

DESCRIPTION

The MP6545 is a three-phase power stage IC designed to drive brushless DC (BLDC) motors or other loads.

The MP6545 operates across a 4.5V to 45V input voltage (V_{IN}) range. It can deliver an output current (I_{OUT}) up to 2.5A per phase, depending on the ambient temperature (T_A) and PCB layout.

Internal safety and diagnostic features include over-current protection (OCP), input over-voltage protection (OVP), input under-voltage lockout (UVLO), and thermal shutdown.

The MP6545 has separate high-side (HS) and low-side (LS) input pins for each output pin. The MP6545 is available in QFN-28 (4mmx5mm) and TSSOP-28EP packages.

FEATURES

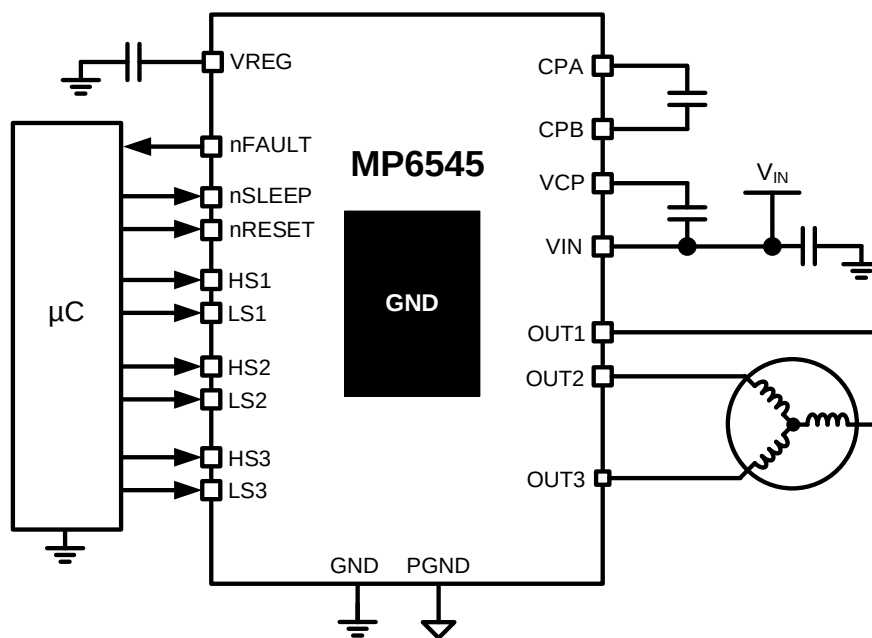
- 4.5V to 45V Operating Input Voltage (V_{IN}) Range
- 2.5A Maximum Output Current (I_{OUT_MAX})
- Three-Channel Half-Bridge (HB) Driver
- Low 150m Ω On Resistance ($R_{DS(ON)}$) per MOSFET
- Protection Functions Include:
 - Over-Current Protection (OCP)
 - Over-Voltage Protection (OVP)
 - Under-Voltage Lockout (UVLO)
 - Over-Temperature (OT) Shutdown
 - Fault Indication Output
- Available in QFN-28 (4mmx5mm) and TSSOP-28EP Packages

APPLICATIONS

- Brushless DC (BLDC) Motors
- Laser Printers and Copiers
- Textile Machines

All MPS parts are lead-free, halogen-free, and adhere to the RoHS directive. For MPS green status, please visit the MPS website under Quality Assurance. "MPS", the MPS logo, and "Simple, Easy Solutions" are trademarks of Monolithic Power Systems, Inc. or its subsidiaries.

TYPICAL APPLICATION



ORDERING INFORMATION

Part Number*	Package	Top Marking	MSL Rating
MP6545GV	QFN-28 (4mmx5mm)	See Below	2
MP6545GF	TSSOP-28EP	See Below	2a

* For Tape & Reel, add suffix -Z (e.g. MP6545GV-Z).

* For Tape & Reel, add suffix -Z (e.g. MP6545GF-Z).

TOP MARKING (MP6545GF)

MPSYYWW
MP6545
LLLLLLLL

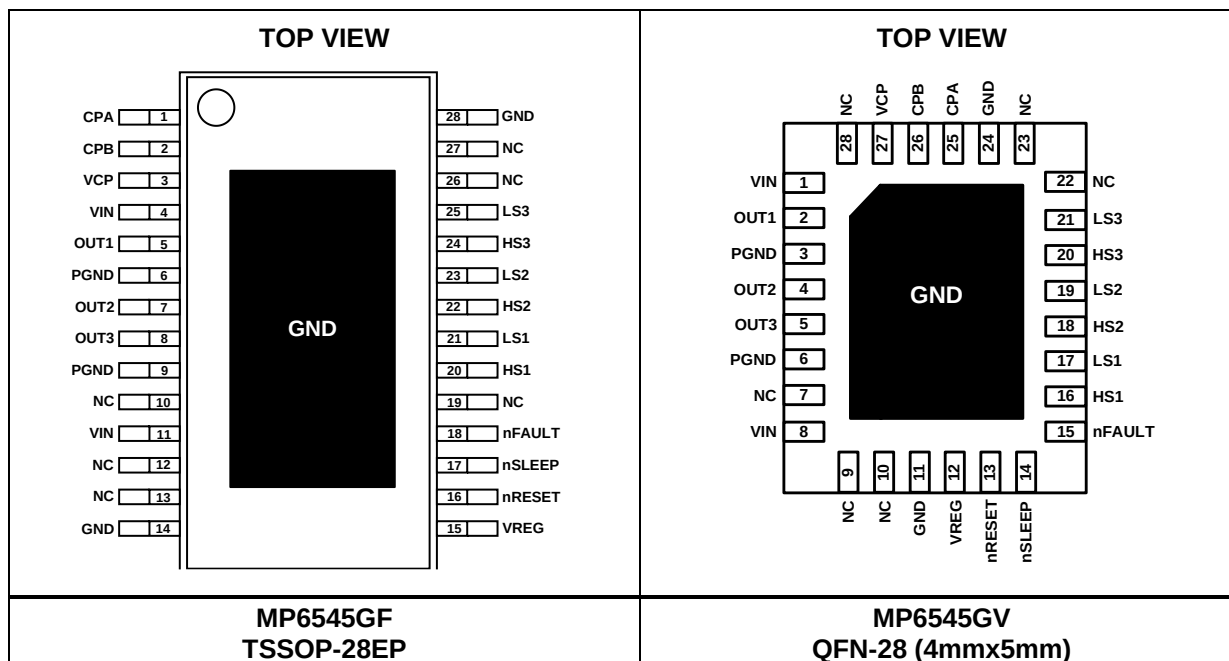
MPS: MPS prefix
YY: Year code
WW: Week code
MP6545: Part number
LLLLLLLL: Lot number

TOP MARKING (MP6545GV)

MPSYWW
MP6545
LLLLLL

MPS: MPS prefix
YY: Year code
WW: Week code
MP6545: Part number
LLLLLL: Lot number

