LMP8645/LMP8645HV Precision High Voltage Current Sense Amplifier

Check for Samples: LMP8645, LMP8645HV

FEATURES

- **Typical values, T_A = 25°C**
- **High common-mode voltage Range**
  - **LMP8645 -2V to 42V**
  - **LMP8645HV -2V to 76V**
- **Supply voltage Range 2.7V to 12V**
- **Gain configurable with a single resistor**
- **Max variable gain accuracy (with external resistor) 2.0%**
- **Transconductance 200 µA/V**
- **Low offset voltage 1 mV**
- **Input bias 12 µA**
- **PSRR 90 dB**
- **CMRR 95 dB**
- **Temperature Range −40°C to 125°C**
- **6-Pin TSOT Package**

APPLICATIONS

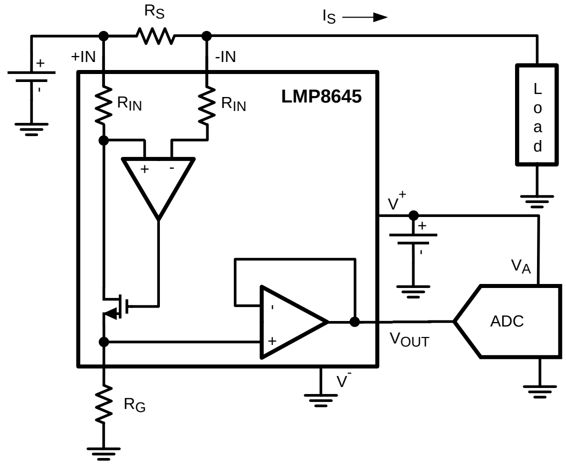
- **High-side current sense**
- **Vehicle current measurement**
- **Motor controls**
- **Battery monitoring**
- **Remote sensing**
- **Power management**

DESCRIPTION

The LMP8645 and the LMP8645HV are precision current sense amplifiers that detect small differential voltages across a sense resistor in the presence of high input common mode voltages with a supply voltage Range from 2.7V to 12V.

The LMP8645 accepts input signals with common mode voltage Range from -2V to 42V, while the LMP8645HV accepts input signal with common mode voltage Range from -2V to 76V. The LMP8645 and LMP8645HV have adjustable gain for applications where supply current and high common mode voltage are the determining factors. The gain is configured with a single resistor, providing a high level of flexibility, the accuracy could be as low as 2% (max) including the gain setting resistor. The output is buffered in order to provide low output impedance. This high side current sense amplifier is ideal for sensing and monitoring currents in DC or battery powered systems, excellent AC and DC specifications over temperature, and keeps errors in the current sense loop to a minimum. The LMP8645 is an ideal choice for industrial, automotive and consumer applications, and it is available in TSOT-6 package.

Typical Application



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings [(1)]

ESD Tolerance [(2)]	
Human Body Model	
For input pins +IN, -IN	±5000V
For all other pins	±2000V
Machine Model	200V
Charge device model	1250V
Supply Voltage ($V_S = V^+ - V^-$)	13.2V
Differential voltage +IN- (-IN)	6V
Voltage at pins +IN, -IN	
LMP8645HV	-6V to 80V
LMP8645	-6V to 60V
Voltage at R_G pin	13.2V
Voltage at OUT pin	V^- to V^+
Storage Temperature Range	-65°C to 150°C
Junction Temperature [(3)]	150°C
For soldering specifications, see product folder at www.national.com and www.national.com/ms/MS/MS-SOLDERING.pdf	

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the Electrical Characteristics Tables.
(2) Human Body Model, applicable std. MIL-STD-883, Method 3015.7. Machine Model, applicable std. JESD22-A115-A (ESD MM std. of JEDEC) Field-Induced Charge-Device Model, applicable std. JESD22-C101-C (ESD FICDM std. of JEDEC).
(3) The maximum power dissipation must be derated at elevated temperatures and is dictated by $T_{J(MAX)}$, θ_{JA}, and the ambient temperature, T_A. The maximum allowable power dissipation $P_{DMAX} = (T_{J(MAX)} - T_A)/ \theta_{JA}$ or the number given in Absolute Maximum Ratings, whichever is lower.

Operating Ratings [(1)]

Supply Voltage ($V_S = V^+ - V^-$)	2.7V to 12V

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the Electrical Characteristics Tables.

Operating Ratings [1] (continued)

Temperature Range [2]	-40°C to 125°C
Package Thermal Resistance [2]	
TSOT-6	96°C/W

(2) The maximum power dissipation must be derated at elevated temperatures and is dictated by $T_{J(MAX)}$, θ_{JA}, and the ambient temperature, T_A. The maximum allowable power dissipation $P_{DMAX} = (T_{J(MAX)} - T_A)/ \theta_{JA}$ or the number given in Absolute Maximum Ratings, whichever is lower.

2.7V Electrical Characteristics [1]

