to IEC/UL 60730-1 'Class B'
- High voltage three phase gate driver with 600 V blocking voltage
- 15 V supply voltage for gate driver
- Integrated boot strap diode structure
- Isolation 1500 V_{RMS} 1 min
- 3.3 V or 5.0 V controller supply voltage
- 3 different power MOSFET options: 6 Ω/500 V, 1.4 Ω/650 V and 0.95 Ω/650 V
- Very compact 12 x 12 mm PQFN package

Potential applications

- Small and major home appliances
- Fans, Pumps, Compressors
- General purpose variable speed drives

Product validation

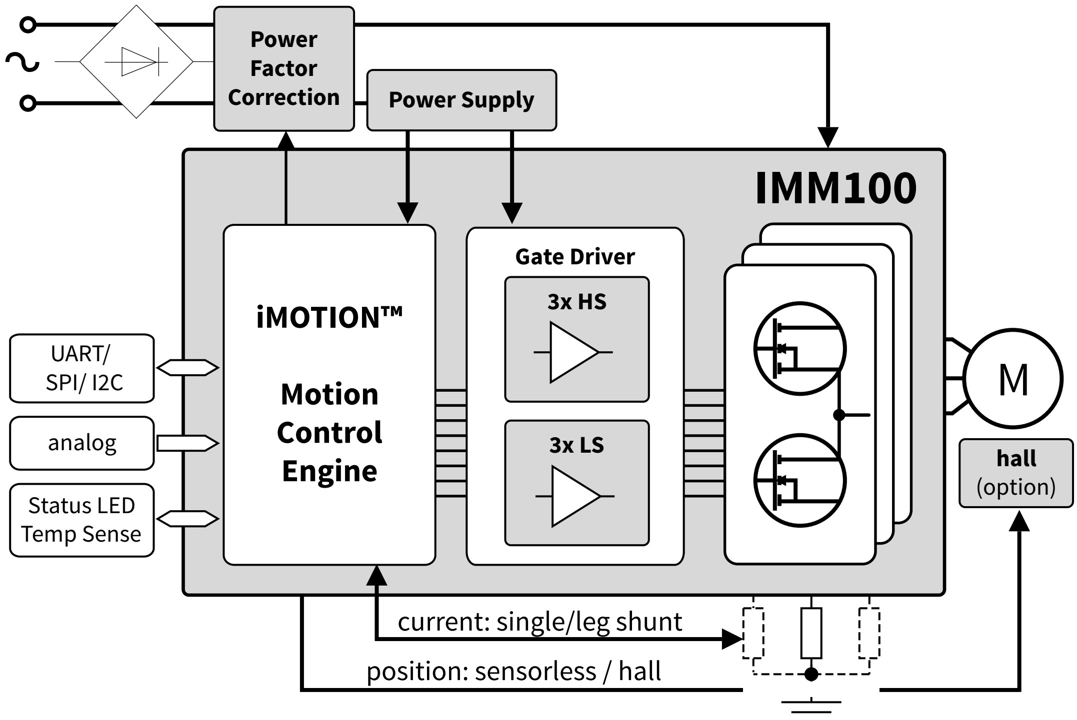
Qualified for industrial applications according to the relevant tests of JEDEC47/20/22.

Description

IMM100T devices belong to IMM100 series of iMOTION™ IPMs. IMM100T is a family of fully-integrated, turnkey high-voltage motor drive modules designed for high-performance, high-efficiency PMSM/BLDC motor drive applications such as fans, pumps and small compressors.

IMM100T integrates the motor controller, a 3-phase high-voltage, rugged gate driver with integrated bootstrap functionality and either 500 V FredFET or 650 V CoolMOS™ MOSFETs. Depending on the MOSFETs employed in the package, IMM100T covers applications with a rated output power from 25 W to 80 W with 500 V or 600 V maximum DC voltage. It uses a compact 12 x 12 mm^2 surface-mount package which minimizes external components count and PCB area and features a 1.3 mm creepage distance between the high-voltage pads to increase the robustness of the system.

The motor controller uses the Motion Control Engine (MCE) to create a ready-to-use solution to perform control of a permanent magnet synchronous motor (PMSM) and an optional power factor correction (PFC) providing the shortest time to market for any motor system at the lowest system and development cost. The integrated script engine allows to add application flexibility without interfering with the motor control algorithm.



Ordering information

Product type	Application	Output rating
IMM101T-015M	Single motor control	500 V/1 A
IMM101T-046M	Single motor control	600 V/4 A
IMM101T-056M	Single motor control	600 V/4 A (optimized for low-frequency operation)
IMM102T-015M	Single motor control + boost PFC	500 V/1 A
IMM102T-046M	Single motor control + boost PFC	600 V/4 A
IMM102T-056M	Single motor control + boost PFC	600 V/4 A (optimized for low-frequency operation)

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1 Block diagram reference

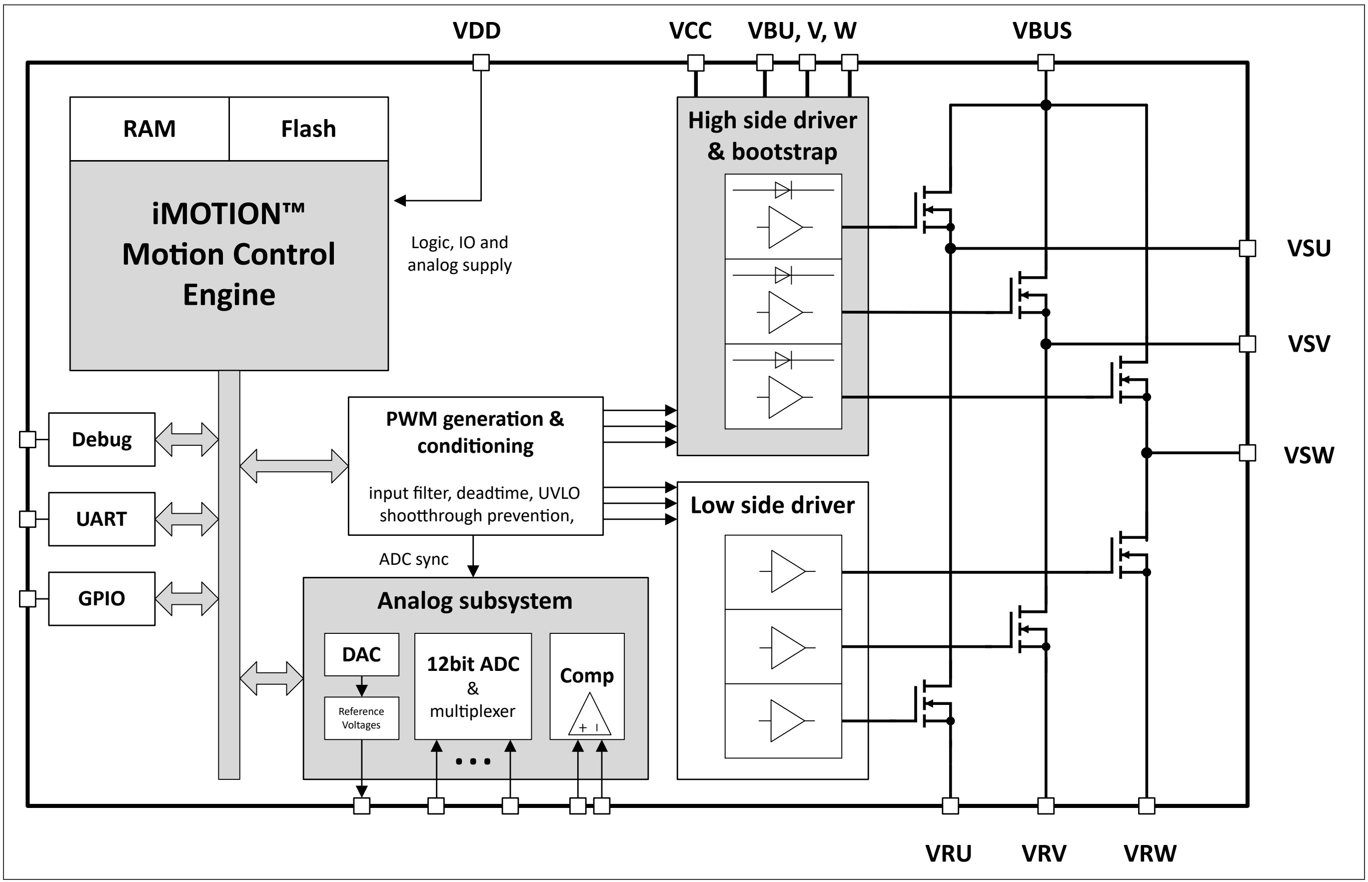

Figure 1 **Block diagram reference**

2 Pin types and pad structure

The pin type is specified as follows:

- P - power
- I - digital input
- O - digital output
- IO – digital input or output
- AIN - analog input
- AO - analog output

Figure 2 shows the pad structure and pin function control configuration for the input and output pins of the controller integrated.

The pin function, type and pull up/pull down circuit configuration are all controlled by the Motion Control Engine. Digital input, output or analog input signals that are not assigned to MCE functions can be assigned to the script engine.The gate driver outputs are controlled by MCE PWM signals internally connected to the gate driver inputs.

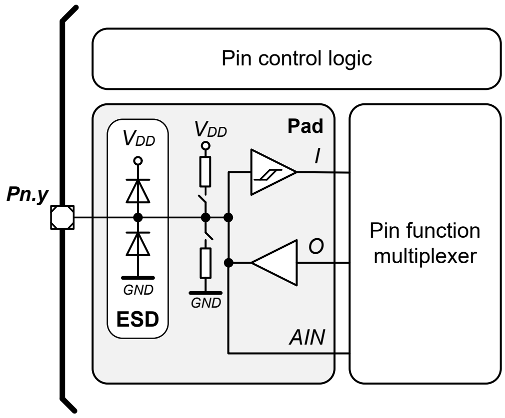

Figure 2 Pin Pad and Function Configuration

The pin function table given below refers to the standard configuration. The pin control or interface functions are defined by the version of software downloaded to the device and may change. Some of the input pins can be configured to have pull up or pull down resistor and some output pins can be configured to push-pull or open drain. This is described in the respective software reference manual.

Pins can serve multiple functions and have to be configured accordingly. Please also refer to the respective pin configuration drawings in this data sheet and the description in the MCE software reference manual.

Pins that do not have any signal assigned are reserved for future use. These pins should be left unconnected and neither be connected to ground nor to the positive supply.

Note: All required reference voltages are generated by an internal DAC, therefore the AO pins like IREF, REFU, REFV, and REFW only require a blocking capacitor.

2.1 Pin Configuration IMM101T

Table 1 Pin definitions and functions IMM101T series – single motor control – typical configuration

Pin	Name	Type	Description
1	*VBUS* scaled	AIN	Vbus scaled ADC input
2	*CREF*	I/O	Analog overcurrent comparator threshold DAC
3	*VDD*	P	Digital V_{DD} input [3.3 V – 5.0 V]
4	*GPIO1*/ TROUT0	I/O	Digital input --- analog and digital output /TRIAC control
5	*VCC*	P	15 V gate driver power supply input
6	*VSS1*	P	Gate driver power ground, connect externally via PCB to pin 36
7	*VBV*	P	V phase bootstrap capacitor positive
8	*VBW*	P	W phase bootstrap capacitor positive
9,10	*VSU*	P	U phase output
11,12	*VRU*	P	Leg U return – low-side MOS source
13,14	*VRV*	P	Leg V return – low-side MOS source
15,16, 40	*VSV*	P	V phase output and V phase bootstrap capacitor negative
17,18,19	*VSW*	P	W phase output and W phase bootstrap capacitor negative
20,21	*VRW*	P	Leg W return – low-side MOS source
22~29	*VBUS*	P	DC bus voltage
30, 39	*VSU*	P	U phase bootstrap capacitor negative
31	*VBU*	P	U phase bootstrap capacitor positive
32	*RX0*/ SCL/ IR0	IO	Serial port receive input / I2C/ IR
33	*TX0*/ SDA	IO	Serial port transmit output/ I2C
34	*VSP*/ IR2	I	Analog voltage set point input/ IR
35	*IW* (or *H0*)	AIN	Analog current sense input phase W or Hall 0 input
36,41	*VSS2*	P	Signal ground --- Connect externally via PCB to pin 6
37	*IV* (or *H1*)/ TRIN0	I	Analog current sense input phase V or Hall 1 input/ TRIAC control
38	*ISS* or *IU*	AIN	Analog current sense input phase U or single shunt