PACKAGE REFERENCE



PIN FUNCTIONS

Pin # (QFN)	Pin # (TSSOP)	Name	Description
1, 8	4, 11	VIN	Input supply voltage. Decouple the VIN pin to ground using a minimum 100nF ceramic capacitor. Additional bulk capacitance may be required.
2	5	OUT1	Output terminal 1.
3, 6	6, 9	PGND	Power ground for half H-bridge outputs.
4	7	OUT2	Output terminal 2.
5	8	OUT3	Output terminal 3.
11, 24	14, 28	GND	Signal ground.
12	15	VREG	Internal regulator. Connect a 1 μ F, 16V ceramic capacitor (X7R) to ground.
13	16	nRESET	Reset input. Pull the nRESET pin active low to reset the protection circuits and disable the outputs. This pin has an internal pull-down resistor.
14	17	nSLEEP	Sleep mode input. Pull the nSLEEP pin logic low to enter low-power sleep mode. This pin has an internal pull-down resistor.
15	18	nFAULT	Fault indication. The nFAULT pin is an open-drain output. If used, nFAULT requires an external pull-up resistor. nFAULT is in logic low under fault conditions.
16	20	HS1	High input turns on the OUT1 high-side MOSFET (HS FET). The HS1 pin has an internal pull-down resistor.
17	21	LS1	High input turns on the OUT1 low-side MOSFET (LS FET). The LS1 pin has an internal pull-down resistor.
18	22	HS2	High input turns on the OUT2 HS-FET. The HS2 pin has an internal pull-down resistor.
19	23	LS2	High input turns on the OUT2 LS-FET. The LS2 pin has an internal pull-down resistor.
20	24	HS3	High input turns on the OUT3 HS-FET. The HS3 pin has an internal pull-down resistor.
21	25	LS3	High input turns on the OUT3 LS-FET. The LS3 pin has an internal pull-down resistor.
25	1	CPA	Charge pump capacitor. Connect a 100nF ceramic capacitor that is rated for V _{IN} between the CPA and CPB pins.
26	2	CPB	
27	3	VCP	Charge pump output. The VCP pin requires a 1 μ F, 16V ceramic capacitor to VIN.

ABSOLUTE MAXIMUM RATINGS ⁽¹⁾

Supply voltage (V_{IN})	-0.3V to +48V
OUTx voltage (V_{OUT1} , V_{OUT2} , V_{OUT3})	-0.7V to +48V
VCP, CPB	V_{IN} to $V_{IN} + 6.5V$
PGND to GND	-0.3V to +0.3V
All other pins to GND	-0.3V to +6.5V
Continuous power dissipation ($T_A = 25^\circ C$) ⁽²⁾	
QFN	3.125W
TSSOP	3.9W
Storage temperature	-55°C to +150°C
Junction temperature	150°C
Lead temperature (solder)	260°C

ESD Ratings

Human body model (HBM)	±2kV
Charged device model (CDM)	±2kV

Recommended Operating Conditions ⁽³⁾

Supply voltage (V_{IN})	4.5V to 45V
PGND to GND	-0.2V to +0.2V
Operating junction temp (T_J)	-40°C to +125°C

Thermal Resistance ⁽⁴⁾ θ_{JA} θ_{JC}

QFN-28 (4mmx5mm)	40.....9.....°C/W
TSSOP-28EP	32.....6.....°C/W

Notes:

- 1) Exceeding these ratings may damage the device.
- 2) The maximum allowable power dissipation is a function of the maximum junction temperature, T_J (MAX), the junction-to-ambient thermal resistance, θ_{JA} , and the ambient temperature, T_A . The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = $(T_J$ (MAX) - T_A) / θ_{JA} . Exceeding the maximum allowable power dissipation can produce an excessive die temperature, which may cause the regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
- 3) The device is not guaranteed to function outside of its operating conditions.
- 4) Measured on JESD51-7, a 4-layer PCB.

ELECTRICAL CHARACTERISTICS

$V_{IN} = 24V$, $T_A = 25^{\circ}C$, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Power Supply						
Input supply voltage	V_{IN}		4.5		45	V
Quiescent current	I_{INQ}	nSLEEP = 1, with no load		2.8		mA
	$I_{INSLEEP}$	nSLEEP = 0		0.9	10	μA
Internal MOSFETs						
Output on resistance	$R_{DS(ON)_{HS}}$	$I_{OUT} = 1A$, $T_J = 25^{\circ}C$		135	170	m Ω
	$R_{DS(ON)_{LS}}$	$I_{OUT} = 1A$, $T_J = 25^{\circ}C$		150	185	m Ω
Body diode forward voltage	V_F	$I_{OUT} = 1A$			1.1	V
Control Logic Inputs						
Logic-low input threshold	V_{IL}				0.8	V
Logic-high input threshold	V_{IH}		2			V
Logic input current	I_{IN_H}	$V_{IN} = 5V$	-100		+100	μA
	I_{IN_L}	$V_{IN} = 0V$	-20		+20	μA
Internal pull-down resistance	R_{PD}	To GND		100		k Ω
nFAULT Output						
Output low voltage	V_{OL}	$I_{OUT} = 5mA$			0.5	V
Output high leakage current	I_{OH}	$V_{OUT} = 5V$			1	μA
Protection Circuits						
V_{IN} under-voltage lockout (UVLO) rising threshold	V_{UVLO}				4.5	V
V_{IN} UVLO hysteresis	ΔV_{UVLO}			300		mV
V_{IN} over-voltage protection (OVP) threshold	V_{OVP}		45		48	V
Over-current (OC) trip level	I_{OCP1}	Sinking	3	4.5		A
	I_{OCP2}	Sourcing	3	4.5		A
OC deglitch time	t_{OCP}			1		μs
Thermal shutdown	T_{TSD}			165		$^{\circ}C$
Thermal shutdown hysteresis	ΔT_{TSD}			15		$^{\circ}C$

TYPICAL TIMING CHARACTERISTICS

$V_{IN} = 24V$, $T_A = 25^{\circ}C$, unless otherwise noted.