Unless otherwise specified, all limits guaranteed for at T_A = 25°C, $V_S=V^+ - V^-$, V^+ = 2.7V, V^- = 0V, −2V < V_{CM} < 76V, R_G= 25kΩ, R_L = 10 MΩ. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Condition	Min [2]	Typ [3]	Max [2]	Units
V_{OS}	Input Offset Voltage	V_{CM} = 2.1V	-1 **-1.7**		1 **1.7**	mV
TCV_{OS}	Input Offset Voltage Drift [4] [5]	V_{CM} = 2.1V			7	μV/°C
I_B	Input Bias Current [6]	V_{CM} = 2.1V		12	20	μA
e_{ni}	Input Voltage Noise [5]	f > 10 kHz, R_G = 5 kΩ		120		$nV/\sqrt{Hz}$
$V_{SENSE(MAX)}$	Max Input Sense Voltage [5]	V_{CM} = 12V, R_G = 5 kΩ		600		mV
Gain A_V	Adjustable Gain Setting [5]	V_{CM} = 12V	1		100	V/V
Gm	Transconductance	V_{CM} = 2.1V		200		μA/V
	Accuracy	V_{CM} = 2.1V	-2 **-3.4**		2 **3.4**	%
	Gm drift [5]	−40°C to 125°C, V_{CM}=2.1V			140	ppm /°C
PSRR	Power Supply Rejection Ratio	V_{CM} = 2.1V, 2.7V < V^+ < 12V	90			dB
CMRR	Common Mode Rejection Ratio	LMP8645HV 2.1V < V_{CM} < 76V LMP8645 2.1V < V_{CM}< 42V	95			dB
		-2V <V_{CM} < 2V	60			
BW	−3 dB Bandwidth [5]	R_G = 10 kΩ,, C_G = 4 pF V_{SENSE} = 400 mV, C_L = 30 pF ,R_L= 1MΩ		990		kHz
		R_G = 25 kΩ, C_G = 4 pF, V_{SENSE} = 200 mV, C_L = 30 pF, R_L = 1MΩ		260		
		Rg = 50kΩ, C_G = 4 pF, V_{SENSE} = 100 mV, C_L = 30 pF, R_L = 1MΩ		135		
SR	Slew Rate [7] [5]	V_{CM} =5V, C_G = 4 pF, V_{SENSE} from 25 mV to 175 mV, C_L = 30 pF, R_L = 1MΩ		0.5		V/μs
I_S	Supply Current	V_{CM} = 2.1V		380	525 **710**	uA
		V_{CM} = −2V		2000	2500 **2700**	
V_{OUT}	Maximum Output Voltage	V_{CM} = 2.1V, Rg= 500 kΩ	1.2			V
	Minimum Output Voltage	V_{CM} = 2.1V			20	mV
I_{OUT}	Output current [5]	Sourcing, V_{OUT}= 600mV, Rg = 150kΩ		5		mA
		Sinking, V_{OUT}= 600mV, Rg = 150kΩ		5		
C_{LOAD}	Max Output Capacitance Load [5]			30		pF

(1) Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that $T_J = T_A$. No guarantee of parametric performance is indicated in the electrical tables under conditions of internal self-heating where $T_J > T_A$.
(2) All limits are guaranteed by testing, design, or statistical analysis.
(3) Typical values represent the most likely parametric norm at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not guaranteed on shipped production material.
(4) Offset voltage temperature drift is determined by dividing the change in V_{OS} at the temperature extremes by the total temperature change.
(5) This parameter is guaranteed by design and/or characterization and is not tested in production.
(6) Positive Bias Current corresponds to current flowing into the device.
(7) The number specified is the average of rising and falling slew rates and measured at 90% to 10%.

5V Electrical Characteristics [(1)]

Unless otherwise specified, all limits guaranteed for at T_A = 25°C, V_S=V^+-V^-, V^+ = 5V, V^- = 0V, −2V < V_{CM} < 76V, R_g= 25kΩ, R_L = 10 MΩ. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Condition	Min [(2)]	Typ [(3)]	Max [(2)]	Units
V_{OS}	Input Offset Voltage	V_{CM} = 2.1V	-1 **-1.7**		1 **1.7**	mV
TCV_{OS}	Input Offset Voltage Drift [(4)] [(5)]	V_{CM} = 2.1V			7	µV/°C
I_B	Input Bias Current [(6)]	V_{CM} = 2.1V		12.5	22	µA
e_{ni}	Input Voltage Noise [(5)]	f > 10 kHz, R_G = 5 kΩ		120		nV/$\sqrt{Hz}$
$V_{SENSE(MAX)}$	Max Input Sense Voltage [(5)]	V_{CM} = 12V, R_G = 5 kΩ		600		mV
Gain A_V	Adjustable Gain Setting [(5)]	V_{CM} = 12V	1		100	V/V
Gm	Transconductance	V_{CM} = 2.1V		200		µA/V
	Accuracy	V_{CM} = 2.1V	-2 **-3.4**		2 **3.4**	%
	Gm drift [(5)]	−40°C to 125°C, V_{CM}= 2.1V			140	ppm /°C
PSRR	Power Supply Rejection Ratio	V_{CM} = 2.1V, , 2.7V < V^+ < 12V	90			dB
CMRR	Common Mode Rejection Ratio	LMP8645HV 2.1V <V_{CM} < 76V LMP8645 2.1V <V_{CM}< 42V	95			dB
		-2V < V_{CM} < 2V	60			
BW	−3 dB Bandwidth [(5)]	R_G= 10 kΩ, C_G = 4 pF V_{SENSE} = 400 mV, C_L = 30 pF, R_L = 1MΩ		850		kHz
		R_G= 25 kΩ, C_G = 4 pF, V_{SENSE} = 300 mV, C_L = 30 pF, R_L = 1MΩ		260		
		R_G= 50 kΩ, C_G = 4 pF, V_{SENSE} = 300mV, C_L = 30 pF, R_L = 1MΩ		140		
SR	Slew Rate [(7)] [(5)]	V_{CM} = 5V, C_G = 4 pF, V_{SENSE} from 100 mV to 500 mV, C_L = 30 pF, R_L= 1MΩ		0.5		V/µs
I_S	Supply Current	V_{CM} = 2.1V		450	610 **780**	uA
		V_{CM} = −2V		2100	2800 **3030**	
V_{OUT}	Maximum Output Voltage	V_{CM} =5V, Rg= 500 kΩ	3.3			V
	Minimum Output Voltage	V_{CM} =2.1V			22	mV
I_{OUT}	Output current [(5)]	Sourcing, V_{OUT}= 1.65V, Rg= 150kΩ		5		mA
		Sinking, V_{OUT}= 1.65V, Rg= 150kΩ		5		
C_{LOAD}	Max Output Capacitance Load [(5)]			30		pF

(1) Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that T_J = T_A. No guarantee of parametric performance is indicated in the electrical tables under conditions of internal self-heating where T_J > T_A.
(2) All limits are guaranteed by testing, design, or statistical analysis.
(3) Typical values represent the most likely parametric norm at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not guaranteed on shipped production material.
(4) Offset voltage temperature drift is determined by dividing the change in V_{OS} at the temperature extremes by the total temperature change.
(5) This parameter is guaranteed by design and/or characterization and is not tested in production.
(6) Positive Bias Current corresponds to current flowing into the device.
(7) The number specified is the average of rising and falling slew rates and measured at 90% to 10%.