2.2 Pin Configuration IMM102T

Table 2 Pin definitions and functions IMM102T series – single motor + PFC – typical configuration

Pin	Name	Type	Description
1	*VBUS* scaled	AIN	Vbus scaled ADC input
2	*CREF*	I/O	Analog overcurrent comparator threshold DAC
3	*VDD*	P	Digital V_{DD} input [3.3 V – 5.0 V]
4	*PFCG*	O	PWM output to PFC gate driver
5	*VCC*	P	15 V gate driver power supply input
6	*VSS1*	P	Gate driver power ground, connect externally via PCB to pin 36
7	*VBV*	P	V phase bootstrap capacitor positive
8	*VBW*	P	W phase bootstrap capacitor positive
9,10	*VSU*	P	U phase output
11,12	*VRU*	P	Leg U return – low-side MOS source
13,14	*VRV*	P	Leg V return – low-side MOS source
15,16, 40	*VSV*	P	V phase output and V phase bootstrap capacitor negative
17,18,19	*VSW*	P	W phase output and W phase bootstrap capacitor negative
20,21	*VRW*	P	Leg W return – low-side MOS source
22~29	*VBUS*	P	DC bus voltage
30, 39	*VSU*	P	U phase bootstrap capacitor negative
31	*VBU*	P	U phase bootstrap capacitor positive
32	*RX0*/ SCL/IR0	IO	Serial port receive input / I2C/ IR
33	*TX0*/ SDA	IO	Serial port transmit output/ I2C
34	*VAC+*	AIN	Vac input ac+ voltage sensing through resistor external divider
35	*VAC-*	AIN	Vac input ac- voltage sensing through resistor external divider
36,41	*VSS2*	P	Signal ground --- Connect externally via PCB to pin 6
37	*IPFC*	AIN	Analog current sense input PFC
38	*ISS*	AIN	Analog current sense input single shunt

2.3 Pin configuration drawing

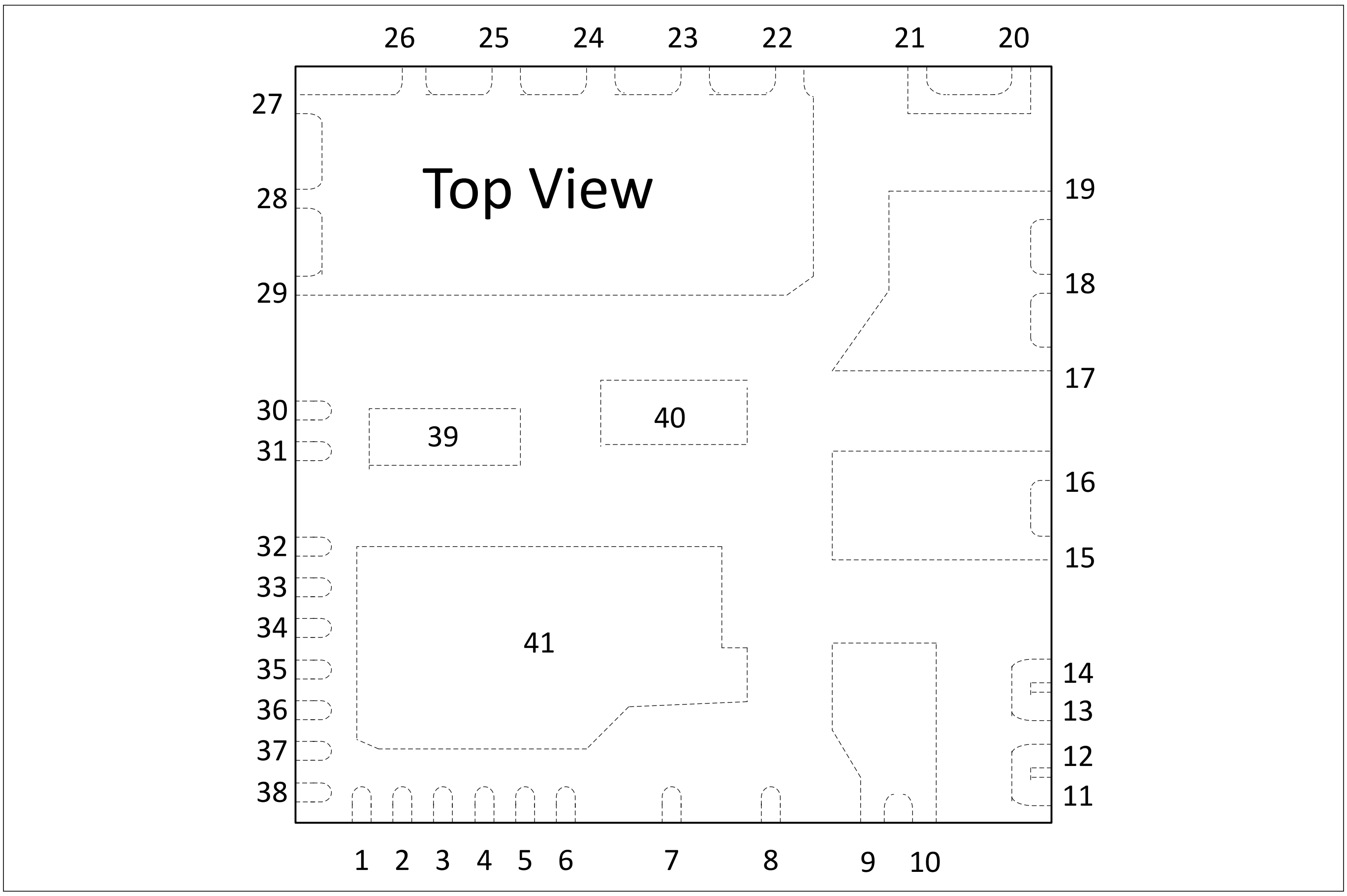

Figure 3 **Pin assignment**

Note: Pins 39 and 40 are not required to be connected electrically on the PCB but are recommended to be soldered for mechanical stability.

3 Functional description

3.1 Overview

The IMM100 modules integrate a controller, a high-voltage three-phase gate driver and six MOSFETs into a single compact package. The high-voltage level shifting function with boot strap diode function is integrated into the gate driver IC. The power stage is built with six low-loss 500 V power FET or 650 V CoolMOS™ MOSFETs which form a three phase inverter circuit.

3.2 Motion Control Engine

iMOTION™ IMM100T use the latest generation of the Motion Control Engine (MCE). The MCE is a ready-to-use solution for variable speed drives and contains all control functions to perform closed loop control of a three phase motor. Optionally, control of a power factor correction (PFC) is provided running in parallel to the motor.

Multiple configurable protections like over- and under-voltage, over current or rotor lock are integrated protecting the power stage as well as the motor itself.

iMOTION™ IMM100T supports the use in applications requiring functional safety according to IEC/UL 60730-1 (‘Class B’)

Using the MCE does not require any software development. Instead the MCE is configured for the concrete power stage configuration and motor type using PC based tools. Following parameter creation the behavior of the motor control loop can be monitored and fine tuned in real time. The respective tools are available for download from the iMOTION™ web pages.

For improved application flexibility the MCE contains a scripting engine running user scripts in the background task. Writing, downloading and monitoring scripts is supported by the above mentioned tools.

The MCE is driven by an internal temperature compensated oscillator that supports peripheral operation at 96 MHz and data processing at 48 MHz.

This data sheet provides all electrical, mechanical, thermal and quality parameters of the IMM100T. A more detailed description of the features and functionality of the MCE can be found in the respective reference manual. The MCE software images are made available for download from the Infineon web site. A special secure boot algorithm assures that these MCE software images can only be installed onto the matching hardware derivative, i.e. the product variant for which the software has been tested for.

3.3 Gate driver function

3.3.1 Features and protections

The 3-phase high-voltage gate driver integrated in IMM100T is based on 600 V high-voltage junction isolation technology . It integrates a boot strap bootFET structure, so only external bootstrap capacitors are needed outside the module for bootstrap functionality. The driver output impedance is designed to meet an optimal dv/dt for EMI and switching loss trade offs. It is designed for 5 to 6 V/nsec at a rated current condition. The driver employs the anti-shoot-through protection, the integrated bootstrap function for high-side floating supplies, the low standby power and the under voltage lockout protection function for V_{CC} and high-side V_{BS} supplies. The under voltage lockout for V_{CC} is reported as latched fault at pin *RFE*, and the *RFE* pin is connected to *GK* pin of the controller.

3.3.2 Block diagram

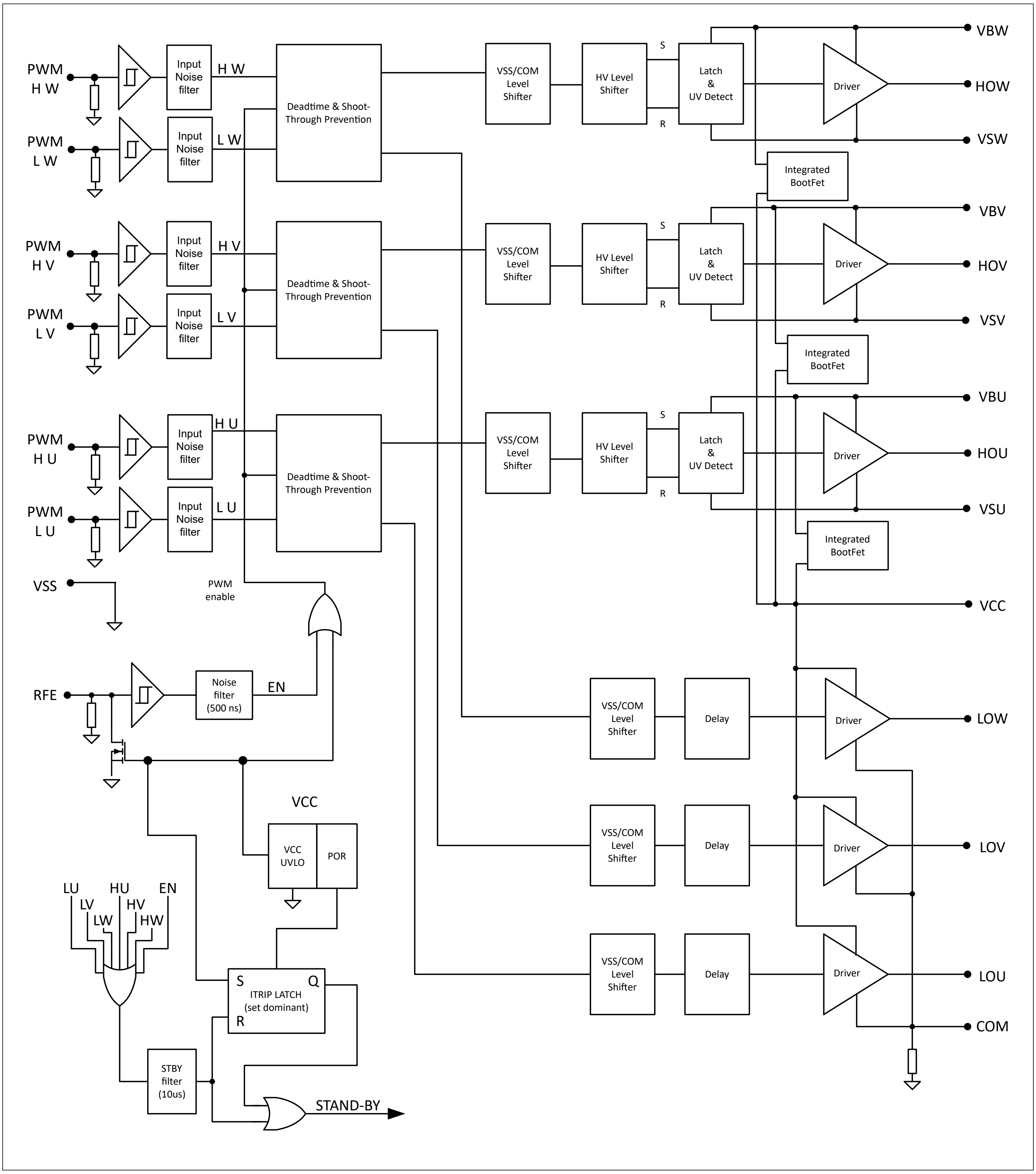

Figure 4 Block diagram of gate driver function

3.3.3 I/O structure

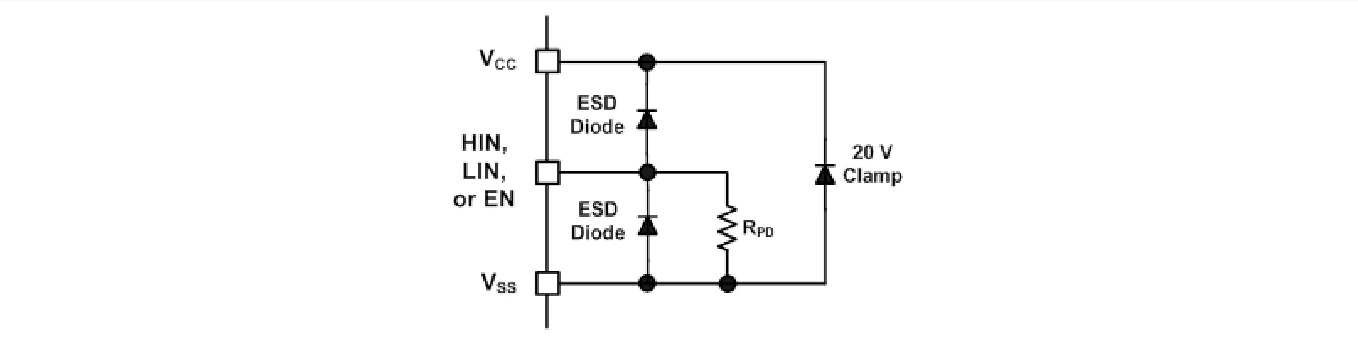

Figure 5 V_{CC} **pin I/O gate driver structure**

3.4 MOSFETs

The IMM100 modules are available in three different MOSFET power stage options.