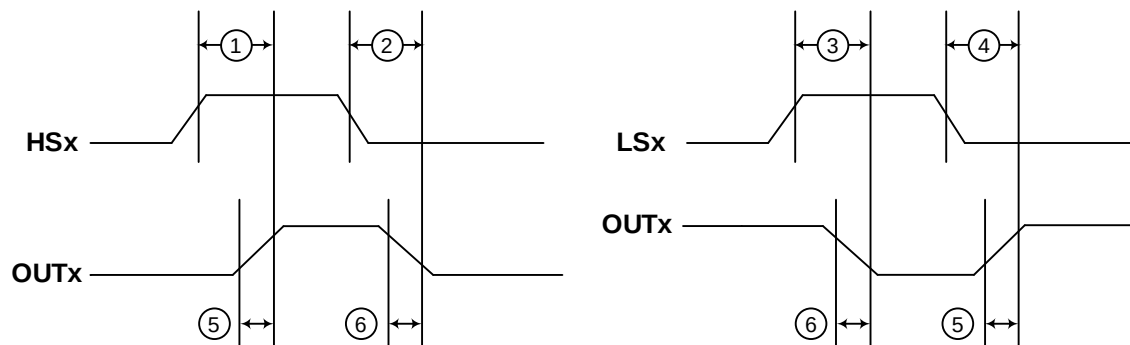
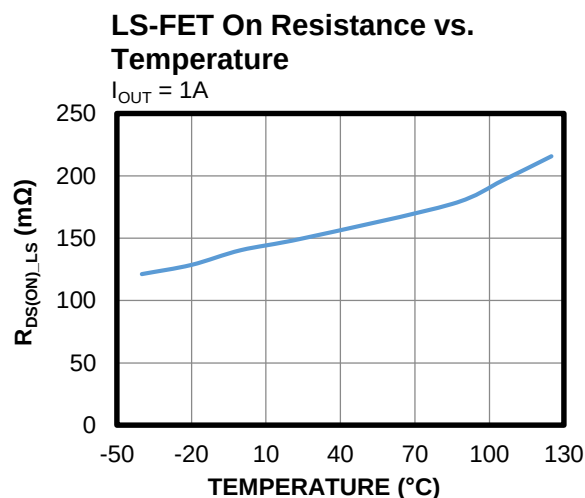
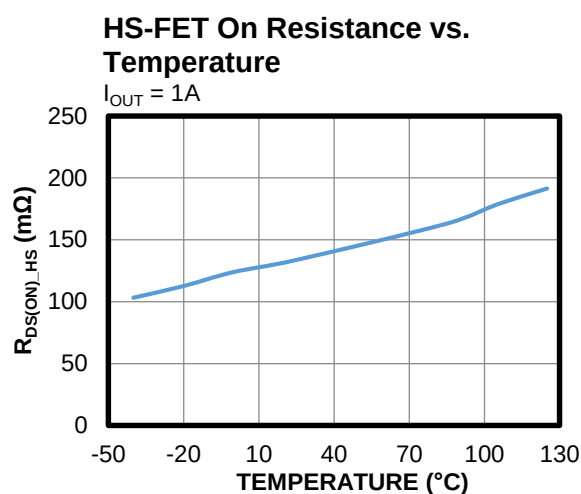
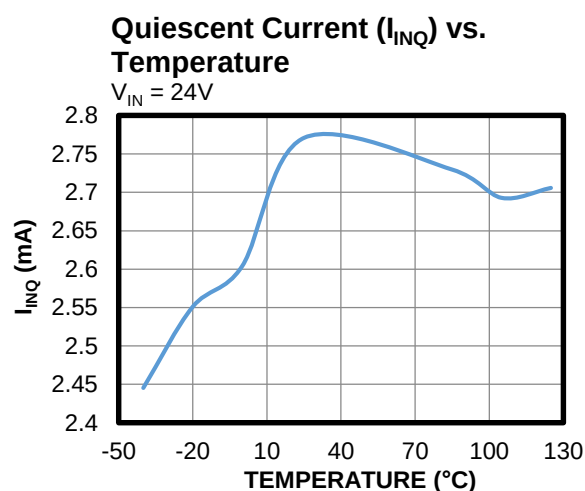
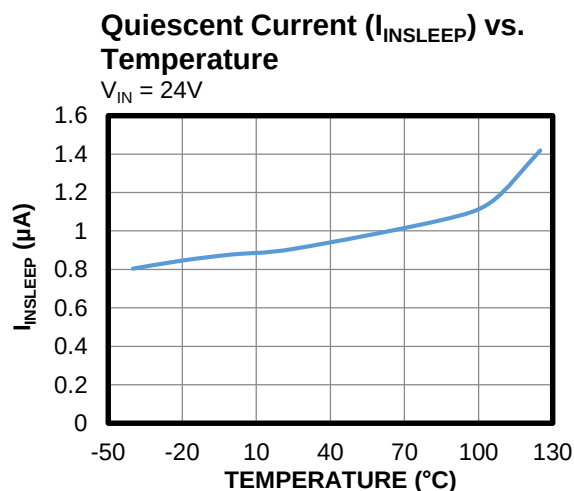
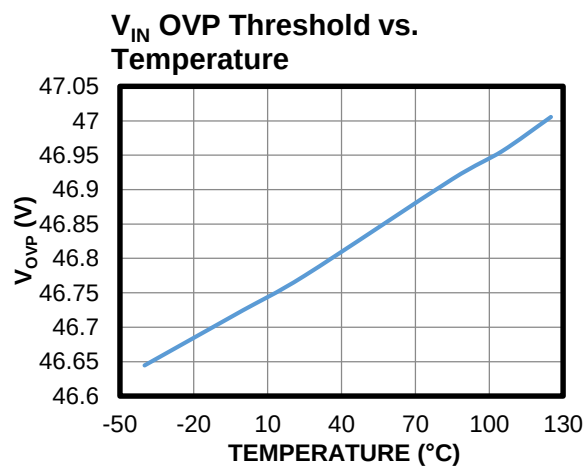
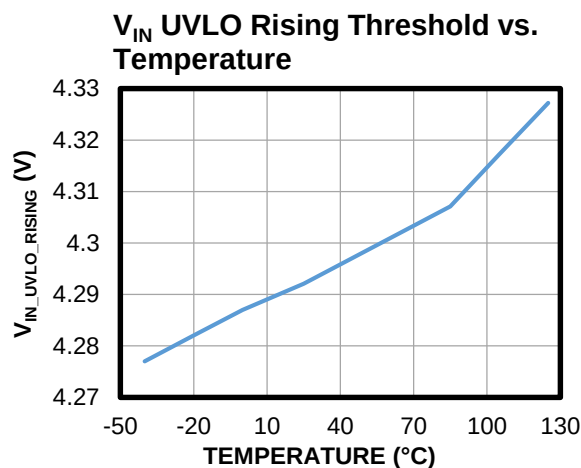


Figure 1: Timing Diagram

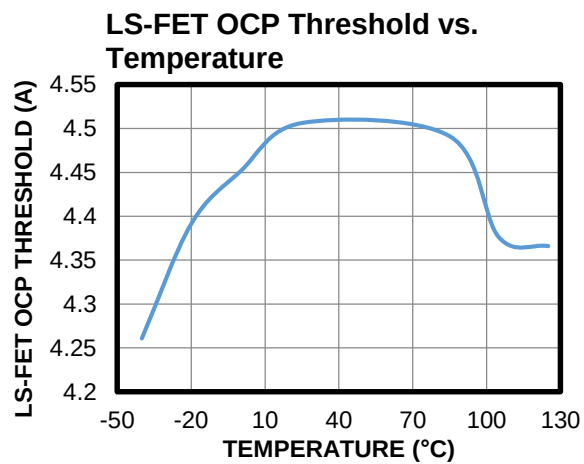
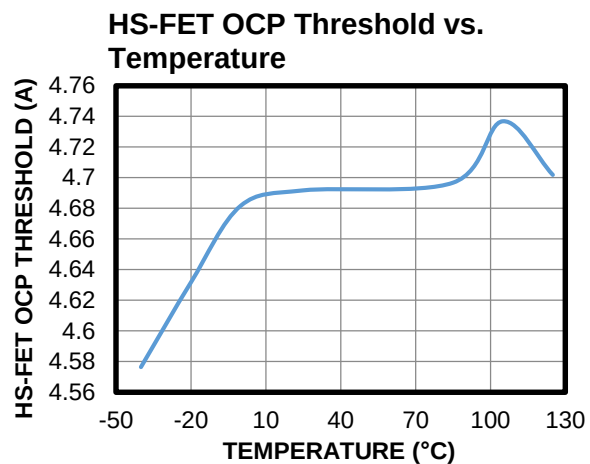
Table 1: Timing Characteristics

Parameter	Symbol	Condition	Min	Typ	Max	Units
HSx high to OUTx high delay time	t_1	10mA load connected from OUTx to GND	40		360	ns
HSx low to OUTx low delay time	t_2		40		360	ns
LSx high to OUTx low delay time	t_3	10mA load connected from OUTx to VIN	40		360	ns
LSx low to OUTx high delay time	t_4		40		360	ns
Output rising time	t_5		1		55	ns
Output falling time	t_6		1		165	ns
Dead time	--				80	ns

TYPICAL CHARACTERISTICS



TYPICAL CHARACTERISTICS *(continued)*



TYPICAL PERFORMANCE CHARACTERISTICS

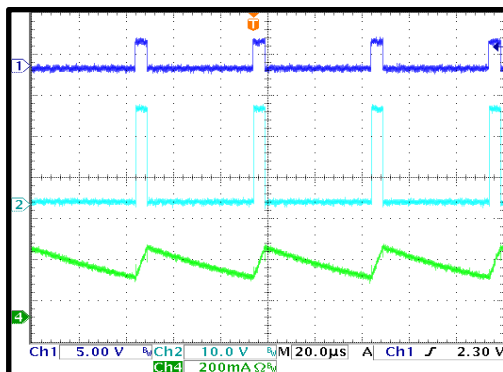
$V_{IN} = 24V$, phase 1: switching with 20kHz frequency, phase 2: LS-FET on, phase 3: disabled, $T_A = 25^\circ C$, resistor + inductor load: $4\Omega + 0.34mH$ per phase with star connection.