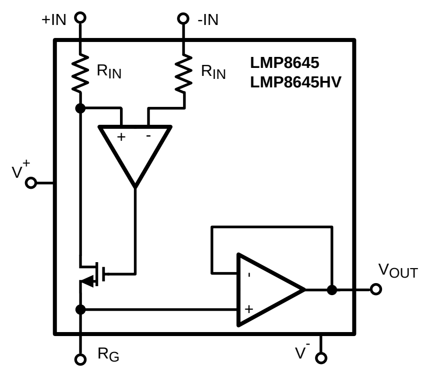
12V Electrical Characteristics [1]

Unless otherwise specified, all limits guaranteed for at T_A = 25°C, $V_S=V^+-V^-$, V^+ = 12V, V^- = 0V, −2V < V_{CM} < 76V, R_g= 25kΩ, R_L = 10 MΩ. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Condition	Min [2]	Typ [3]	Max [2]	Units
V_{OS}	Input Offset Voltage	V_{CM} = 2.1V	-1 **-1.7**		1 **1.7**	mV
TCV_{OS}	Input Offset Voltage Drift [4] [5]	V_{CM} = 2.1V			7	μV/°C
I_B	Input Bias Current [6]	V_{CM} = 2.1V		13	23	μA
e_{ni}	Input Voltage Noise [5]	f > 10 kHz, R_G = 5 kΩ		120		$nV/\sqrt{Hz}$
$V_{SENSE(MAX)}$	Max Input Sense Voltage [5]	V_{CM} =12V, R_G = 5 kΩ		600		mV
Gain A_V	Adjustable Gain Setting [5]	V_{CM} = 12V	1		100	V/V
Gm	Transconductance	V_{CM} = 2.1V		200		μA/V
	Accuracy	V_{CM} = 2.1V	-2 **-3.4**		2 **3.4**	%
	Gm drift [5]	−40°C to 125°C, V_{CM} =2.1V			140	ppm /°C
PSRR	Power Supply Rejection Ratio	V_{CM} =2.1V, 2.7V <V^+ < 12V	90			dB
CMRR	Common Mode Rejection Ratio	LMP8645HV 2.1V <V_{CM} < 76V LMP8645 2.1V <V_{CM}< 42V	95			dB
		–2V <V_{CM} < 2V	60			
BW	−3 dB Bandwidth [5]	R_G = 10 kΩ, C_G = 4 pF V_{SENSE} = 400 mV, C_L = 30 pF, R_L= 1MΩ		860		kHz
		R_G = 25 kΩ, C_G = 4 pF, V_{SENSE} = 400 mV, C_L = 30 pF, R_L= 1MΩ		260		
		R_G = 50 kΩ, C_G = 4 pF, V_{SENSE} =400 mV, C_L = 30 pF, R_L= 1MΩ		140		
SR	Slew Rate [7] [5]	V_{CM} = 5V, C_G = 4 pF, V_{SENSE} from 100 mV to 500 mV, C_L = 30 pF, R_L=1MΩ		0.6		V/μs
I_S	Supply Current	V_{CM} = 2.1V		555	765 **920**	uA
		V_{CM} = −2V		2200	2900 **3110**	
V_{OUT}	Maximum Output Voltage	V_{CM} = 12V, R_G= 500kΩ	10.2			V
	Minimum Output Voltage	V_{CM} = 2.1V			24	mV
I_{OUT}	Output current [5]	Sourcing, V_{OUT}= 5.25V, Rg= 150kΩ		5		mA
		Sinking, V_{OUT}= 5.25V, Rg= 150kΩ		5		
C_{LOAD}	Max Output Capacitance Load [5]			30		pF

(1) Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that $T_J = T_A$. No guarantee of parametric performance is indicated in the electrical tables under conditions of internal self-heating where $T_J > T_A$.
(2) All limits are guaranteed by testing, design, or statistical analysis.
(3) Typical values represent the most likely parametric norm at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not guaranteed on shipped production material.
(4) Offset voltage temperature drift is determined by dividing the change in V_{OS} at the temperature extremes by the total temperature change.
(5) This parameter is guaranteed by design and/or characterization and is not tested in production.
(6) Positive Bias Current corresponds to current flowing into the device.
(7) The number specified is the average of rising and falling slew rates and measured at 90% to 10%.

Block Diagram



Connection Diagram

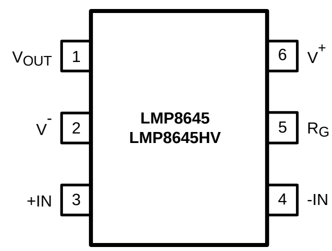


Figure 1. 6-Pin TSOT - Top View

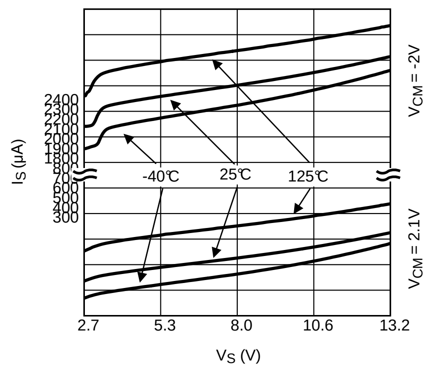
Table 1. Pin Descriptions

Pin	Name	Description
1	V_{OUT}	Single Ended Output
2	V^-	Negative Supply Voltage
3	+IN	Positive Input
4	-IN	Negative Input
5	R_G	External Gain Resistor
6	V^+	Positive Supply Voltage

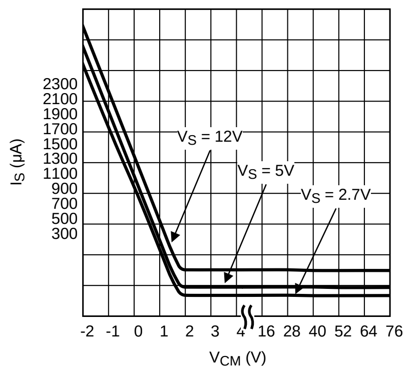
Typical Performance Characteristics

Unless otherwise specified: T_A = 25°C, V_S=V^+-V^-, V_{SENSE}= +IN - (-IN), R_L = 10 MΩ.