- 6 Ohm 500 V trench MOSFETs in version IMM10xx-015
- 1.4 Ohm 650 V CoolMOS™ in version IMM10xx-046 (600 V maximum voltage is defined by gate driver technology)
- 0.95 Ohm 650 V CoolMOS™ in version IMM10xx-056 (600 V maximum voltage is defined by gate driver technology)

3.5 Application diagrams

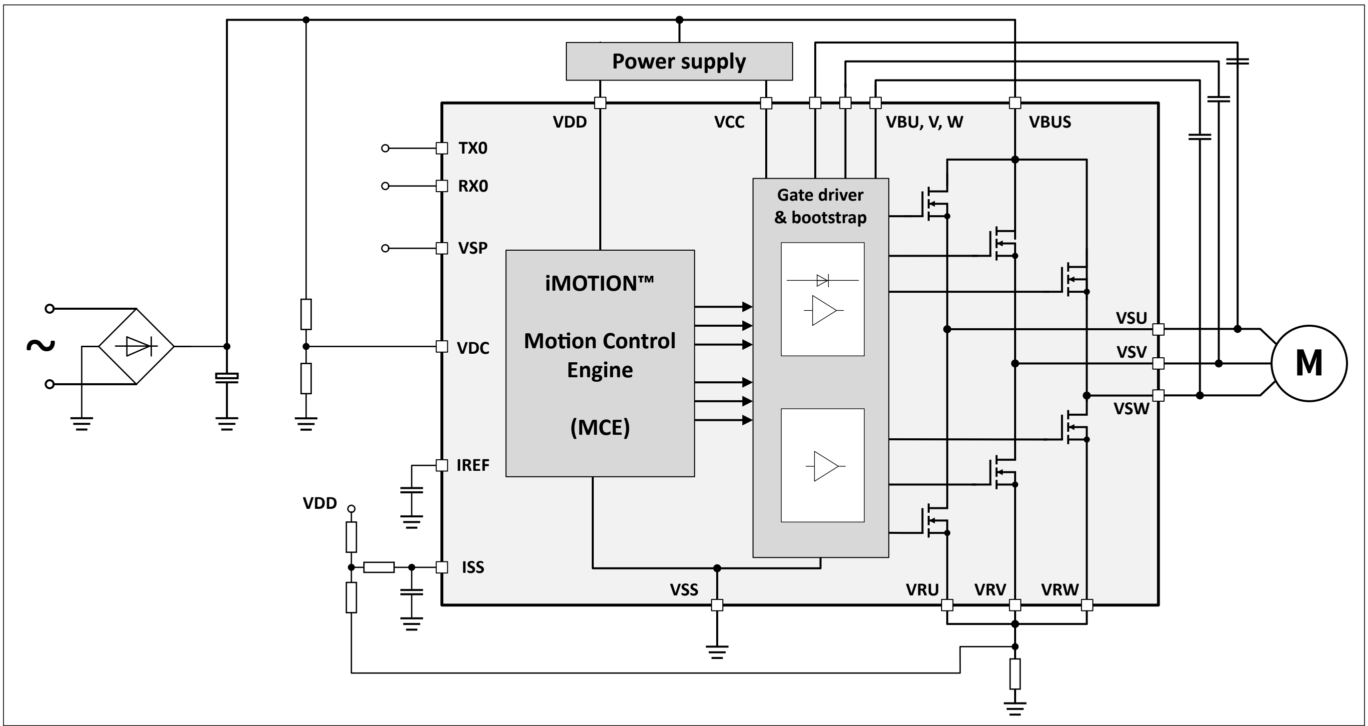

Figure 6 Application block diagram using single shunt current sensing

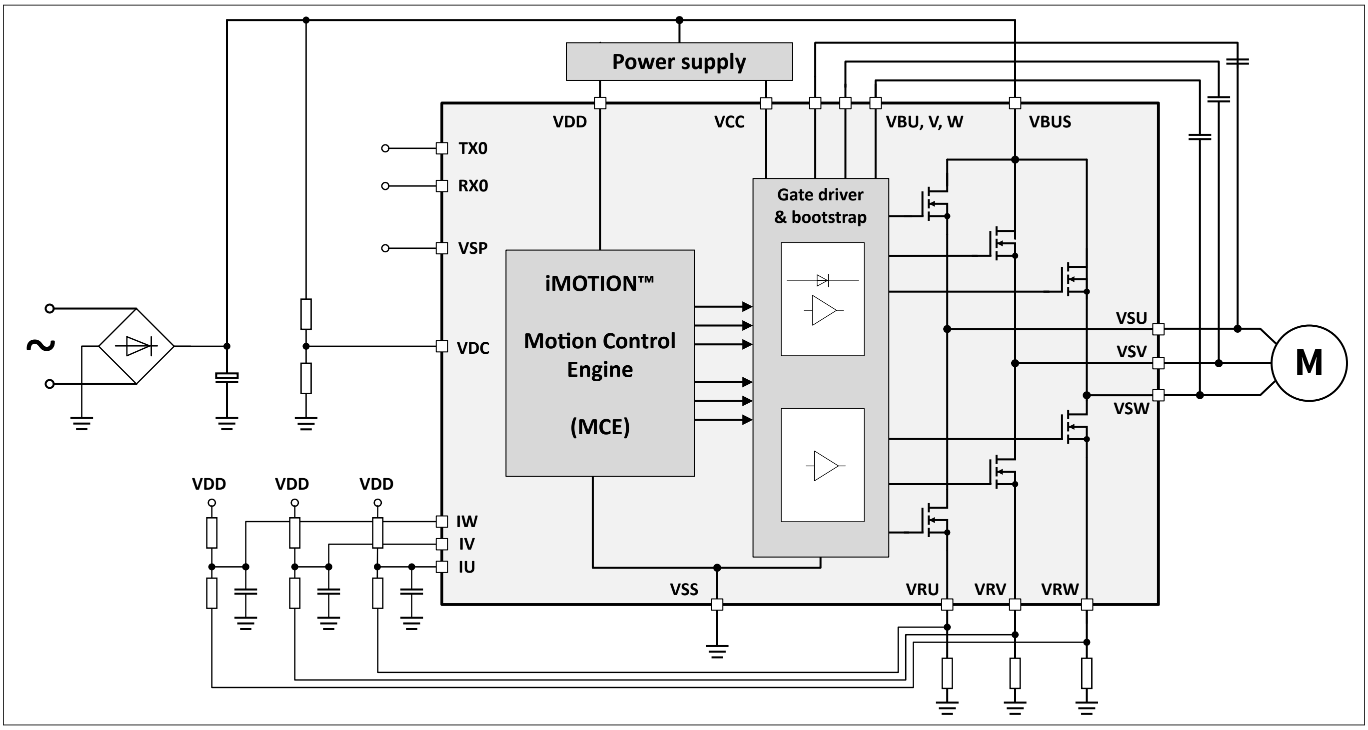

Figure 7 Application block diagram using leg shunts current sensing

4 Electrical characteristics and parameters

4.1 General parameters

4.1.1 Parameter Interpretation

The parameters listed in this section represent partly the characteristics of the IMM100T and partly its requirements on the system. To aid interpreting the parameters easily when evaluating them for a design, they are indicated by the abbreviations in the "Symbol" column:

- **CC**
  Such parameters indicate **C**ontroller **C**haracteristics, which are distinctive feature of the IMM100T and must be regarded for a system design.
- **SR**
  Such parameters indicate **S**ystem **R**equirements, which must be provided by the application system in which the IMM100T is designed in.

4.1.2 Absolute maximum ratings

Stresses above the values listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Table 3 Absolute maximum ratings

Parameter	Symbol	Values		Unit	Note or Test Condition
		Min.	Max.		
Ambient temperature	T_A SR	-40	105	°C	
Junction temperature	T_J SR	-40	115	°C	Digital controller
		-40	150	°C	Gate driver, power transistors
Storage temperature	T_{ST} SR	-40	125	°C	
Lead temperature (soldering, 30 seconds)	T_L SR	---	260	°C	
Digital Controller voltage	V_{DD} SR	-0.3	6	V	
Controller digital and analog pin voltage	V_{ID} SR	-0.3	V_{DD}+0.3	V	
Input current on any controller pin during overload condition	I_{IN} SR	-10	10	mA	
Absolute sum of all controller input currents during overload condition	ΣI_{IN} SR	-50	50	mA	
Gate driver high-side floating rated voltage	$V_{B1,2,3}$ SR	-0.3	600	V	

(table continues...)

Table 3 (continued) Absolute maximum ratings

Parameter	Symbol		Values		Unit	Note or Test Condition
			Min.	Max.		
Gate driver low-side supply voltage	V_{CC} SR		-0.3	20	V	
MOSFET blocking voltage	BV_{DSS}	-015M	---	500	V	
		-046M, -056M	---	650	V	
Power module maximum voltage	BV_{MODULE}	-015M	---	500	V	
		-046M, -056M	---	600	V	
DC output current per MOSFET	I_O	-015M	---	1	A	T_C = 25°C
		-046M, -056M	---	4	A	
Pulsed output current	I_{OP}	-015M	---	6	A	Pulse width = 100 µs, T_C = 25°C, Duty = 1%
		-046M	---	8.2	A	
		-056M	---	11	A	
Maximum power dissipation per MOSFET	P_D	-015M	---	11	W	Single MOSFET in TO220 package at T_C = 25°C
		-046M	---	28.4	W	
		-056M	---	36.7	W	
Isolation voltage (1 min)	V_{ISO}		---	1500	V_{RMS}	---

Note: Characterized, not tested at manufacturing.

Note: Voltages referenced to V_{SS} if not stated otherwise

4.1.3 Pin Reliability in Overload

When receiving signals from higher voltage devices, low-voltage devices experience overload currents and voltages that go beyond their own IO power supplies specification.

The table below defines overload conditions that will not cause any negative reliability impact if all the following conditions are met:

- full operation life-time is not exceeded
- Operating Conditions are met for
  - pad supply levels (V_{DD})
  - temperature

If a pin current is outside of the Operating Conditions but within the overload conditions, then the parameters of this pin as stated in the Operating Conditions can no longer be guaranteed. Operation is still possible in most cases but with relaxed parameters.

Note: An overload condition on one or more pins does not require a reset.

Note: A series resistor at the pin to limit the current to the maximum permitted overload current is sufficient to handle failure situations like short to battery.

Table 4 Overload Parameters

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Input current on analog port pins during overload condition	I_{OVA} SR	-3	–	3	mA	
Input current on any port pin during overload condition	I_{OV} SR	-5	–	5	mA	
Absolute sum of all input currents during overload condition	I_{OVS} SR	–	–	25	mA	

Figure 8 shows the path of the input currents during overload via the ESD protection structures. The diodes against V_{DD} and ground are a simplified representation of these ESD protection structures.