Steady State

Duty = 10%

CH1: HS1

CH2: V_{OUT1}

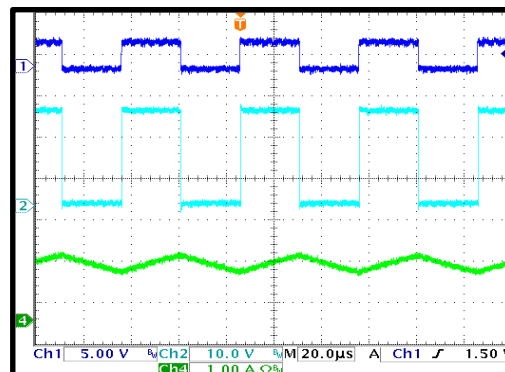
CH4: I_{OUT1}


Steady State

Duty = 50%

CH1: HS1

CH2: V_{OUT1}

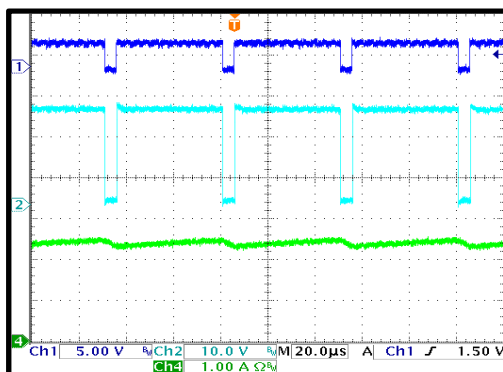
CH4: I_{OUT1}


Steady State

Duty = 90%

CH1: HS1

CH2: V_{OUT1}

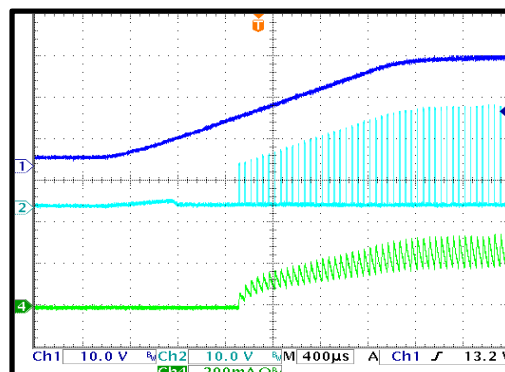
CH4: I_{OUT1}


Power Ramping Up

Duty = 10%

CH1: V_{IN}

CH2: V_{OUT1}

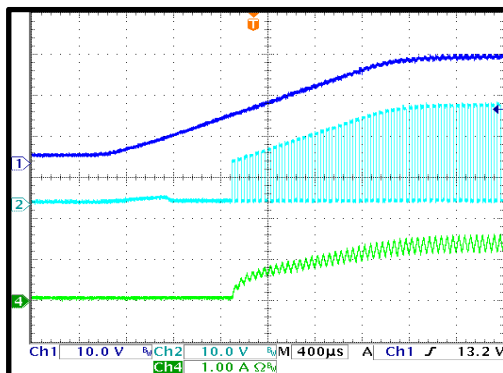
CH4: I_{OUT1}


Power Ramping Up

Duty = 50%

CH1: V_{IN}

CH2: V_{OUT1}

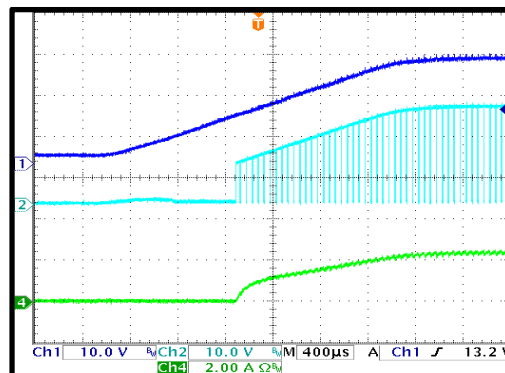
CH4: I_{OUT1}


Power Ramping Up

Duty = 90%

CH1: V_{IN}

CH2: V_{OUT1}

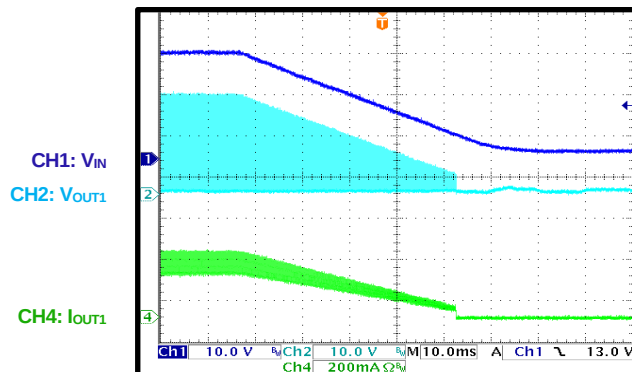
CH4: I_{OUT1}


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN} = 24V$, phase 1: switching with 20kHz frequency, phase 2: LS-FET on, phase 3: disabled, $T_A = 25^\circ C$, resistor + inductor load: $4\Omega + 0.34mH$ per phase with star connection.