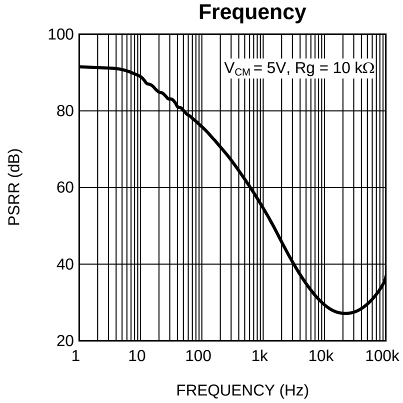
Supply Curent vs. Supply Voltage



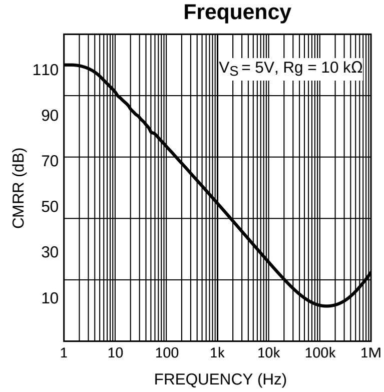
Supply current vs. V_{CM}



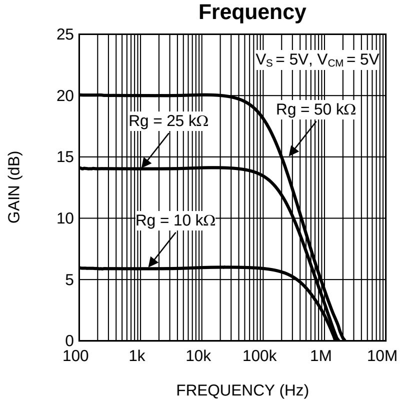
AC PSRR vs. Frequency



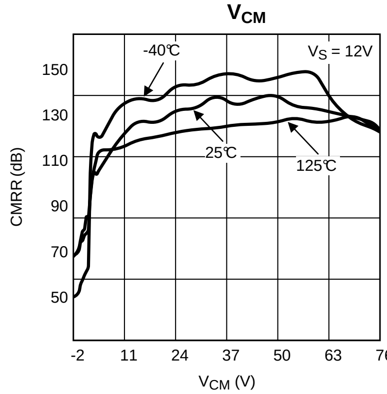
AC CMRR vs. Frequency



Gain vs. Frequency



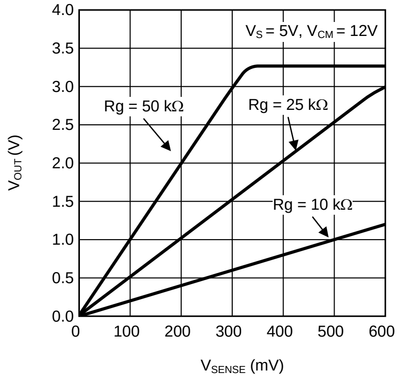
CMRR vs. V_{CM}



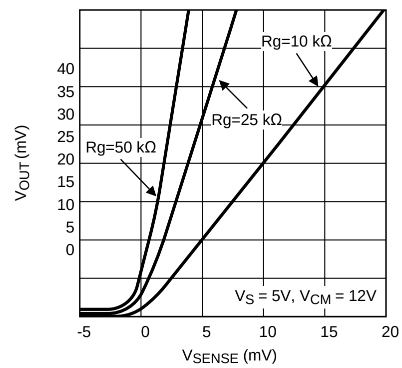
Typical Performance Characteristics (continued)

Unless otherwise specified: T_A = 25°C, V_S=V^+-V^-, V_{SENSE}= +IN - (-IN), R_L = 10 MΩ.

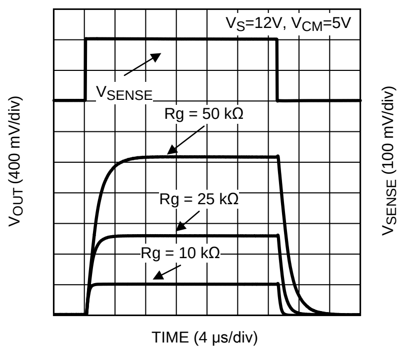
Output voltage vs. V_{SENSE}



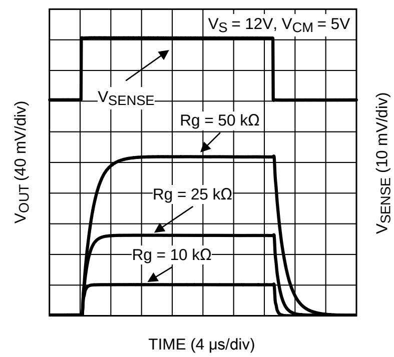
Output voltage vs. V_{SENSE} (ZOOM close to 0V)



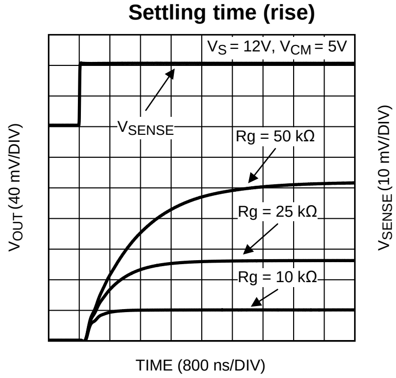
Large Step response



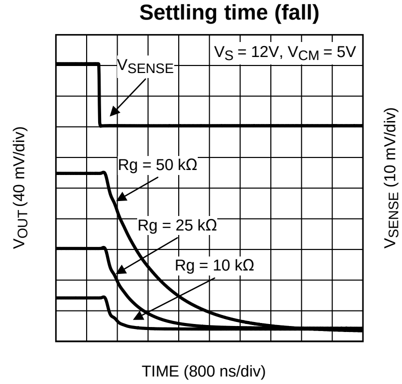
Small Step response



Settling time (rise)



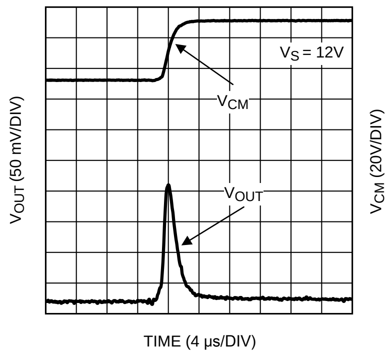
Settling time (fall)



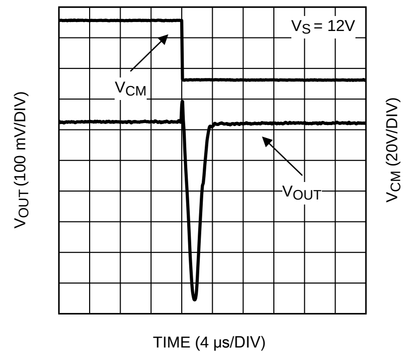
Typical Performance Characteristics (continued)

Unless otherwise specified: T_A = 25°C, V_S=V^+-V^-, V_{SENSE}= +IN - (-IN), R_L = 10 MΩ.