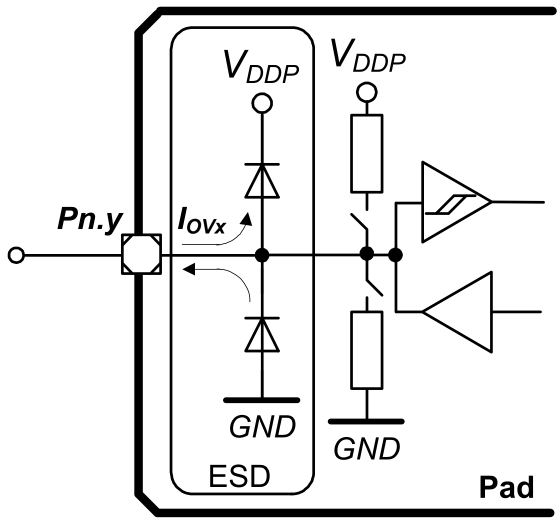

Figure 8 Input Overload Current via ESD structures

Table 5 and Table 6 list input voltages that can be reached under overload conditions. Note that the absolute maximum input voltages as defined in the Absolute maximum ratings must not be exceeded during overload.

Table 5 PN-Junction Characterisitics for positive Overload

Pad Type	I_{OV} = 5 mA
Standard, High-current, AN/DIG_IN	$V_{IN} = V_{DD}$ +(0.3 ... 0.5) V $V_{AIN} = V_{DD}$ + 0.5 V $V_{AREF} = V_{DD}$ + 0.5 V

Table 6 PN-Junction Characterisitics for negative Overload

Pad Type	I_{OV} = 5 mA
Standard, High-current, AN/DIG_IN	$V_{IN} = V_{SS}$ - (0.3 … 0.5) V $V_{AIN} = V_{SS}$ - 0.5 V $V_{AREF} = V_{SS}$ - 0.5 V

4.1.4 Operating Conditions

The following operating conditions must not be exceeded in order to ensure correct operation and reliability of the IMM100T. All parameters specified in the following tables refer to these operating conditions, unless noted otherwise.

Table 7 Recommended Operating Conditions

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Positive DC Bus Input Voltage	V_{BUS} SR	-	-	480	V	
Gate Driver High Side Floating Supply Voltage	$V_{B1,2,3}$ SR	V_S + 12.5	-	V_S + 17.5	V	
Gate Driver Low Side Supply Voltage	V_{CC} SR	13.5	-	16.5	V	
Digital supply voltage[1)]	V_{DD} SR	3.0	3.3	5.5	V	

1 All supply pins must be driven with the same voltage.

4.2 DC characteristics

4.2.1 Input/Output Characteristics

The table below provides the characteristics of the input/output pins of the controller.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Note: Unless otherwise stated, input DC and AC characteristics, including peripheral timings, assume that the input pads operate with the standard hysteresis.

Table 8 Input/Output Characteristics (Operating Conditions apply)

Parameter	Symbol		Limit Values		Unit	Test Conditions
			Min.	Max.		
Input low voltage on port pins (Standard Hysteresis)	V_{ILPS}	SR	–	$0.19 \times V_{DD}$	V	CMOS Mode
Input high voltage on port pins (Standard Hysteresis)	V_{IHPS}	SR	$0.7 \times V_{DD}$	–	V	CMOS Mode
Input low voltage on port pins (Large Hysteresis, scripting pins only)	V_{ILPL}	SR	–	$0.08 \times V_{DD}$	V	CMOS Mode
Input high voltage on port pins (Large Hysteresis, scripting pins only)	V_{IHPL}	SR	$0.85 \times V_{DD}$	–	V	CMOS Mode
Output low voltage on port pins	V_{OLP}	CC	–	1.0	V	I_{OL} = 11 mA (V) I_{OL} = 7 mA (3.3 V)
			–	0.4	V	I_{OL} = 5 mA (5 V) I_{OL} = 3.5 mA (3.3 V)
Output high voltage on port pins	V_{OHP}	CC	V_{DD} - 1.0	–	V	I_{OH} = -10 mA (5 V) I_{OH} = -7 mA (3.3 V)
			V_{DD} - 0.4	–	V	I_{OH} = -4.5 mA (5 V) I_{OH} = -2.5 mA (3.3 V)
Rise/fall time on standard pad	t_R, t_F	CC	–	12	ns	50 pF @ 5 V
			–	15	ns	50 pF @ 3.3 V.
Pin capacitance (digital inputs/outputs)	C_{IO}	CC	–	10	pF	
Pull-up/-down resistor on port pins (if enabled in software)	R_{PUP}	CC	20	50	kΩ	$V_{IN} = V_{SS}$

(table continues...)

Table 8 (continued) Input/Output Characteristics (Operating Conditions apply)

Parameter	Symbol		Limit Values		Unit	Test Conditions
			Min.	Max.		
Input leakage current [2)]	I_{OZP}	CC	-1	1	µA	$0 < V_{IN} < V_{DD}$, T_A 105°C
Maximum current per pin standard pin	I_{MP}	SR	-10	11	mA	–
Maximum current into V_{DD} / out of V_{SS}	I_{MVDD} / I_{MVSS}	SR	–	260	mA	

2 An additional error current (I_{INJ}) will flow if an overload current flows through an adjacent pin.

4.2.2 Analog to Digital Converter (ADC)

The following table shows the Analog to Digital Converter (ADC) characteristics. This specification applies to all analog input including the analog Hall sensor interface input (AHALLx+/AHALLx-, where x=1,2) as given in the pin configuration list.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 9 ADC Characteristics (Operating Conditions apply)[3)]

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Supply voltage range	V_{DD} SR	3.0	–	5.5	V	
Analog input voltage range	V_{AIN} SR	V_{SS}- 0.05	–	V_{DD}+ 0.05	V	
Conversion time	t_{C12} CC	–	1.0	–	µs	Defined by SW
Total capacitance of an analog input	C_{AINT} CC	–	–	10	pF	
Total capacitance of the reference input	C_{AREFT} CC	–	–	10	pF	
Sample time	t_{sample} CC	–	333	–	ns	Defined by SW
RMS noise	EN_{RMS} CC	–	1.5	–	LSB12	
DNL error	EA_{DNL} CC	–	±2.0	–	LSB12	
INL error	EA_{INL} CC	–	±4.0	–	LSB12	
Gain error	EA_{GAIN} CC	–	±0.5	–	%	
Offset error	EA_{OFF} CC	–	±8.0	–	mV	

4.2.3 Analog comparator characteristics

The table below shows the Analog Comparator characteristics.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 10 Analog Comparator Characteristics (Operating Conditions apply)

Parameter	Symbol		Values			Unit	Note or Test Conditions
			Min.	Typ.	Max.		
Input Voltage	V_{CMP}	SR	-0.05	–	V_{DDP} + 0.05	V	includes common mode and differential input voltages
Input Offset	V_{CMPOFF}	CC	–	+/-3	–	mV	High power mode ΔV_{CMP} < 200 mV
Input Hysteresis	V_{HYS}	CC	–	+/-15	–	mV	Defined by SW

3 All parameters are defined for the full supply range if not stated otherwise.

4.2.4 Power Supply Current Controller

The total power supply current defined below consists of a leakage and a switching component for the controller through the V_{DD} pin. The V_{CC} supply current is listed under the gate driver parameters.

Application relevant values are typically lower than those given in the following tables, and depend on the customer's system operating conditions (e.g. thermal connection or used application configurations).

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 11 Power supply parameter tableV_{DD}= 5.0V

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Active mode current motor control only	I_{DD1} CC	–	10	20	mA	T_a = 25°C
Active mode current motor control plus PFC	I_{DD2} CC	–	16	20	mA	T_a = 25°C

4.2.5 Flash Memory Parameters

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 12 Flash Memory Parameters

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Data Retention Time	t_{RET} CC	10			years	Max. 100 erase / program cycles
Erase Cycles	N_{ECYC} CC			$5*10^4$	cycles	Sum of page and sector erase cycles a page sees
Total Erase Cycles	N_{TECYC} CC			$2*10^6$	cycles	

4.2.6 Under voltage lockout DC characteristics

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 13 Under voltage lockout DC characteristics

T_A = 25 ˚C, all voltage parameters are referenced to V_{SS} unless specified otherwise.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
V_{DD} brownout reset voltage	V_{DDPBO}	1.55	1.62	1.75	V	
V_{DD} voltage to ensure defined pad states	V_{DDPA}	---	1.0	---	V	
Start-up time from power-on reset	t_{SSW}	---	260	---	µs	
BMI program time	t_{BMI}	---	8.25	---	ms	
V_{CC} and V_{BS} supply undervoltage positive going threshold - gate driver	V_{CCUV+} V_{BSUV+}	8.0	8.9	9.8	V	
V_{CC} and V_{BS} supply undervoltage negative going threshold - gate driver	V_{CCUV-} V_{BSUV-}	7.4	8.2	9.0	V	
V_{CC} and V_{BS} supply under voltage hysteresis – gate driver	V_{CCUVH} V_{BSUVH}	---	0.7	---	V	

4.2.7 Power Supply Current Gate Driver

The V_{CC} quiescent supply current and standy-by current consumptions are listed under the table.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 14 Power supply parameter table; V_{CC}= V_{BS}=15.0V

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Quiescent V_{BS} supply current	I_{QBS} CC	–	70	120	uA	T_a = 25°C
Quiescent V_{CC} supply current	I_{QCC} CC	–	3	3.5	mA	T_a = 25°C
Standby current consumption	I_{STBY} CC	–	200	500	uA	T_a = 25°C

4.2.8 MOSFET static electrical characteristics

Table 15 MOSFET static electrical characteristics

V_{CC} = 15 V, T_A = 25°C unless otherwise specified.

Symbol	Parameter		Values			Unit	Note or condition
			Min.	Typ.	Max.		
I_{LKH}	Leakage current of high-side FETs in parallel	-015M	---	1	---	µA	V_{DS} = 500 V
		-046M -056M	---	1	---		V_{DS} = 650V
I_{LKL}	Leakage current of low-side FETs with gate drive IC in parallel	-015M	---	4	---	µA	V_{DS} = 500 V
		-046M -056M	---	4	---		V_{DS} = 650V
$R_{DS(ON)}$	Drain to source ON resistance	-015M	---	4.8	6	Ω	V_{GS} = 10 V, I_D = 1.5 A
		-046M	---	1.26	1.4		
		-056M	---	0.855	0.95		
I_{DSS}	Zero gate voltage drain current	-015M	---	---	1	µA	V_{DS} = 500 V, V_{GS} = 0 V
		-046M, -056M	---	---	1		V_{DS} = 650 V, V_{GS} = 0 V
V_{SD}	MOSFET diode forward voltage drop	-015M	---	0.8	---	V	V_{GS} = 0 V, I_F = ??? A
		-046M	---	0.9	---		V_{GS} = 0 V, I_F = 1.5 A
		-056M	---	0.9	---		V_{GS} = 0 V, I_F = 2.2 A

Note: Characterized, not tested at manufacturing.