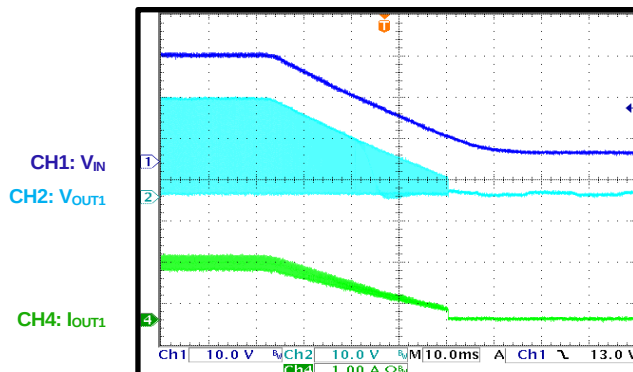
Power Ramping Down

Duty = 10%



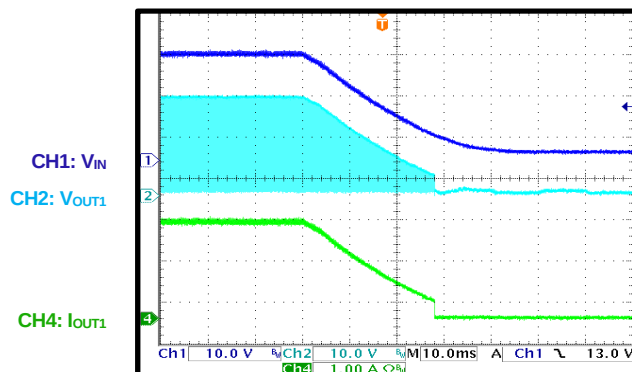
Power Ramping Down

Duty = 50%



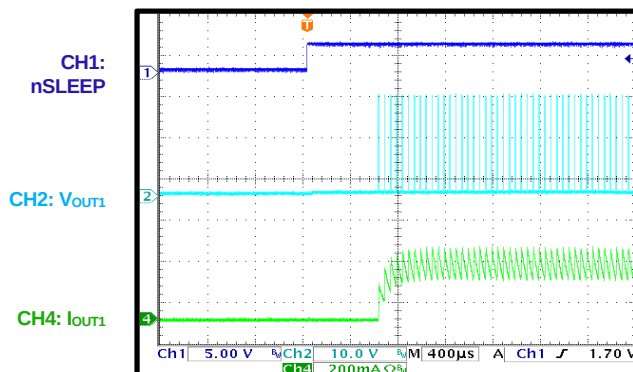
Power Ramping Down

Duty = 90%



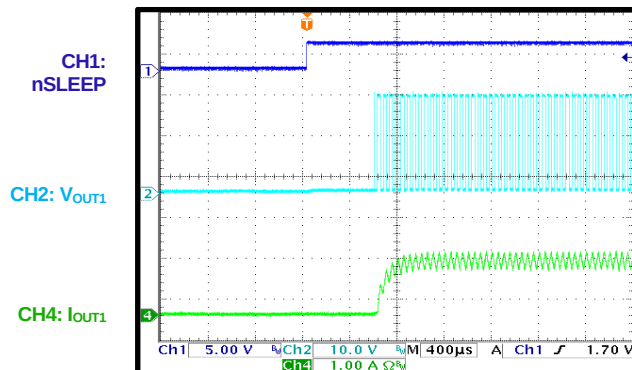
Sleep Recovery

Duty = 10%



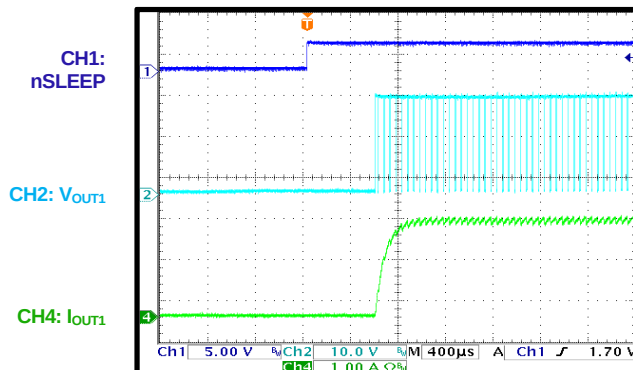
Sleep Recovery

Duty = 50%



Sleep Recovery

Duty = 90%

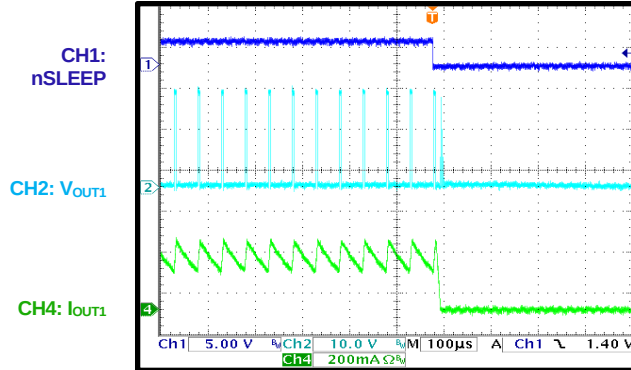


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN} = 24V$, phase 1: switching with 20kHz frequency, phase 2: LS-FET on, phase 3: disabled,
 $T_A = 25^{\circ}C$, resistor + inductor load: $4\Omega + 0.34mH$ per phase with star connection.