Common mode step response (rise)



Common mode step response (fall)



Application Information

GENERAL

The LMP8645 and LMP8645HV are single supply high side current sense amplifiers with variable gain selected through an external resistor and a common mode voltage Range of -2V to 42V or -2V to 76V depending on the grade.

The sense voltage is amplified by a user-selected gain and level shifted from the positive power supply to a ground-referred output.

THEORY OF OPERATION

As seen from the picture below, the current flowing through R_S develops a voltage drop equal to V_{SENSE} across R_S. The high impedance inputs of the amplifier doesn't conduct this current and the high open loop gain of the sense amplifier forces its non-inverting input to the same voltage as the inverting input. In this way the voltage drop across R_{IN} matches V_{SENSE}. A current proportional to I_S according to the following relation:

$$I_S' = V_{SENSE}/R_{IN} = R_S*I_S/R_{IN}\text{ , where }R_{IN} = 1/Gm \quad (1)$$

flows entirely in the external gain resistor developing a voltage drop equal to

$$V_G = I_S' *R_{GAIN} = (V_{SENSE}/R_{IN}) *R_{GAIN} = ((R_S*I_S)/R_{IN})*R_{GAIN} \quad (2)$$

This voltage is buffered and showed at the output with a very low impedance allowing a very easy interface of the LMP8645 with other ICs (ADC, µC…).

$$V_{OUT} = (R_S*I_S)*G\text{, where }G = R_{GAIN}/R_{IN} \quad (3)$$

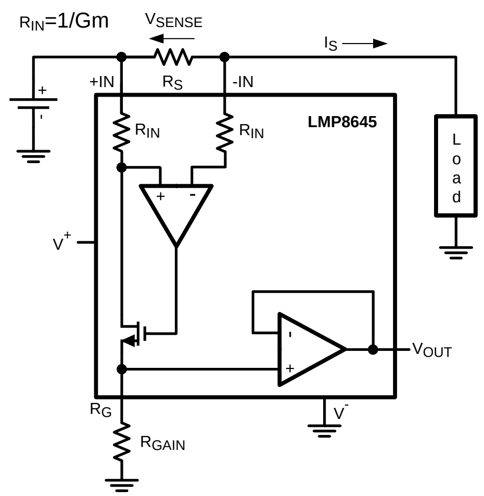


Figure 2. Current monitor

SELECTION OF THE SHUNT RESISTOR

The accuracy of the current measurement strictly depends on the value of the shunt resistor R_S. Its value depends on the application and it is a compromise between small-signal accuracy and maximum permissible voltage loss in the measurement section. High values of R_S provide better accuracy at lower currents by minimizing the effects of offset, while low values of R_S minimize voltage loss in the supply section. For most applications, best performance is obtained with an R_S value that provides a full-scale shunt voltage Range of 100 mV to 200 mV.

SELECTION OF THE GAIN RESISTOR

In the LMP8645 and LMP8645HV the gain is selected through an external resistor connected to the R_G pin. Moreover the gain resistor R_{GAIN} determines the voltage of the output buffer which is related to the supply voltage and to the common mode voltage of the input signal. The gain resistor must be chosen such that the max output voltage does not exceed the LMP8645 max output voltage rating for a given common mode voltage.

The following equations explain how to select the gain resistor for various Range of the input common mode voltage.

Range 1 $-2V < V_{CM} \leq 1.8V$ (4)

The max voltage at the RG pin is given by the following inequality $V_{RG}=V_{sense}*R_{GAIN}*Gm \leq \min(1.3V; Vout\_max)$ where Vout_max is the maximum allowable output voltage according to the Electrical Tables.All the gain resistors (R_{GAIN}) which respect the previous inequality are allowed. The graphical representation in Figure 3 helps in the selection; all the combinations (V_{SENSE}, R_{GAIN}) below the curve are allowed.

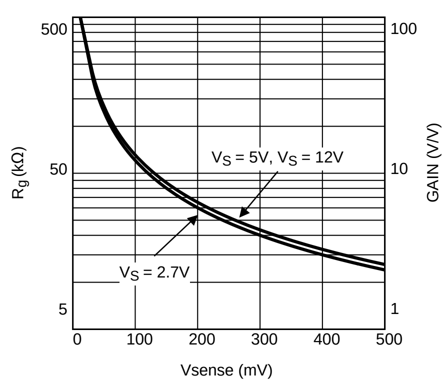


Figure 3. Allowed Gains for Range 1

As a consequence once selected the gain (R_{GAIN}) the V_{SENSE} Range is fixed too. For example if an application required a Gain of 10, R_G will be 50 kΩ and V_{SENSE} will be in the Range 10 mV to 100 mV.

Range 2 $1.8V < V_{CM} \le V_S$ (5)

In this Range the max voltage at the R_G pin is related to the common mode voltage and V_{SENSE}. So all the R_{GAIN} resistors which respect the following inequalities are allowed:

$V_{RG} \le$ min (Vout_max; (V_{CM} - V_{sense}-250mV)) where $V_{RG} = V_{SENSE}{*}R_{GAIN}{*}Gm$ and Vout_max is the maximum allowable output voltage according to the Electrical Tables. (6)

The graphical representation in Figure 4 helps in the selection; all the combinations (V_{SENSE}, R_{GAIN}) below the curves for given V_{CM} and supply voltage are allowed.

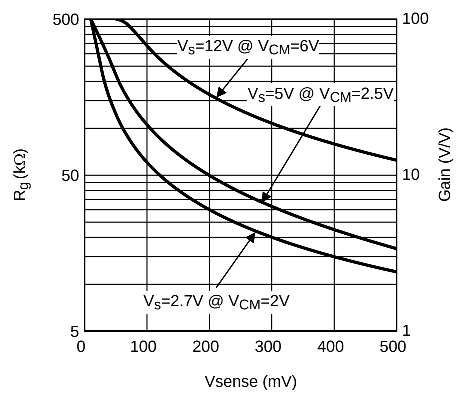


Figure 4. Allowed Gains for Range 2

Also in this Range once selected the R_{GAIN} (Gain) the V_{SENSE} Range is fixed too.