4.3 AC characteristics

4.3.1 Testing Waveforms

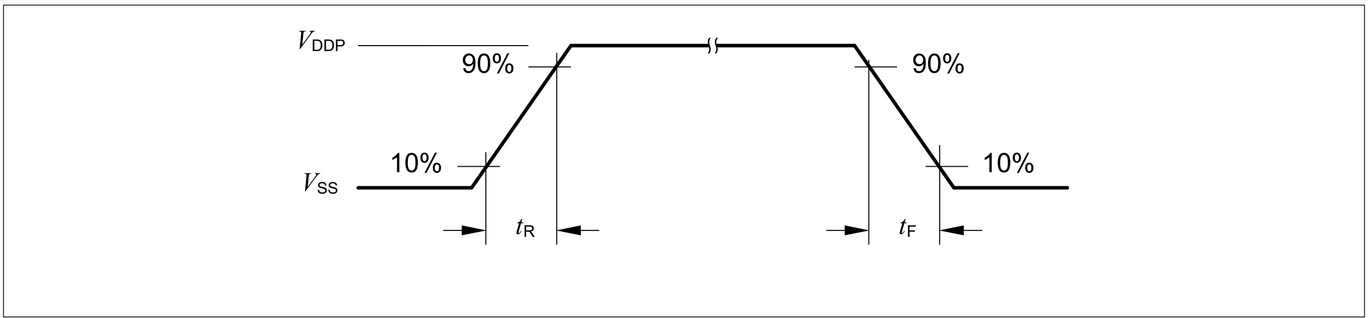

Figure 9 Rise/Fall Time Parameters

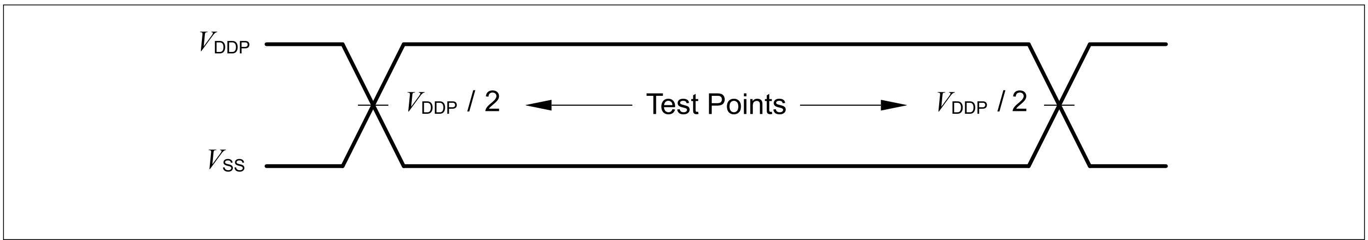

Figure 10 Testing Waveform, Output Delay

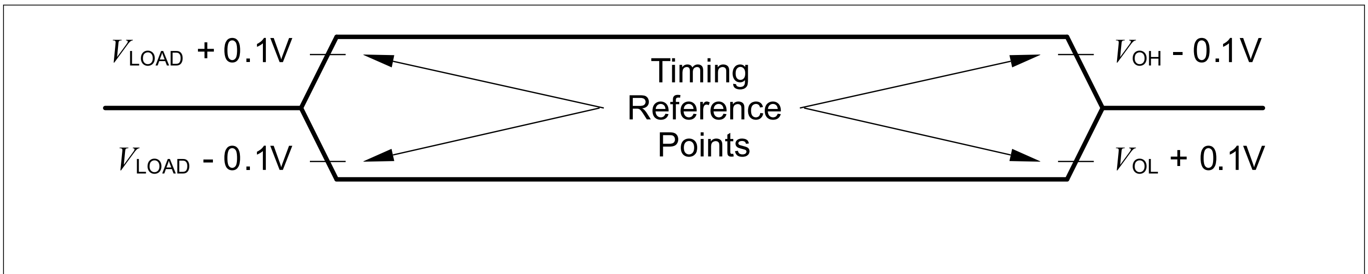

Figure 11 Testing Waveform, Output High Impedance

4.3.2 Power-Up and Supply Threshold Characteristics

This chapter provides the characteristics of the supply threshold for the controller.

The guard band between the lowest valid operating voltage and the brownout reset threshold provides a margin for noise immunity and hysteresis. The electrical parameters may be violated while V_{DD} is outside its operating range.

The brownout detection triggers a reset within the defined range. The prewarning detection can be used to trigger an early warning and issue corrective and/or fail-safe actions in case of a critical supply voltage drop.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Note: Operating Conditions apply.

Table 16 Power-Up and Supply Threshold Parameters

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
V_{DD} ramp-up time	t_{RAMPUP} SR	V_{DD}/ $S_{VDDrise}$	–	10^7	µs	
V_{DD} slew rate	S_{VDDOP} SR	0	–	0.1	V/µs	Slope during normal operation
	S_{VDD10} SR	0	–	10	V/µs	Slope during fast transient within +/-10% of V_{DD}
	$S_{VDDrise}$ SR	0	–	10	V/µs	Slope during power-on or restart after brownout event
	$S_{VDDfall}$[4] SR	0	–	0.25	V/µs	Slope during supply falling out of the +/-10% limits[5]
V_{DD} prewarning voltage	V_{DDPW} CC	2.1	2.25	2.4	V	ANAVDEL.VDEL_SELECT = 00_B
		2.85	3	3.15	V	ANAVDEL.VDEL_SELECT = 01_B
		4.2	4.4	4.6	V	ANAVDEL.VDEL_SELECT = 10_B
V_{DD} brownout reset voltage	V_{DDBO} CC	1.55	1.62	1.75	V	calibrated, before user code starts running
V_{DD} voltage to ensure defined pad states	V_{DDA} CC	–	1.0	–	V	
Start-up time from power-on reset	t_{SSW} CC	–	260	–	µs	Time to the first user code instruction[6]
Start-up time to PWM on	t_{PWMON} CC	5.2	-	360	ms	Time to PWM enabled

Figure 12 Supply Threshold Parameters

4 A capacitor of at least 100 nF has to be added between VDD and VSS to fulfill the requirement as stated for this parameter.
5 Valid for a 100 nF buffer capacitor connected to supply pin where current from capacitor is forwarded only to the chip. A larger capacitor value has to be chosen if the power source sink a current.
6 This values does not include the ramp-up time. During startup firmware execution, MCLK is running at 48 MHz and the clocks to peripheral as specified in register CGATSTAT0 are gated.

4.3.3 On-Chip Oscillator Characteristics

Table 17 provides the characteristics of the 96 MHz digital controlled oscillator DCO1. The DCO1 is used as the time base during normal operation.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 17 96 MHz DCO1 Characteristics

Parameter	Symbol	Limit Values			Unit	Test Conditions
		Min.	Typ.	Max.		
Nominal frequency	f_{NOM} CC	-	96	-	MHz	under nominal conditions after trimming
Accuracy with adjustment algorithm [7] based on temperature sensor	Δf_{LTTS} CC	-0.6	–	+0.6	%	with respect to f_{NOM}(typ), T_A from 0°C to 105°C
		-1.9	–	+1.0	%	with respect to f_{NOM}(typ), T_A from -25 °C to 105°C
		-2.6	–	+1.3	%	with respect to f_{NOM}(typ), T_A from -40° C to 105 °C
Accuracy	Δf_{LT} CC	-1.7	–	+3.4	%	with respect to f_{NOM}(typ), T_A from 0 ° C to 85 °C
		-3.9	–	+4.0	%	with respect to f_{NOM}(typ), T_A from -40° C to 105 °C

Table 18 provides the characteristics of the 32 kHz digital controlled oscillator used internally as a secondary clock source for the internal watchdog.

Table 18 32 kHz DCO2 Characteristics

Parameter	Symbol	Limit Values			Unit	Test Conditions
		Min.	Typ.	Max.		
Nominal frequency	f_{NOM} CC	-	32.75	-	kHz	under nominal conditions[8] after trimming
Accuracy	Δf_{LT} CC	-1.7	–	+3.4	%	with respect to f_{NOM}(typ), T_A from 0 ° C to 85 °C
		-3.9	–	+4.0	%	with respect to f_{NOM}(typ), T_A from -40° C to 105 °C

7 MCE version newer or equal to V1.03.00, clock adjustment algorithm for improved accuracy enabled
8 The deviation is relative to the factory trimmed frequency at nominal V_{DDC} and T_A = + 25°C.

4.3.4 MOSFET dynamic electrical characteristics

Table 19 Dynamic electrical characteristics MOSFETs

V_{CC} = 15 V, T_A = 25°C, all voltage parameters are referenced to V_{SS} unless otherwise specified.

Symbol	Parameter		Values			Unit	Note or condition
			Min.	Typ.	Max.		
E_{ON}	Switching energy, turn on condition	-015M	---	20	---	µJ	T_J = 25°C, V^+ = 300 V, I_D = 0.5 A
		-046M	---	30.8	---		
		-056M	---	36.9	---		
E_{OFF}	Switching energy, turn off condition	-015M	---	2.43	---	µJ	T_J = 25°C, V^+ = 300 V, I_D = 0.5 A
		-046M	---	1.36	---		
		-056M	---	2.02	---		
E_{REC}	Switching energy, diode reverse recovery	-015M	---	5.87	---	µJ	T_J = 25°C, V^+ = 300 V, I_D = 0.5 A
		-046M	---	3.42	---		
		-056M	---	3.78	---		
E_{ON}	Switching energy, turn on condition	-015M	---	26.5	---	µJ	T_J = 95°C, V^+ = 300 V, I_D = 0.5 A
		-046M	---	42.1	---		
		-056M	---	54.8	---		
E_{OFF}	Switching energy, turn off condition	-015M	---	3.89	---	µJ	T_J = 95°C, V^+ = 300 V, I_D = 0.5 A
		-046M	---	4.06	---		
		-056M	---	2.25	---		
E_{REC}	Switching energy, diode reverse recovery	-015M	---	7	---	µJ	T_J = 95°C, V^+ = 300 V, I_D = 0.5 A
		-046M	---	2.06	---		
		-056M	---	5.5	---		

Note: Characterized, not tested at manufacturing.

4.3.5 MOSFET avalanche characteristics

Table 20 MOSFET avalanche characteristics

Symbol	Parameter		Values			Unit	Note or condition
			Min.	Typ.	Max.		
EAS	Single pulse avalanche energy	-015M	---	---	49	mJ	V^+ = 100 V, I_D = 1.7 A
		-046M	---	---	26		V^+ = 50 V, I_D = 0.6 A
		-056M	---	---	50		V^+ = 50 V, I_D = 1 A

Note: Characterized, not tested at manufacturing.

4.4 Motor Control Parameters

The following values are given for reference only. Concrete parameters are defined in the iMOTION™ Motion Control Engine (MCE) software.

4.4.1 PWM Characteristics

Table 21 Electrical characteristics

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Motor PWM Frequency[9]	f_{PWM}	5	16	40	kHz	

4.4.2 Current Sensing

Table 22 Motor Current Sensing

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Input range	I_{PWM}	V_{SS}-0.05	-	V_{DD}+0.05	V	
Configurable analog gain		-	1/ 3/ 6/ 12	-		
Itrip input range	$I_{PWMTRIP}$	V_{SS}-0.05	-	V_{DD}+0.05	V	
Itrip offset		-	±8	-	mV	
Input capacitance	C_{REF}	-	-	10	pF	REFU, REFV, REFW capacitor

9 Actual min. and max. limits defined in resp. software version

4.4.3 Fault Timing

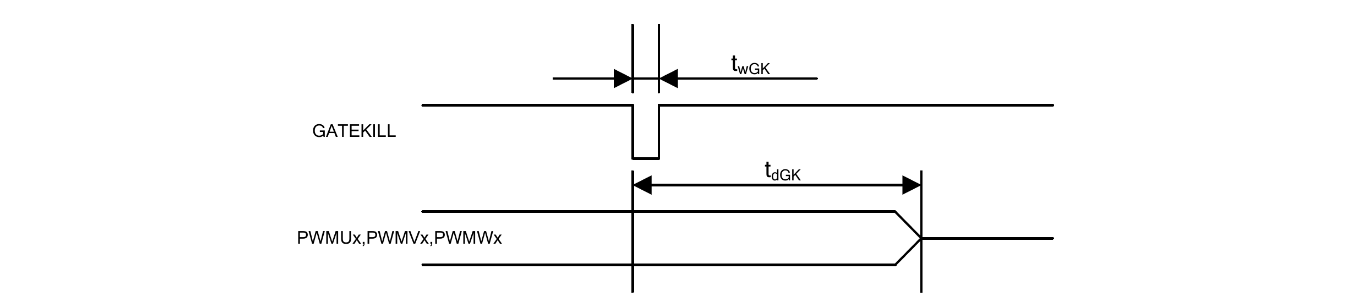

Figure 13 **Fault timing**

Table 23 **Gatekill timing**

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
GK pulse width	t_{wGK}	1	-	-	µs	
GK input to PWM shutoff	t_{GK}	-	1.3	-	µs	
Motor Fault reset timing	t_{RESET}	-	1.84	-	ms	fault reset command via UART to PWM reactivation
MCE digital ITRIP filter window	t_{PWMOFF}	0.075	1.0	10	µs	Configurable in software

Note: The ITRIP filter window must be configured according to the rated short circuit withstand time of the respective power stage taking into consideration any delay in external circuitry. For iMOTION™ devices with integrated power stage the value is specified in the Absolute maximum ratings of the device.

4.5 Power Factor Correction (PFC) parameters

The parameters specified for the power factor correction only refer to products that have the respective control algorithm integrated. The PFC switching frequency is configurable and the range depends on the concrete firmware version.

4.5.1 Boost PFC characteristics

Table 24 Electrical characteristics

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
PFC frequency	f_{PFC}	-	20	50	kHz	MCE rev. 1.3
		-	40	120	kHz	MCE rev. 5.1

4.5.2 Totem Pole PFC characteristics

Table 25 Electrical characteristics

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
PFC frequency	f_{PFC}	-	40		kHz	Max defined by SW

4.5.3 PFC Current Sensing

The current sensing specification applies to both PFC algorithms, boost mode and totem pole.