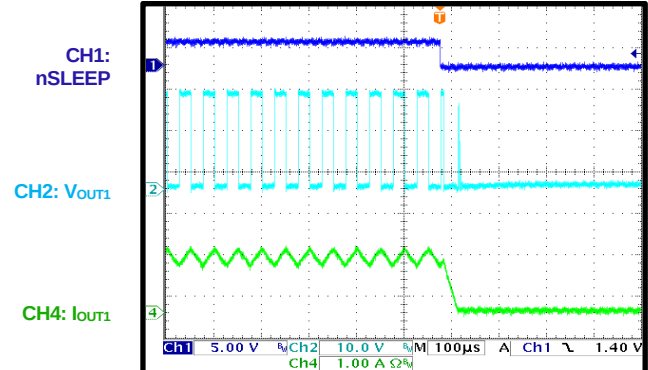
Sleep Entry

Duty = 10%



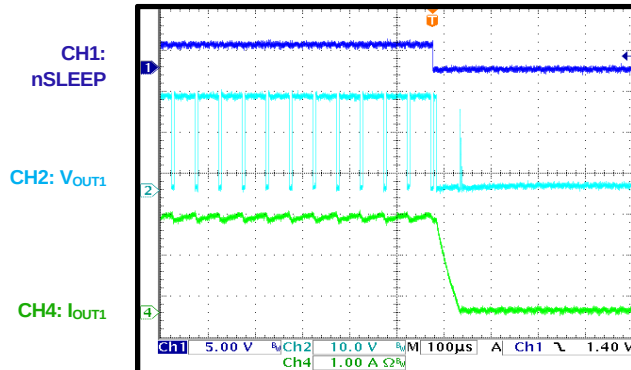
Sleep Entry

Duty = 50%



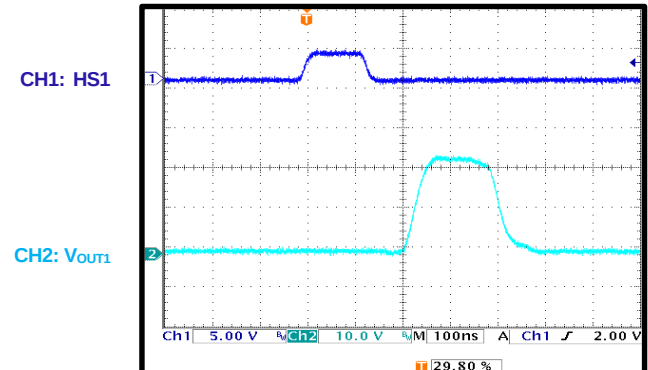
Sleep Entry

Duty = 90%



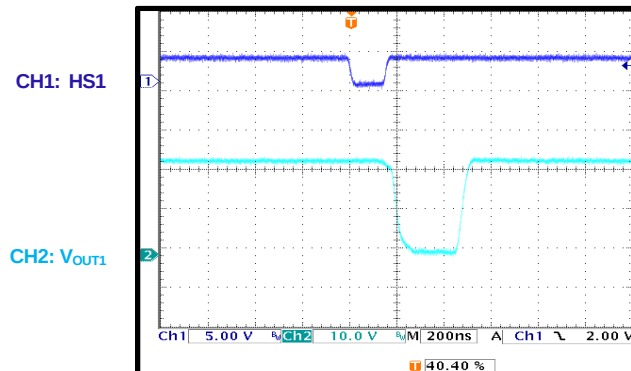
HS-FET Minimum On Time

No load



LS-FET Minimum On Time

No load



FUNCTIONAL BLOCK DIAGRAM

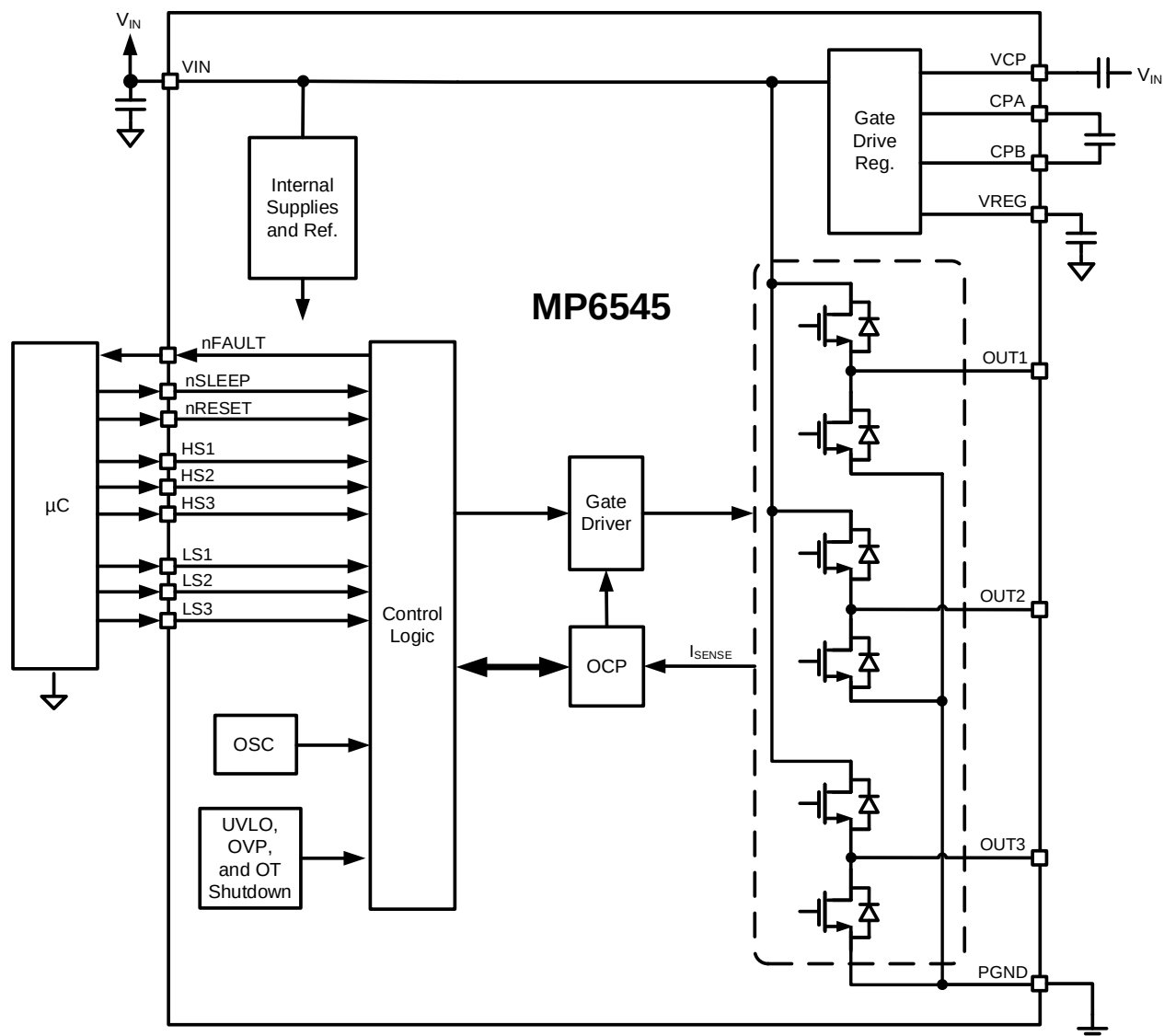


Figure 2: Functional Block Diagram

OPERATION

The MP6545 is a three-phase power stage designed to drive brushless DC (BLDC) motors or other loads. It integrates six N-channel power MOSFETs connected as three half H-bridges, with a 2.5A current capability. The device operates across a wide 4.5V to 45V supply input voltage (V_{IN}) range.

nSLEEP and nRESET

Pull the nSLEEP pin low to force the MP6545 to enter a low-power sleep mode. In this mode, the gate driver charge pump stops, and all the internal circuits and outputs are disabled. All inputs are ignored when nSLEEP is active low.

When the MP6545 exits sleep mode, 600 μ s must pass before driving the motor. This allows the internal circuitry to stabilize. nSLEEP has an internal pull-down resistor.

Pull the nRESET pin low to reset the latched protection features, including over-current protection (OCP) and over-voltage protection (OVP), as well as to disable the outputs to a high-impedance (Hi-Z) state.

Input Interface

The MP6545 includes three half-bridges that operate independently. The device has high-side (HS) and low-side (LS) inputs for each of the output pins. Table 2 shows the HSx and LSx input logic.

Table 2: HSx and LSx Input Logic

HSx	LSx	OUTx
0	0	Hi-Z
0	1	L
1	0	H
1	1	Hi-Z

Note that all logic inputs have weak, internal pull-down resistors.

Automatic Synchronous Rectification

If the output high-side MOSFET (HS-FET) and low-side MOSFET (LS-FET) are turned off, then the recirculation current must continue to flow when driving current through an inductive load. This current is typically passed through the MOSFET body diodes. To prevent excess power dissipation in the body diodes, the MP6545 implements automatic synchronous rectification.

If both the HS-FET and LS-FET are turned off and the voltage on an OUTx pin (V_{OUTx}) is pulled below ground, then the LS-FET turns on until the current flowing through it approaches 0A, or until the HS-FET is commanded to turn on. Similarly, if V_{OUTx} exceeds V_{IN} , then the HS-FET turns on until the current approaches 0A, or until the LS-FET turns on.

Internal Supplies (V_{REG} and V_{CP})

The internal regulators generate a 5V supply (V_{REG}) for the LS gate drive, and a supply exceeding V_{IN} by 5V (V_{CP}) for the HS gate drive. These supplies require external capacitors.

The V_{REG} pin requires a 1 μ F ceramic capacitor to ground. Meanwhile, the V_{CP} pin requires a 1 μ F ceramic capacitor to V_{IN} . Both capacitors should be X7R ceramic capacitors, and rated for at least 16V.

Connect the charge pump flying capacitor between the CPA and CPB pins using a 100nF ceramic capacitor (X7R) rated for at least the maximum V_{IN} .

nFAULT

The MP6545 provides a nFAULT pin to report to the system if a fault condition such as OCP, OVP, or over-temperature protection (OTP) occurs. nFAULT is an open-drain output and is pulled low during fault conditions. If used, nFAULT should be pulled high via an external pull-up resistor.

Over-Current Protection (OCP)

OCP circuitry limits the current through the HS-FET and LS-FET by disabling the gate driver. If the over-current (OC) limit threshold is reached and lasts for longer than the OC deglitch time (t_{OCP}), then all the MOSFETs in the H-bridge are disabled and nFAULT is pulled low. The driver remains disabled until the device is reset by pulling nRESET low, or cycling the power on the MP6545.

OC conditions on both the HS and LS devices (i.e. an over-current condition to ground, supply, or across a motor winding) all result in an OC shutdown.

Over-Voltage Protection (OVP)

If V_{IN} exceeds the OVP threshold (V_{OVP}), then the outputs are disabled and nFAULT is pulled low. The driver remains disabled until the device is reset by pulling nRESET low, or cycling the power on the MP6545.

Input Under-Voltage Lockout (UVLO) Protection

If V_{IN} falls below the under-voltage lockout (UVLO) threshold (V_{IN_UVLO}) at any time, then all

circuitry in the device is disabled and the internal logic resets. Once V_{IN} exceeds V_{UVLO} , the device resumes normal operation.

Thermal Shutdown

If the die temperature exceeds safe limits, then all the MOSFETs in the H-bridge are disabled and nFAULT is pulled low. Once the die temperature falls to a safe level, the MP6545 automatically resumes normal operation.

APPLICATION INFORMATION

Selecting the External Components

Bypass the two VIN pins to GND using a minimum 100nF ceramic capacitor with X7R dielectrics, placed as close to the IC as possible. Place an additional 1μF to 10μF ceramic capacitor close to the 100nF capacitor. Depending on the supply impedance and distance to other large capacitors, an electrolytic bulk capacitor may also be required to stabilize VIN.

Connect a 100nF ceramic capacitor rated for V_{IN} between the CPA and CPB pins. Connect a 1μF, 16V ceramic capacitor between the VIN and VCP pins.

Connect a 1μF, 16V ceramic capacitor with X7R dielectrics from the VREG pin to GND.

PCB Layout Guidelines

Efficient PCB layout is critical to achieve stable operation. For the best results, refer to Figure 3 and Figure 4, and follow the guidelines below:

1. Place the supply bypass and charge pump capacitors as close to the IC as possible, ideally adjacent to the pins on the same PCB layer.
2. Each VIN pin requires a bypass capacitor.
3. Place as much copper on the long pads as possible.
4. Place large copper areas on the pads and the device's outer copper layer.
5. The thermal pad should be soldered directly to the copper on the PCB.
6. Add thermal vias to transfer heat to the other PCB layers.