Range 3 $V_{CM} \ge V_S$ (7)

The max voltage at the R_G pin is Vout_max, it means that $V_{OUT} = V_{SENSE} * R_{GAIN}/R_{IN} \le$ Vout_max where Vout_max is the maximum allowable output voltage according to the Electrical Tables.So all the R_{GAIN} resistors which respect the previous inequality are allowed. The graphical representation in Figure 5 helps in the selection; all the combinations (V_{SENSE}, R_{GAIN}) below the curves are allowed.

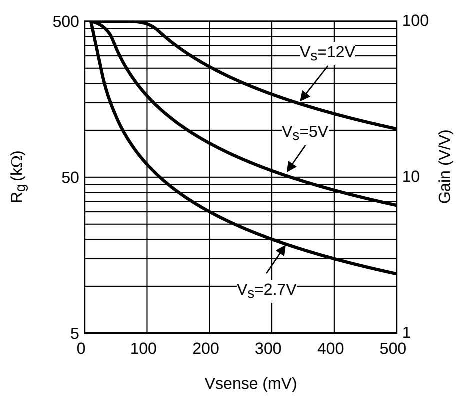


Figure 5. Allowed Gains for Range 3

Also in this Range once selected the R_{GAIN} (Gain) the V_{SENSE} Range is fixed too.

From the Ranges showed above a good way to maximize the output voltage swing of the LMP8645 is to select the max allowable Rgain according to the previous equations. For a fixed supply voltage and Vsense as the common mode voltage increases, the max allowable Rgain increases too.

DESIGN GUIDELINE

Example 1

The LMP8645 is used to monitor the current supply of an active device (Refer to Figure 6). The LMP8645 is supplied at 5V the active device is supplied at 12V and the max current sunk is 1A. In this example the LMP8645 will work in all 3 Ranges: in Range 1 at the turning on of the active device, then in Range 3 passing through the Range 2. Since the purpose of the application is monitor the current of the active device in any operating state working condition (power on, normal operation, etc.), the gain resistor will be selected according to the Range 1, the Range which gives more constraints to the output dynamic voltage of the LMP8645.

At the startup of the monitored device the LMP8645 works at 0V common mode, it means that its max output is 1.3V (Range 1). In order to maximize the resolution the Rsense is calculated as max allowed Vsense (Refer to Figure 3) divided by max current (1A), so Rsesne=0.5Ω. Due to the output limitation the max allowed gain will be 2.6V/V so R_{GAIN}=13kΩ. With this approach the current is monitored at any working condition but without using the entire output dynamic of the LMP8645. Alternatively if the monitored device doesn't sink 1A at any supply voltage, it is possible to design considering the max output voltage of the LMP8645 when operating in Range 3 ($V_{CM} \geq V_S$). Also in this case is possible to maximize the resolution using Rsesne=0.5Ω, and maximize the output dynamic with Rgain=33kΩ. With this approach the max detectable current when V_{CM} is less than 1,8V is about 400mA, while for V_{CM}=2.5V the max detectable current is 600mA (Refer to Figure 3) and for $V_{CM} \geq V_S$ is 1A.

The second approach maximizes the output dynamic but implies some knowledge on the monitored current.

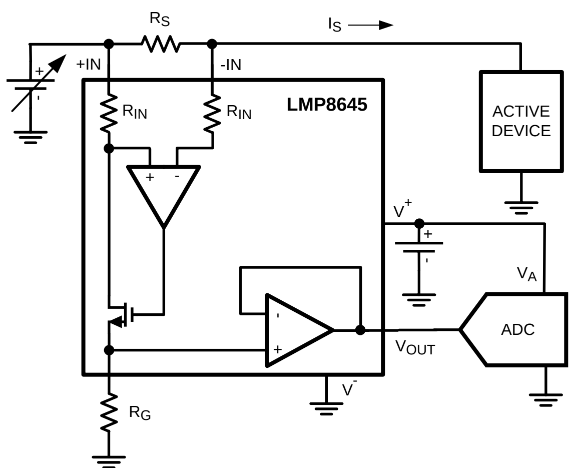


Figure 6. LMP8645 in current monitor application

Example 2

The LMP8645 is used to monitor the current in a high brightness LED application together with LM340x LED drivers. The LMP8645 is supplied at 3.3V and the max voltage at LED's string is 30V, the LED brightness is controlled with the dimming (MOSFET in parallel to the LED). The approach of the high current sense is used especially in automotive application where the cathode of the LED needs to be directly connected to the chassis of the car (Ground of the system). Even though LMP8645 will work in all 3 Ranges as in the previous example, R_{GAIN} will be calculated according to Range 3 because the purpose is regulating the current in the LEDs when the external MOSFET is OFF (LMP8645 at high V_{CM}). Even if this approach makes the LMP8645 able to sense high peak current only in Range 3 where the dynamic output is higher than Range 1 the current resolution is maximized. At each switch ON/OFF of the MOSFET the LMP8645 goes from Range 1 (MOSFET ON, string of LED OFF), to Range 3 (MOSFET OFF, string of LED ON) passing through Range 2 (MOSFET OFF, string of LED OFF). Since the purpose of the application is to sense the current with high precision when the LED string is ON, the R_{GAIN} will be calculated according to the Range 3.

To summarize, the R_{GAIN} will be calculated according to the range of operation in which the application will mainly work. Once selected the range, will be taken in account the more stringent constraint

DRIVING ADC

The input stage of an Analog to Digital converter can be modeled with a resistor and a capacitance versus ground. So if the voltage source doesn't have a low impedance an error in the amplitude's measurement will occur. In this Range a buffer is needed to drive the ADC. The LMP8645 has an internal output buffer able to drive a capacitance load up to 30 pF or the input stage of an ADC. If required an external low pass RC filter can be added at the output of the LMP8645 to reduce the noise and the bandwidth of the current sense. Any other filter solution which implies a capacitance connected to the R_G pin is not suggested due to the high impedance of that pin.