Table 26 PFC Current Sensing

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Input range	I_{PFC}	V_{SS}- 0.05	-	V_{DD}+ 0.05	V	V_{DD}= 3.3 or 5.0 V
Configurable analog gain		-	1/ 3/ 6/ 12	-		
PFC Itrip input range	$I_{PFCTRIP}$	V_{SS}-0.05	-	V_{DD}+ 0.05	V	V_{DD}= 3.3 or 5.0 V
Itrip offset		-	± 3	-	mV	Input voltage difference > 200mV
Input capacitance	C_{REF}	-	-	10	pF	PFCREF capacitor

4.5.4 PFC Fault Timing

Table 27 PFC Fault timing

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Itrip to PFC PWM shutoff	t_{PFCOFF}	-	1.18	-	µs	

(table continues...)

Table 27 (continued) PFC Fault timing

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
PFC fault reset timing	t_{RESET}	-	1.0	-	ms	fault reset command via UART to PWM reactivation

4.6 Device Interfaces

iMOTION™ devices provide several interfaces to either control the motor drive in the application or report back its status. The availability of a specific interface depends upon the concrete device chosen as well as the version of the Motion Control Engine (MCE) applied. The following sections and tables specify these interfaces as well as the respective limits. The configuration settings for these interfaces are described in the MCE Reference Manual.

Note: These parameters are not subject to production test, but verified by design and/or characterization. Operating conditions apply.

4.6.1 UART Interface

The UART interface is configured as given below.

Table 28 Electrical characteristics

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
UART baud rate		1200	57600	-	Bps	
UART mode		-	8-N-1	-		data-parity-stop bit
UART sampling filter period [10]	$T_{UARTFIL}$	-	1/16	-	T_{BAUD}	

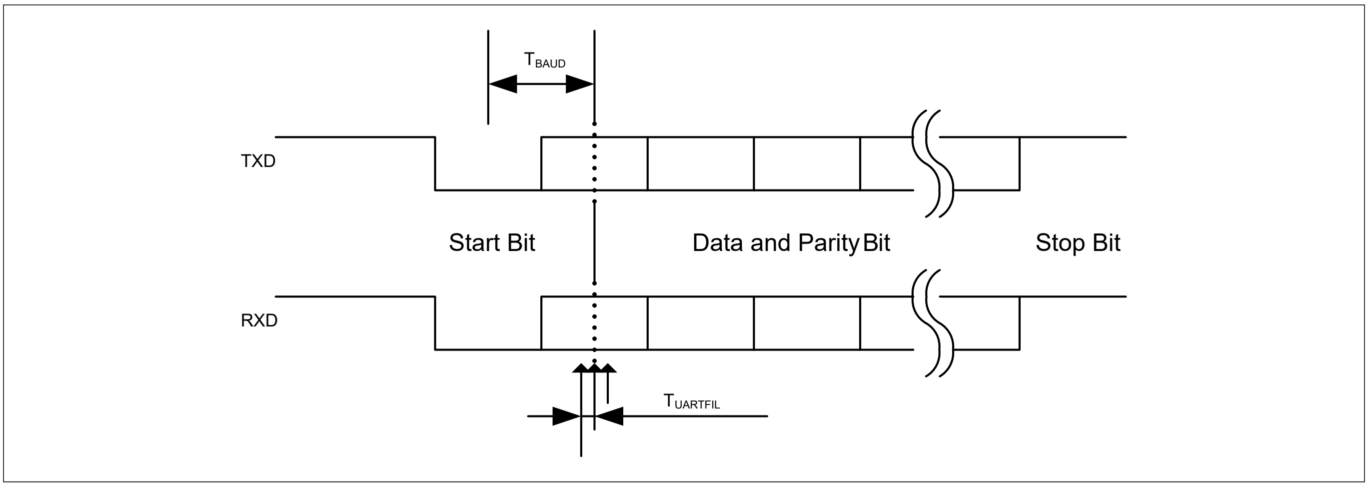

Figure 14 UART timing

10 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.

4.6.2 Analog Speed Input

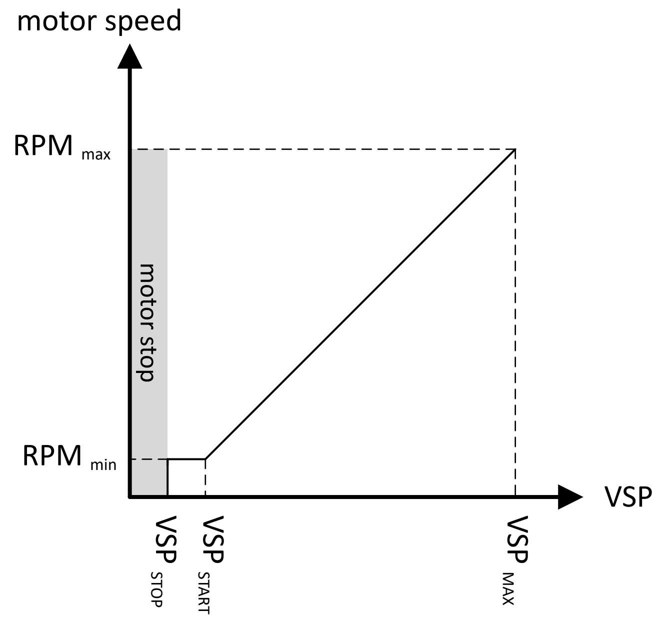

Figure 15 **VSP analog control mode**

Table 29 **Analog Speed Control Voltage (VSP)**

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Motor start voltage	VSP_{START}	-	1.2	-	V	Configured VSP_{STOP}=1.0V
Motor stop voltage	VSP_{STOP}	-	1.0	-	V	Configured VSP_{STOP}=1.0V
Motor max voltage	VSP_{MAX}	-	4.9	4.95	V	V_{DD}=5.0V
VSP active to PWM start	t_{START}	-	44	-	ms	
VSP inactive to PWM stop	t_{STOP}	-	16	-	ms	

4.6.3 Frequency Input

In frequency input control mode, the motor operations like motor start, motor stop and speed change are controlled by applying a square wave frequency signal on a digital input pin.

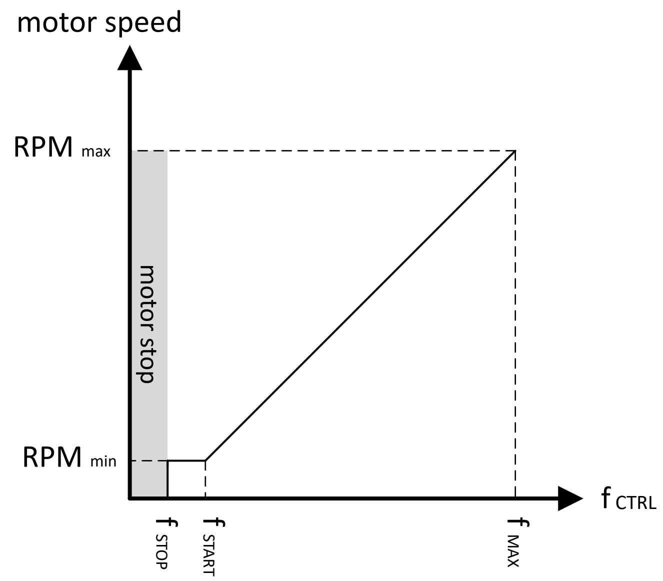

Figure 16 **Frequency input control mode**

Table 30 **Frequency Control Mode**

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Motor start frequency	f_{START}	-	100	360	Hz	$f_{START} > f_{STOP}$
Motor stop frequency	f_{STOP}	-	50	-	Hz	
Motor max speed frequency	f_{MAX}	-	-	1000	Hz	
Frequency input duty cycle	T_{DUTY}	10	-	90	%	

4.6.4 Duty Cycle Input

In duty cycle input control mode, the motor operations like motor start, stop and speed change are controlled by varying the duty cycle of a rectangular wave signal on a digital input pin.

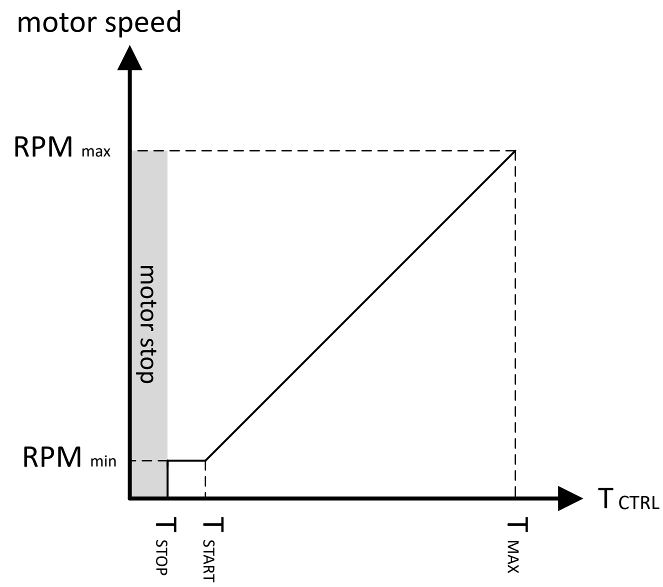

Figure 17 **Duty cycle input control mode**

Table 31 **Duty Cycle Control Mode**

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Input signal frequency	f_{DUTY}	5	1000	20000	Hz	
Motor start duty cycle	T_{START}	-	10	-	%	$T_{START} > T_{STOP}$
Motor stop duty cycle	T_{STOP}	-	5	-	%	
Motor max duty cycle	T_{MAX}	-	95	-	%	

5 Device and package specifications

5.1 Quality declaration

Table 32 Quality Parameters

Parameter	Symbol		Limit Values		Unit	Notes
			Min.	Max.		
Moisture sensitivity level	MSL CC		–	3	–	JEDEC J-STD-020D
Soldering temperature	T_{SDR} SR		–	260	°C	JEDEC J-STD-020D

5.2 SBSL and Chip-IDs

The table below gives the IDs for the individual devices in the IMM100T family. Depending upon the mode either the SBSL-ID (secure boot loader) or the Chip-ID should be used to identify the device. For details refer to the Reference Manual or the iMOTION™ Programming Manual.

Table 33 SBSL-IDs and Chip-IDs

Product Type	Package	Chip-ID	SBSL-ID
IMM101T-015M	QFN12x12	0x31010150	021b53d63e0a7866b8ee0e9e63b7fea1
IMM101T-046M	QFN12x12	0x31010460	02f091428614b7ed3da4f6bc375b97f9
IMM101T-056M	QFN12x12	0x31010560	02eae31caf13e13d3047581f168b5a12
IMM102T-015M	QFN12x12	0x31020150	02d71062b66a3e09d3aaf7352e58ae51
IMM102T-046M	QFN12x12	0x31020460	02981cc1339fb18f3b694cd11d01e771
IMM102T-056M	QFN12x12	0x31020560	0299c1b0ddd069e994dab332e586b253

5.3 Thermal characteristics

Note: The value of $R_{th(J-amb)}$ has been obtained under the following testing condition: t_{amb} = 25°C, $t_{hotspot}$ = 51.6°C and a dissipated power of 1 W. A FR4 PCB with 2 oz copper has been used and the PCB layout is shown in the user manual of EVAL-IMM101 board.

Table 34 Thermal characteristics

Parameter	Symbol		Values			Unit	Note or test condition
			Min.	Typ.	Max.		
Total thermal resistance junction to ambient	$R_{th(J-amb)}$			27.7		°C/W	

Note: Characterized, not tested at manufacturing.

5.4 Thermal characterization

The following figures show the thermal characterizations of the three part numbers under the following conditions:

- Ambient temperature (T_A)
  - Figure 18, Figure 19, Figure 20: T_A = 25°C
  - Figure 21, Figure 22, Figure 23: T_A = 60°C
- Different phase current values until the case reaches 105°C
- Two PWM frequencies (6 kHz and 16 kHz)
- Two different modulation types (3-phase modulation and 2-phase flat bottom modulation)

2-phase flat bottom modulation allows the reduction of the switching losses compared with 3-phase SVPWM (symmetrical placement of zero vectors). For the test with t_{amb} = 60°C, the 3-phase modulation has not been used.

For all the tests, the phase current has been limited to 600 mA_{rms} in order to avoid damage to the motor used for the tests. A FR4 PCB with 2 oz copper has been used and the PCB layout is shown in the Thermal Characteristics.