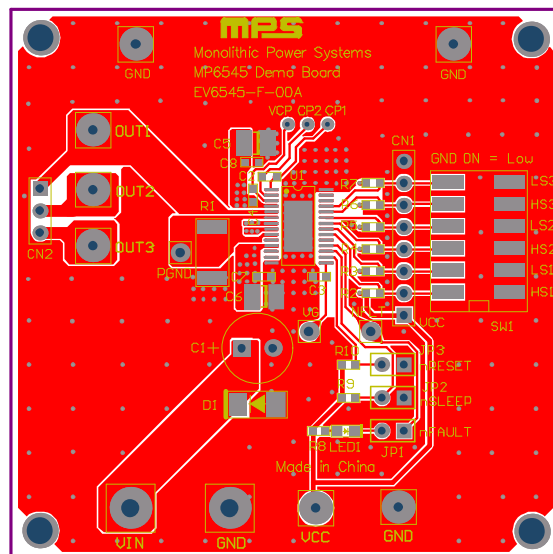


Figure 3: Recommended PCB Layout (MP6545GF)

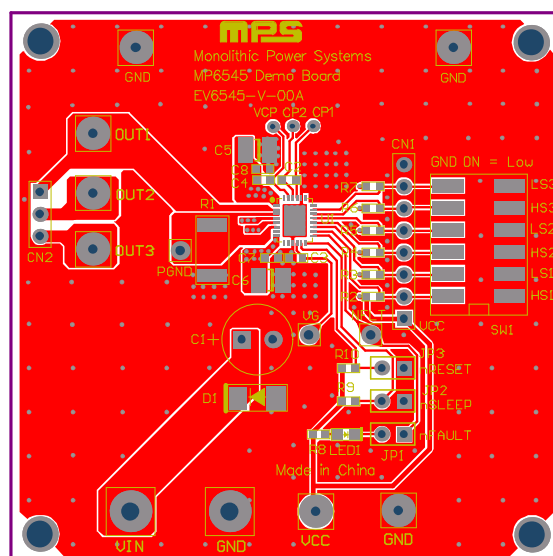


Figure 4: Recommended PCB Layout (MP6545GV)

TYPICAL APPLICATION CIRCUIT

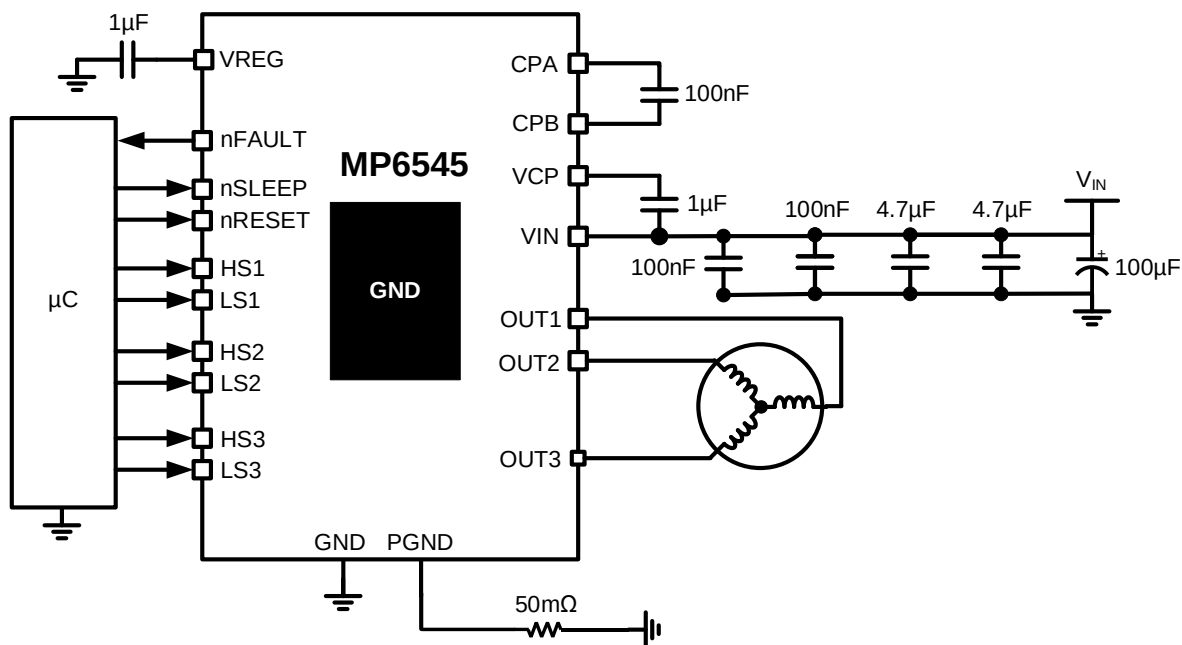
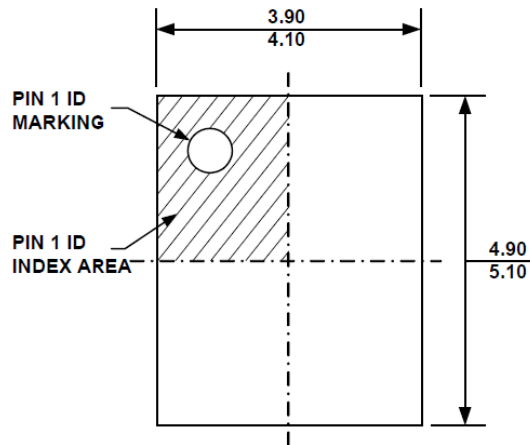


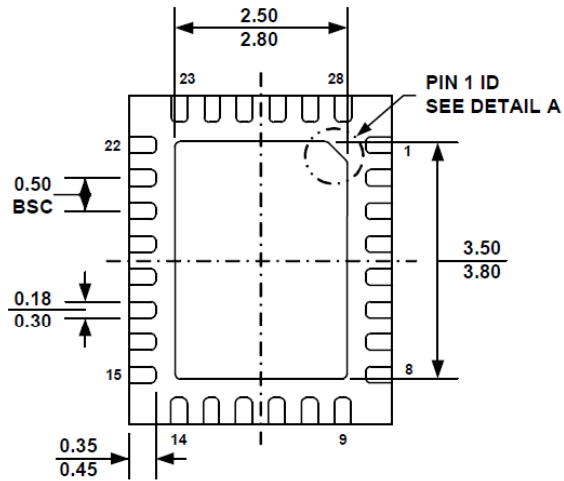
Figure 5: Typical Application Circuit

PACKAGE INFORMATION

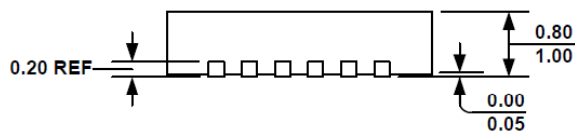
QFN-28 (4mm×5mm)



TOP VIEW



BOTTOM VIEW



SIDE VIEW

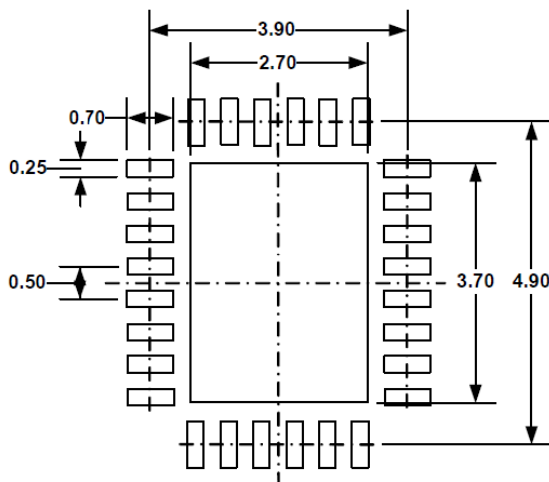
PIN 1 ID OPTION A
0.30x45° TYP.