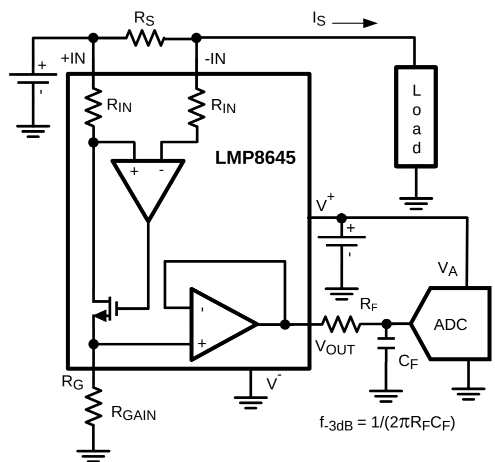


Figure 7. LMP8645 to ADC interface

SENSING CURRENT IN LED DRIVER APPLICATIONS

The LMP8645 is the right choice in the applications which requires high side current sense, such as High Brightness LED for automotive where the LED's cathode has to be connected to the Range (ground) of the car. In this Range the classical low side current sense with a shunt resistor connected between the LED's cathode and the Range doesn't guarantee the ground connection. In Figure 8, the LMP8645 monitors the current for the LM3406 a constant current buck regulator. The LMP8645 is supplied by the internal LDO of the LM3406 thorough the pin VCC, the current which flows in the LED is programmed according the following formula: $I_F = V_{CS}/(R_S*Gain)$, where Gain = R_{GAIN}*Gm and V_{CS}=200 mV. In this application the current which flows in the HB LED is in the Range between 350 mA and 1A, so in order to reduce the power dissipation on the shunt resistor and have a good accuracy, the R_S should be in the Range between 50 mΩ and 200 mΩ. In the table below two examples are analyzed.

	I_F=350mA	**I_F=1A**
R_{GAIN}	40kΩ	36kΩ
R_S	77mΩ	27mΩ
Dissipated Power	9.5mW	27mW
Total Accuracy	≅5%	≅5%

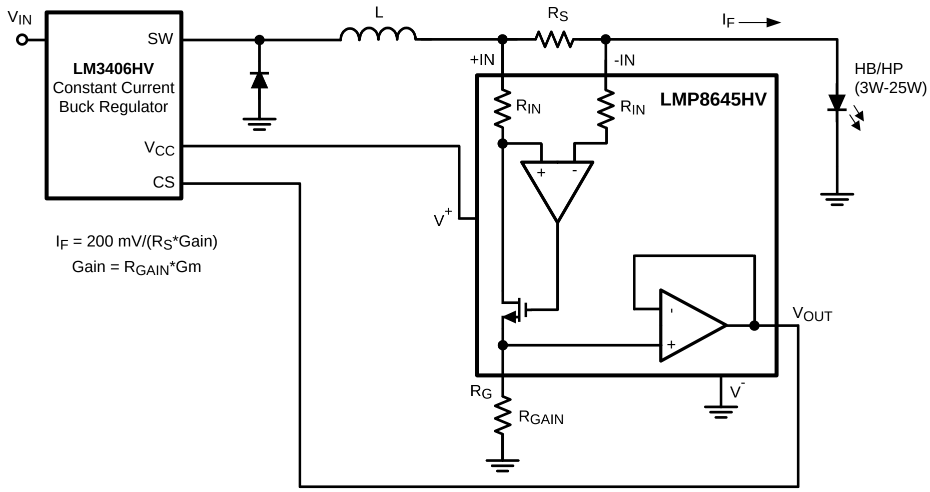


Figure 8. High Side Current Sensing in Driving HP/HB LED

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Samples (Requires Login)
LMP8645HVMK/NOPB	ACTIVE	SOT	DDC	6	1000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
LMP8645HVMKE/NOPB	ACTIVE	SOT	DDC	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
LMP8645HVMKX/NOPB	ACTIVE	SOT	DDC	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
LMP8645MK/NOPB	ACTIVE	SOT	DDC	6	1000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
LMP8645MKE/NOPB	ACTIVE	SOT	DDC	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
LMP8645MKX/NOPB	ACTIVE	SOT	DDC	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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TAPE AND REEL INFORMATION

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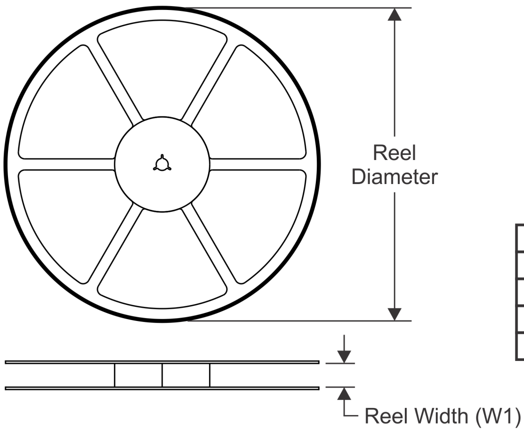
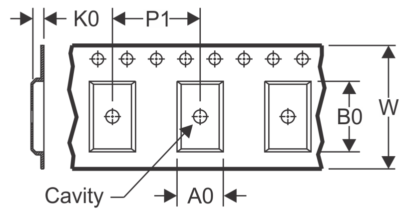
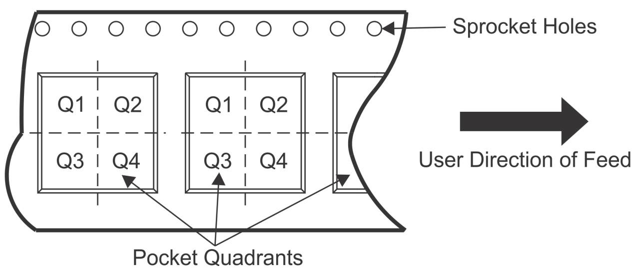