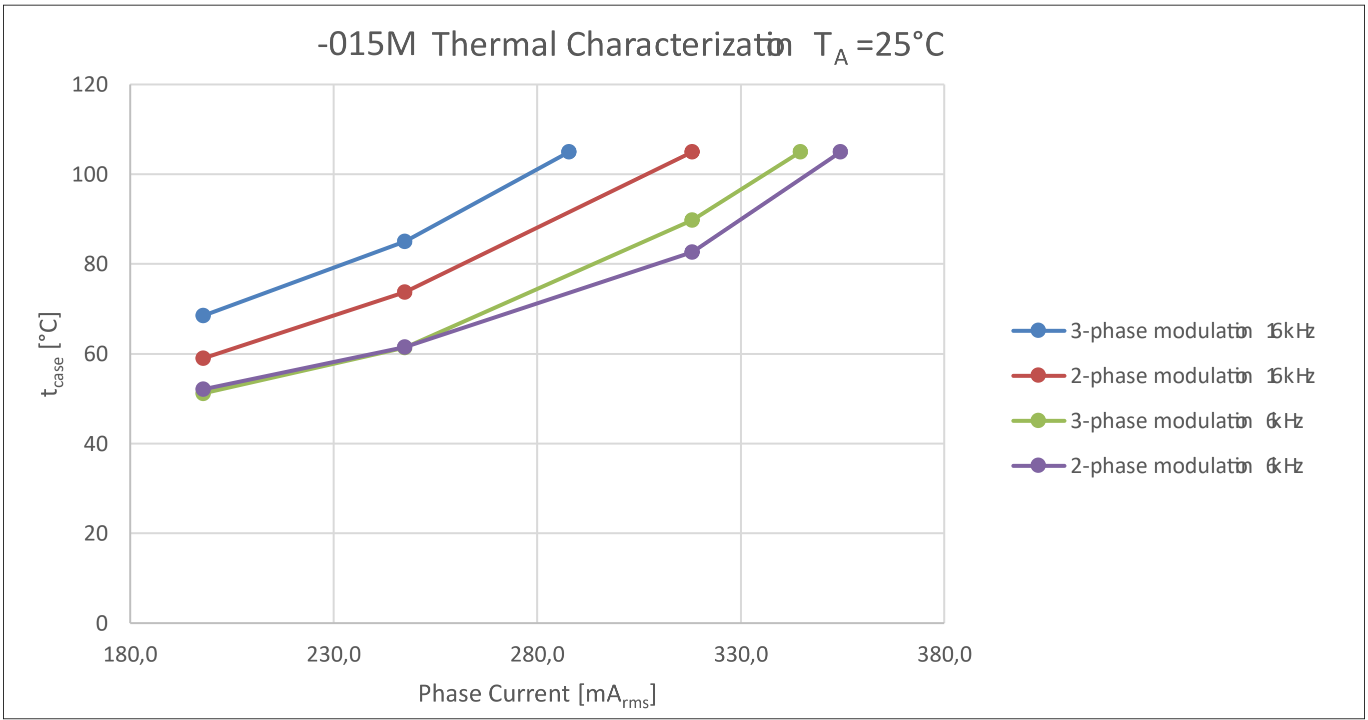

Figure 18 **IMM100T-015M thermal characterization, T_A = 25°C, different phase current values until the case reaches 105°C, FR4 PCB with 2oz copper**

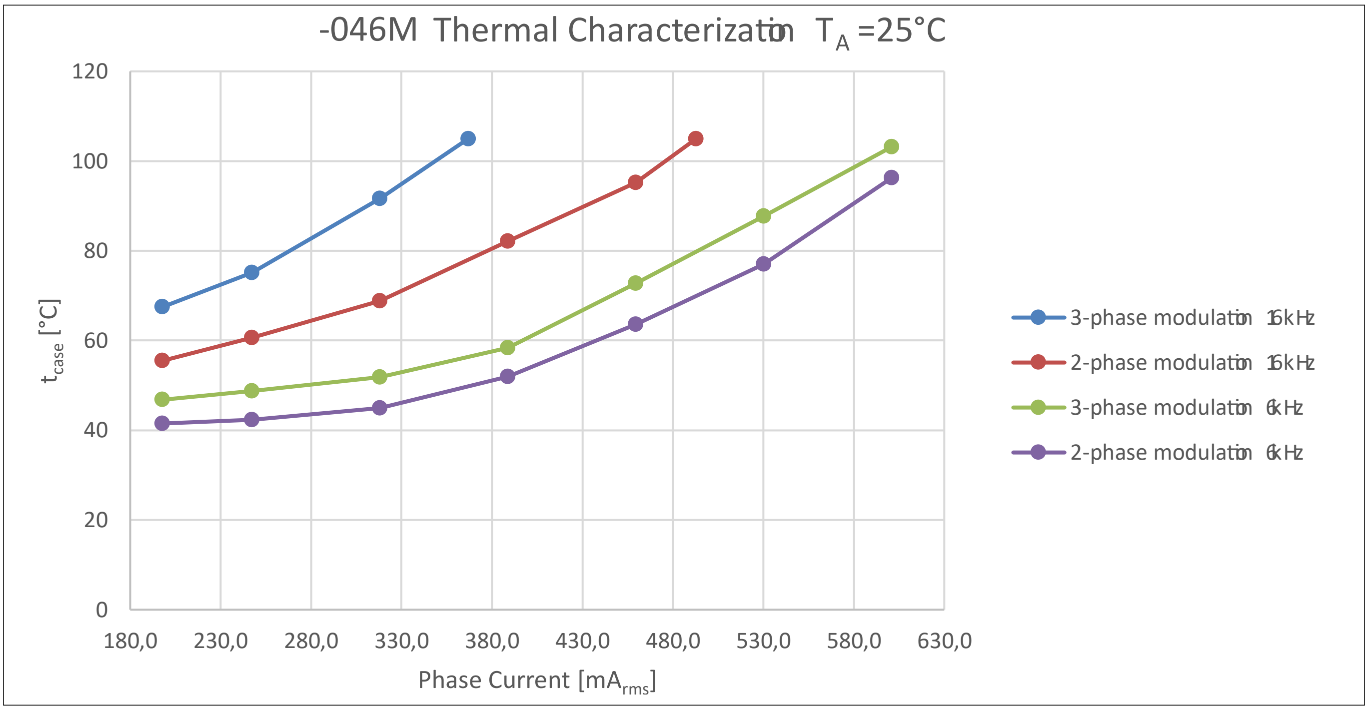

Figure 19 **IMM100T-046M thermal characterization, T_A = 25°C, different phase current values until the case reaches 105°C, FR4 PCB with 2oz copper**

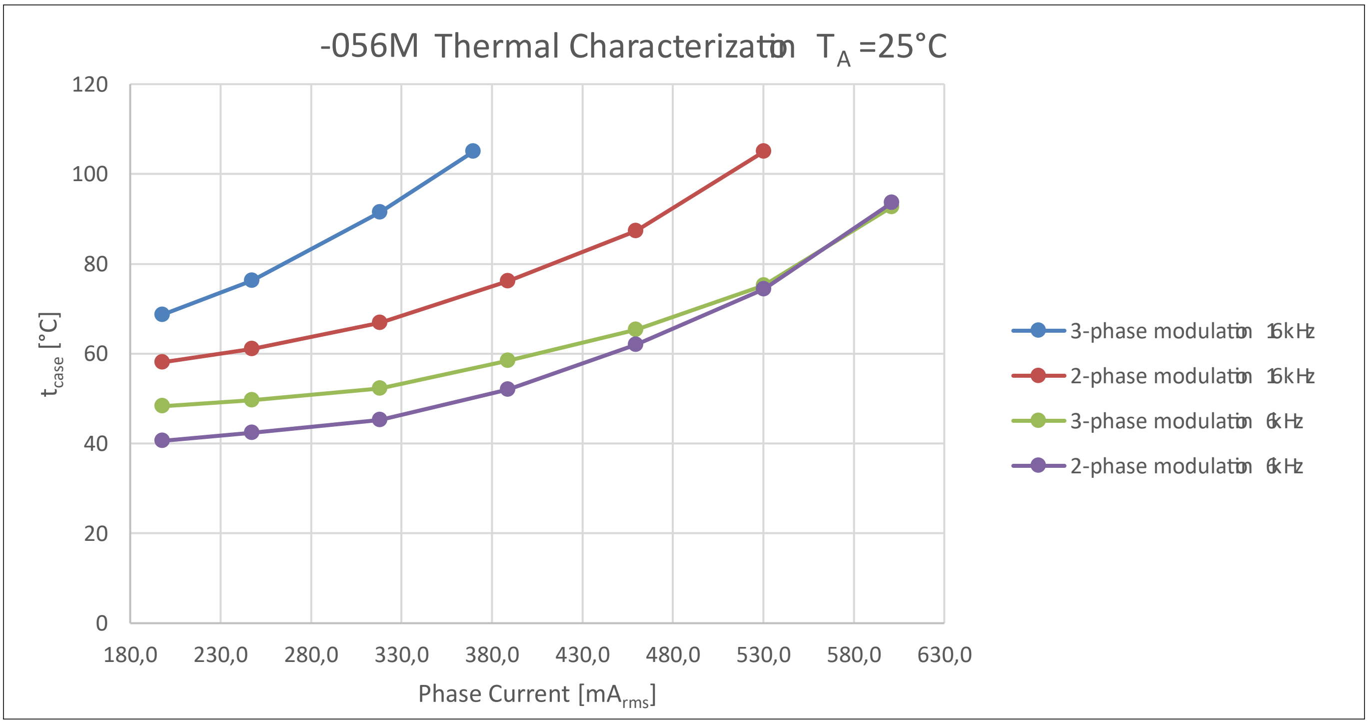

Figure 20 **IMM100T-056M thermal characterization, T_A = 25°C, different phase current values until the case reaches 105°C, FR4 PCB with 2oz copper**

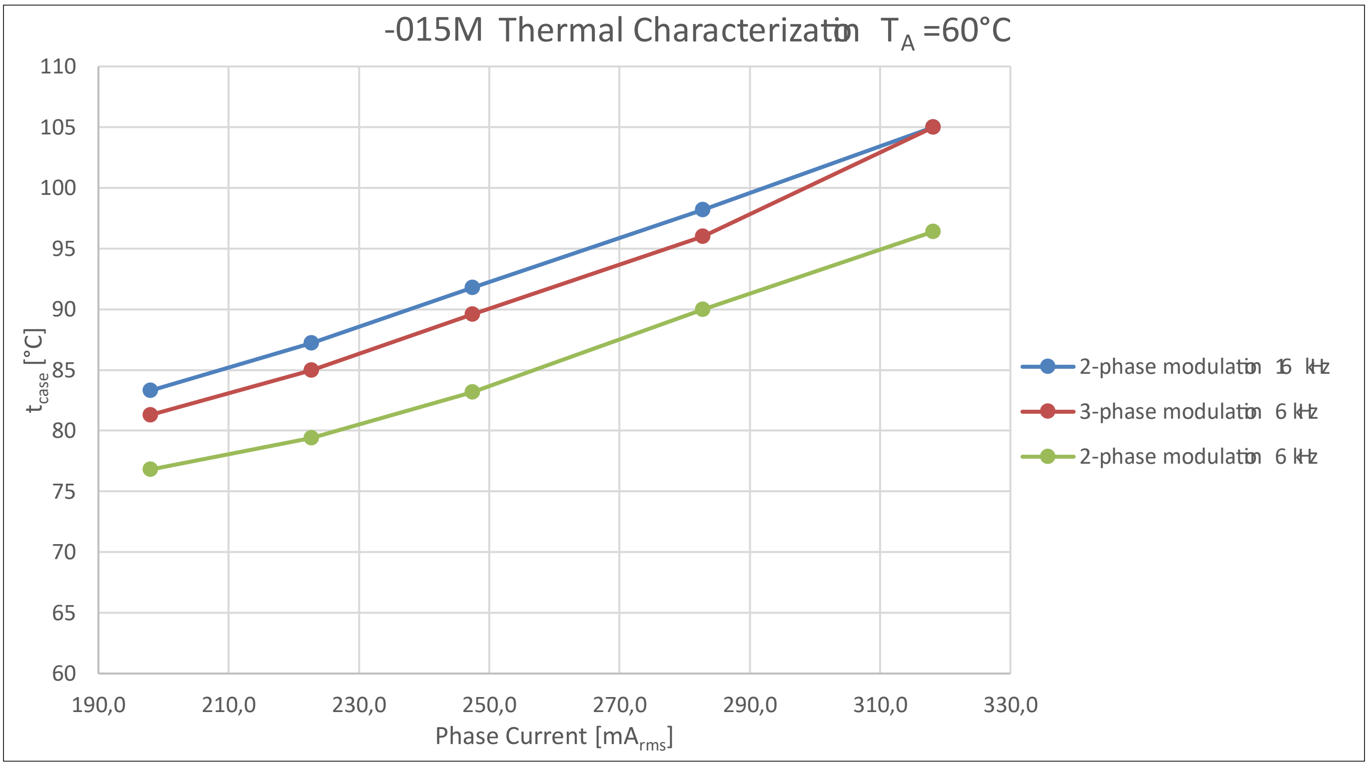

Figure 21 **IMM100T-015M thermal characterization, T_A = 60°C, different phase current values until the case reaches 105°C, FR4 PCB with 2oz copper**