PIN 1 ID OPTION B
R0.25 TYP.



DETAIL A



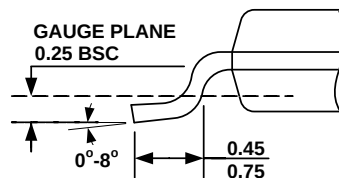
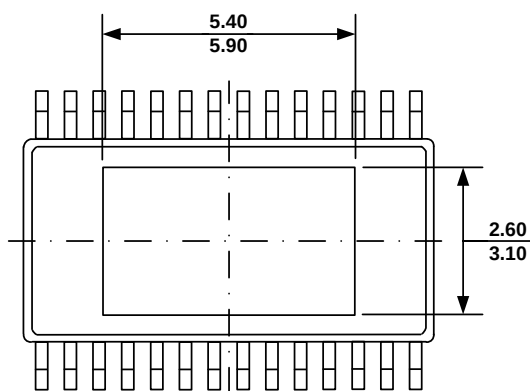
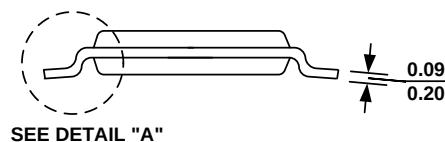
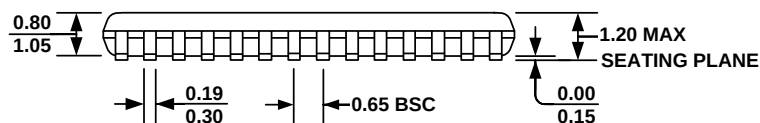
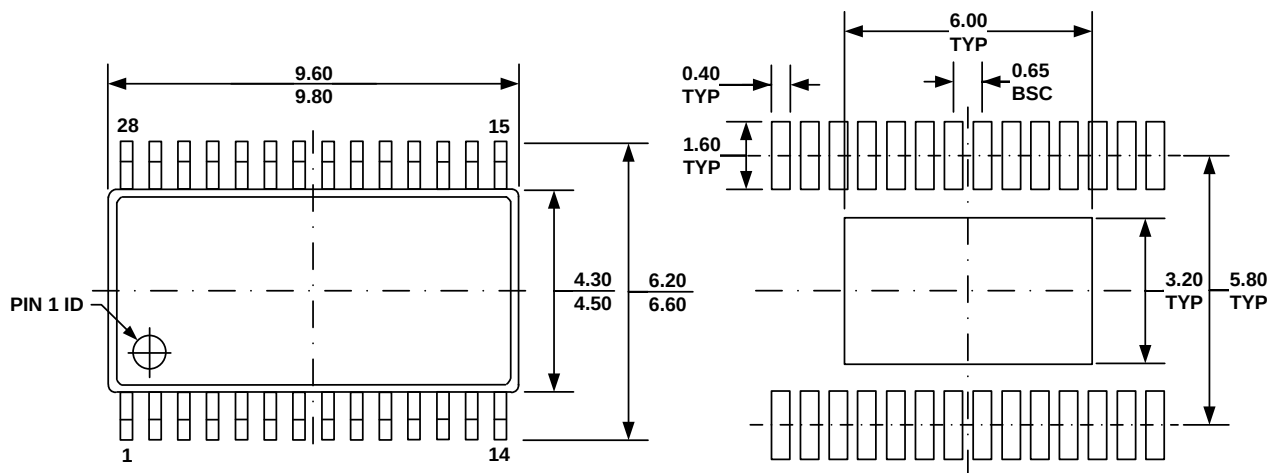
RECOMMENDED LAND PATTERN

NOTE:

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.
- 2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
- 3) LEAD COPLANARITY SHALL BE 0.10 MILLIMETER MAX.
- 4) DRAWING CONFORMS TO JEDEC MO-220, VARIATION VHGD-3.
- 5) DRAWING IS NOT TO SCALE.

PACKAGE INFORMATION (continued)

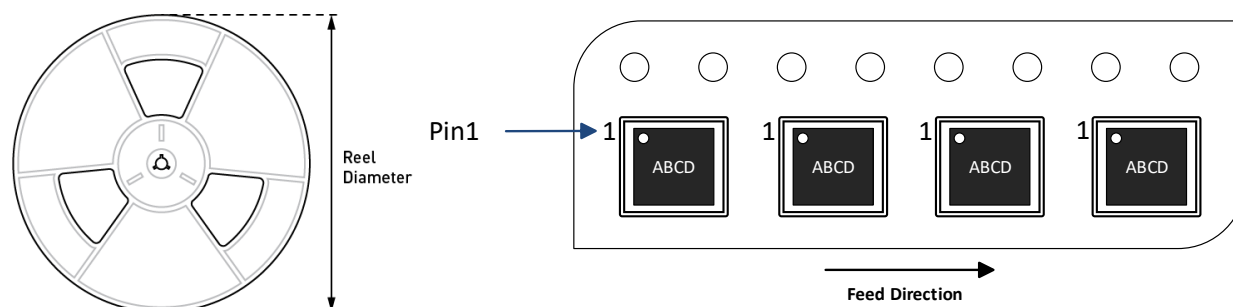
TSSOP-28EP



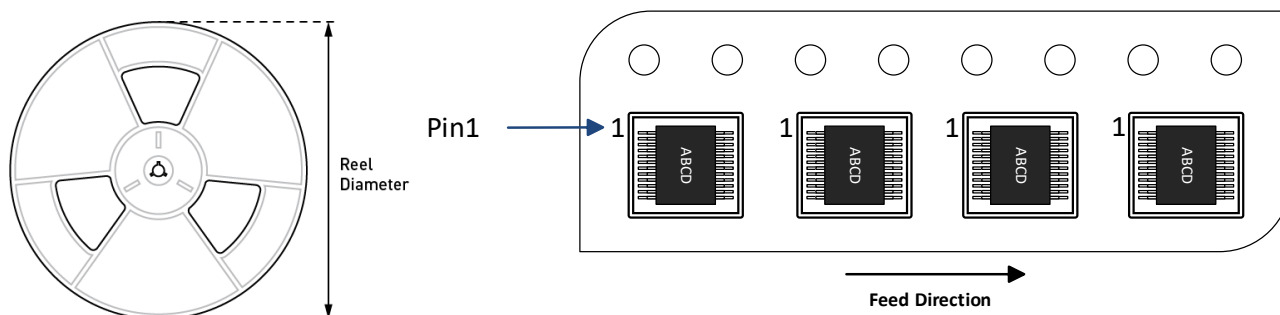
NOTE:

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.
- 2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSION OR GATE BURR.
- 3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION.
- 4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.10 MILLIMETERS MAX.
- 5) DRAWING CONFORMS TO JEDEC MO-153, VARIATION AET.
- 6) DRAWING IS NOT TO SCALE.

CARRIER INFORMATION



Part Number	Package Description	Quantity/ Reel	Quantity/ Tube	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MP6545GV-Z	QFN-28 (4mmx5mm)	5000	N/A	13in	12mm	8mm



Part Number	Package Description	Quantity/ Reel	Quantity/ Tube	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MP6545GF-Z	TSSOP-28EP	2500	50	13in	16mm	8mm

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	10/13/2022	Initial Release	-
1.1	5/12/2023	Updated the MSL rating for the MP6545GV to “2” in the Ordering Information section	2

Notice: The information in this document is subject to change without notice. Users should warrant and guarantee that third-party Intellectual Property rights are not infringed upon when integrating MPS products into any application. MPS will not assume any legal responsibility for any said applications.