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

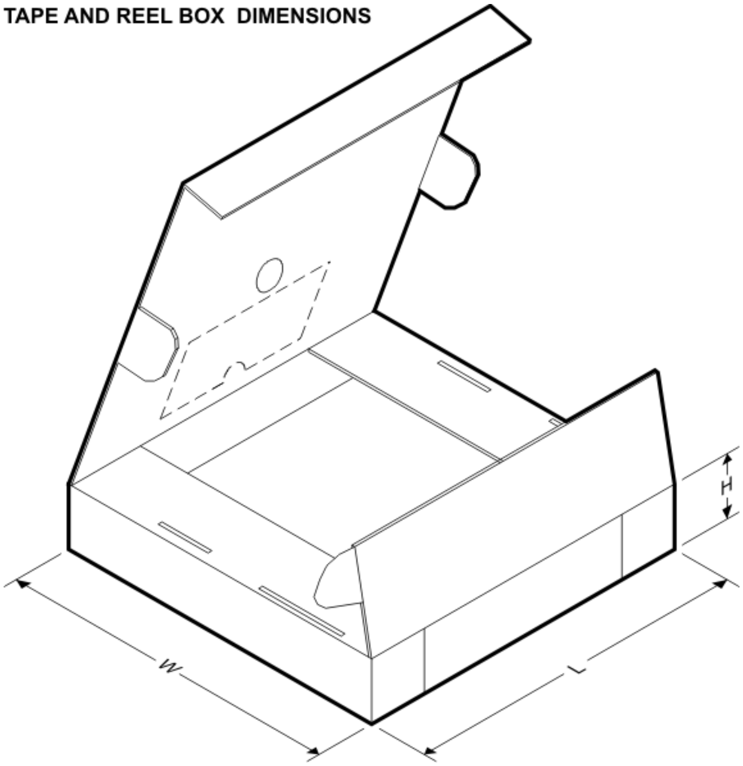
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LMP8645HVMK/NOPB	SOT	DDC	6	1000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMP8645HVMKE/NOPB	SOT	DDC	6	250	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMP8645HVMKX/NOPB	SOT	DDC	6	3000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMP8645MK/NOPB	SOT	DDC	6	1000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMP8645MKE/NOPB	SOT	DDC	6	250	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LMP8645MKX/NOPB	SOT	DDC	6	3000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3

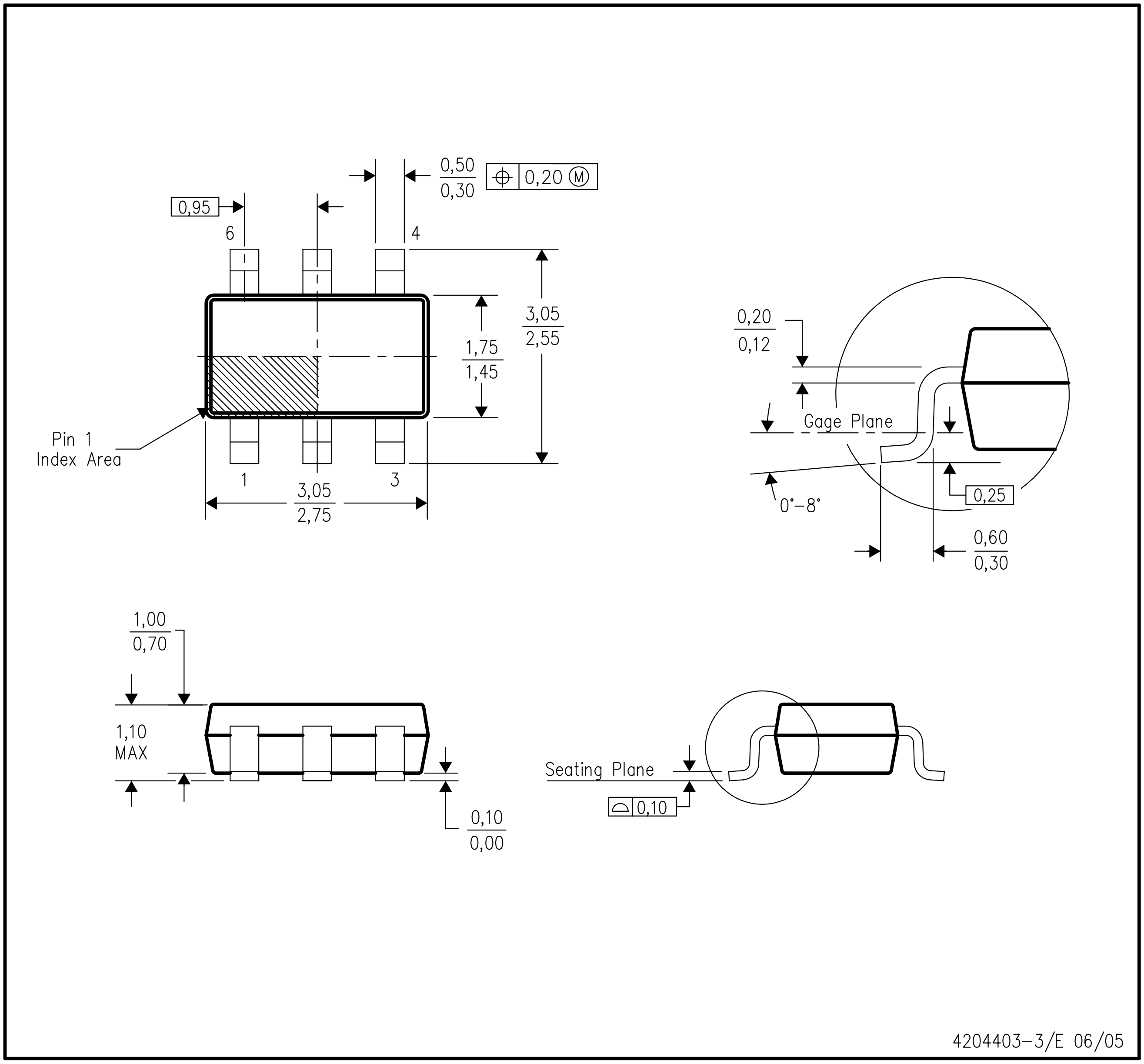
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMP8645HVMK/NOPB	SOT	DDC	6	1000	203.0	190.0	41.0
LMP8645HVMKE/NOPB	SOT	DDC	6	250	203.0	190.0	41.0
LMP8645HVMKX/NOPB	SOT	DDC	6	3000	206.0	191.0	90.0
LMP8645MK/NOPB	SOT	DDC	6	1000	203.0	190.0	41.0
LMP8645MKE/NOPB	SOT	DDC	6	250	203.0	190.0	41.0
LMP8645MKX/NOPB	SOT	DDC	6	3000	206.0	191.0	90.0

DDC (R–PDSO–G6) PLASTIC SMALL–OUTLINE



NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC MO–193 variation AA (6 pin).

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