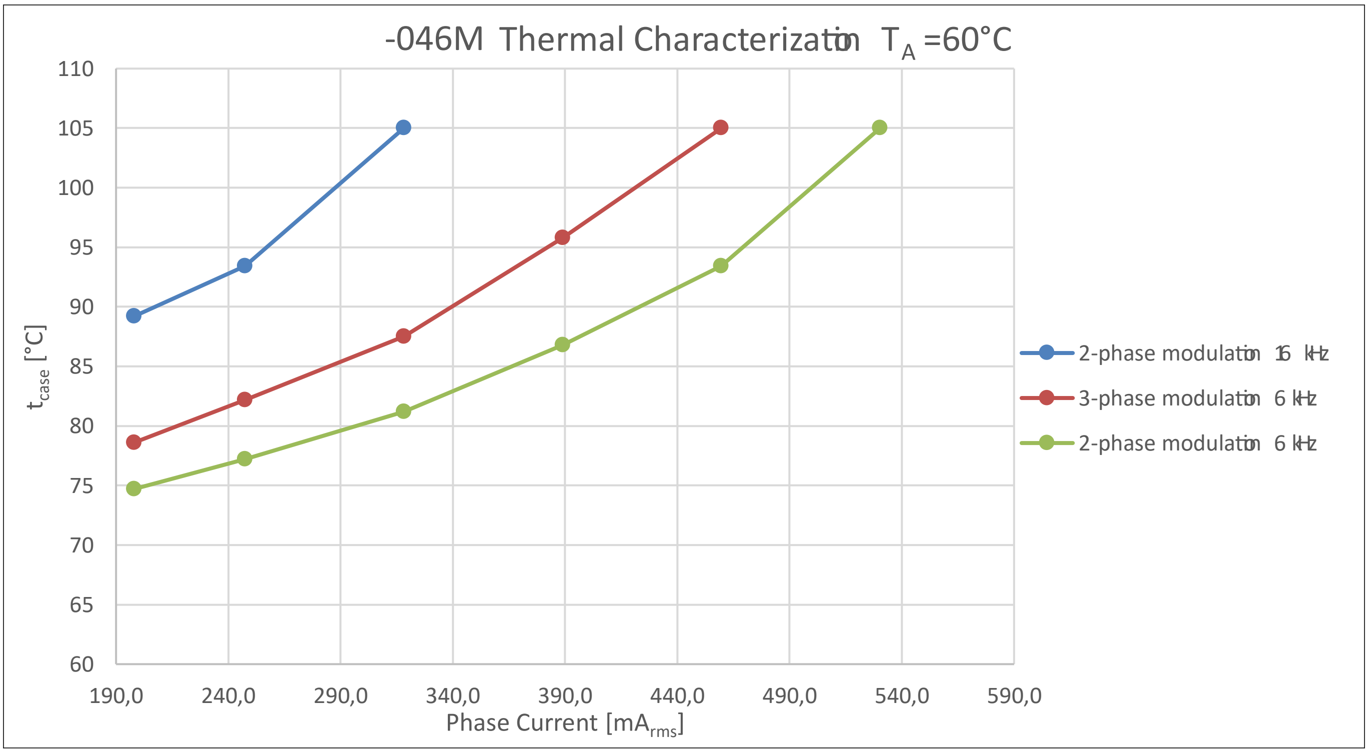

Figure 22 **IMM100T-046M thermal characterization, T_A = 60°C, different phase current values until the case reaches 105°C, FR4 PCB with 2oz copper**

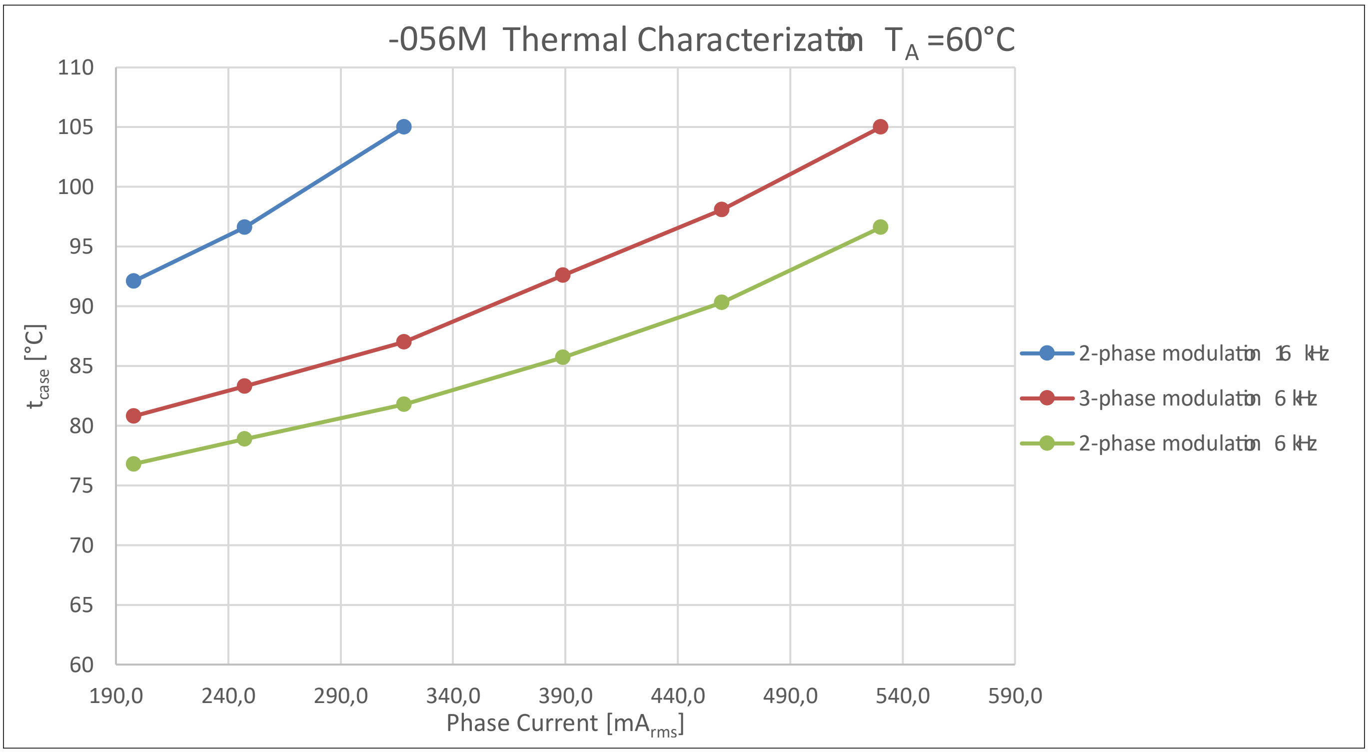

Figure 23 **IMM100T-056M thermal characterization, T_A = 60°C, different phase current values until the case reaches 105°C, FR4 PCB with 2oz copper**

Note: *Characterized, not tested at manufacturing.*

5.5 Package outline PG-IQFN-38-1

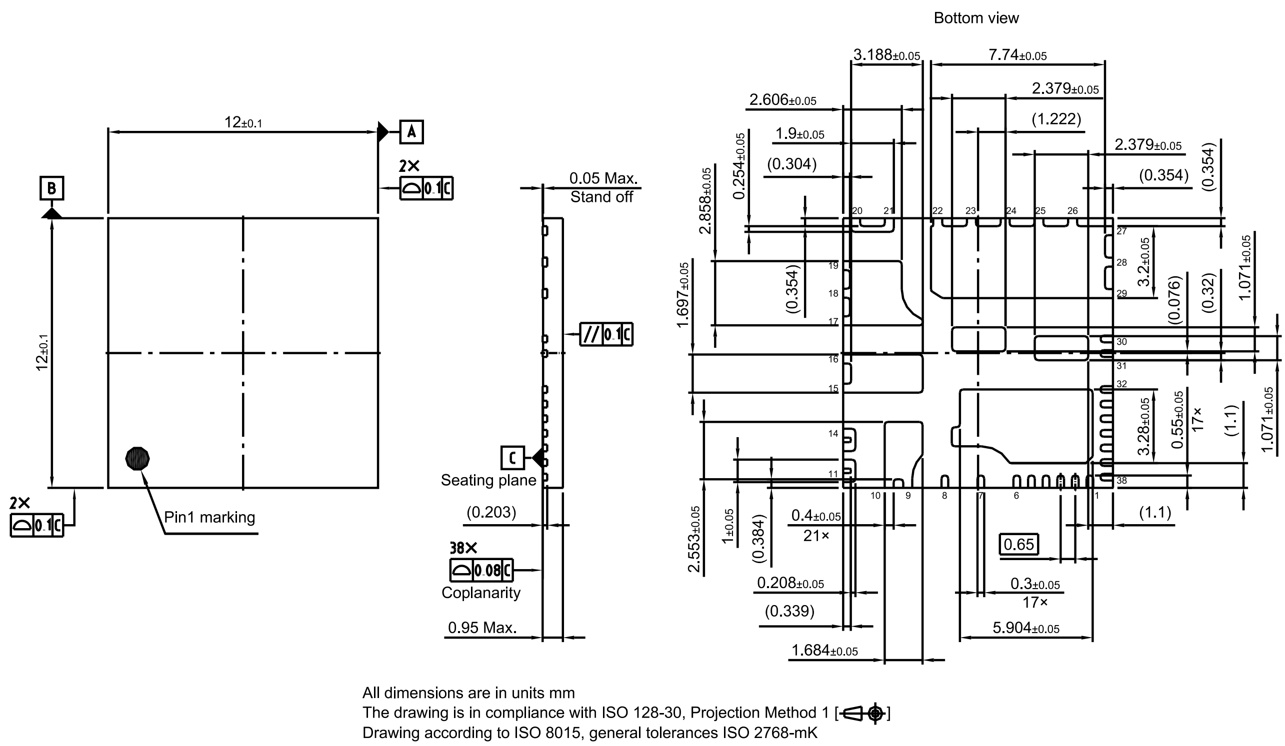

Figure 24 PG-IQFN-38-1

5.6 Part marking information

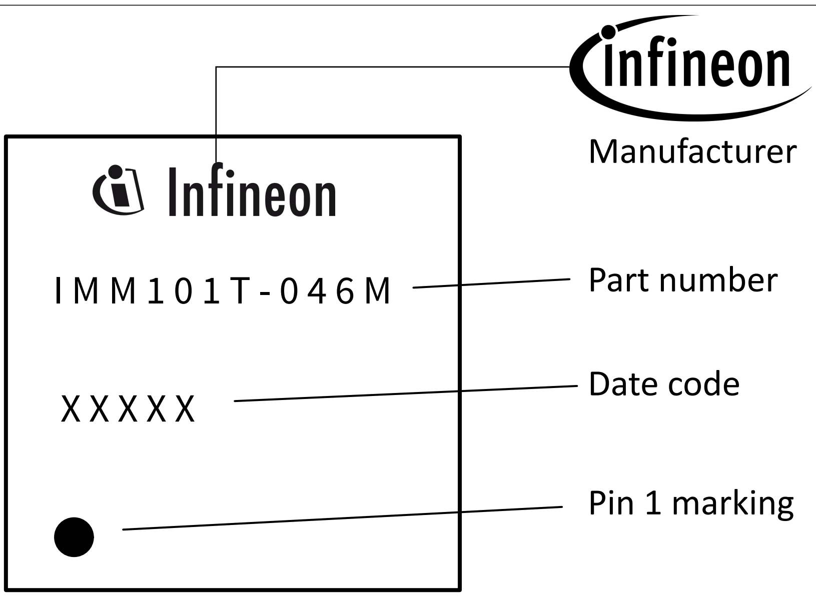

Figure 25 Part marking

6 Revision history

Document version	Date of release	Description of changes
1.0	2019-04-10	• Initial release
1.1	2019-06-05	• Typo Corrections
1.2	2020-04-24	• Revised oscillator accuracy specs, changed maximum PWM frequency
1.3	2023-09-13	• Structural changes • Added SBSL IDs • New features pin mapping of TRIAC/I2C/IR added
1.3.1	2023-10-23	• Standby current unit typo change • Thermal characteristics note change

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Edition 2023-10-23

Published by

Infineon Technologies AG

81726 Munich, Germany

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Document reference
IFX-qsr1667915999810