

## LMS1145

### 5-Bit Programmable, High Frequency Multi-phase PWM Controller

#### General Description

The LMS1145 provides an attractive solution for power supplies of high power microprocessors (such as Pentium™ II, M II™, K6®-2, K6-3, Merced, etc.) exhibiting ultra fast load transients. Compared to a conventional single-phase supply, an LMS1145 based multi-phase supply distributes the thermal and electrical loading among components in multiple phases and greatly reduces the corresponding stress in each component. The LMS1145 can be programmed to control either a 3-phase converter or a 4-phase converter. Phase shift among the phases is 120° in the case of three phase and 90° with four-phase. Because the power channels are out of phase, there can be significant ripple cancellation for both the input and output current, resulting in reduced input and output capacitor size. Due to the nominal operating frequency of 2 MHz per phase, the size of the output inductors can be greatly reduced which results in a much faster load transient response and a dramatically shrunk output capacitor bank. Microprocessor power supplies with all surface mount components can be easily built.

The internal high speed transconductance amplifier guarantees good dynamic performance.

The internal master clock frequency of up to 8 MHz is set by an external reference resistor. An external clock of 10 MHz can also be used to drive the chip to achieve frequency control and multi-chip operation.

The LMS1145 also provides input under-voltage lock-out with hysteresis, input over-current protection and output voltage power good detection.

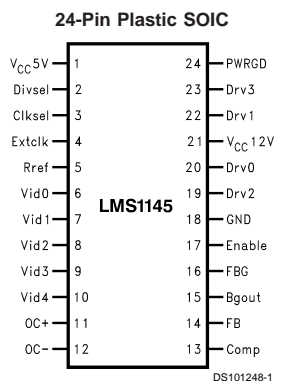
#### Features

- Ultra fast load transient response
- Enables all surface-mount-design
- Selectable 2, 3, 4 phase operation
- Clock frequency from 40 kHz to 10 MHz
- Precision load current sharing
- 5-bit programmable from 3.5V to 1.3V
- Selectable internal or external clock
- Digital 16-step soft start
- Input under-voltage lock-out, over-current protection
- Open-drain power good signal output

#### Applications

- Servers and workstations
- High current, ultra-fast transient microprocessors

#### Pin Configuration



**Top View**  
**See NS Package Number M24B**

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**LMS1145 5-Bit Programmable, High Frequency Multi-phase PWM Controller**

**Absolute Maximum Ratings** (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

$V_{CC5V}$	7V
PWRGD	( $V_{CC} 5V + 0.2V$ )
$V_{CC12V}$	20V
Junction Temperature	125°C
Power Dissipation (Note 2)	1.6W

Storage Temperature  $-65^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$

ESD Susceptibility (Note 8) 2 kV

Soldering Time, Temperature 10 sec., 300°C

**Operating Ratings** (Note 1)

$V_{CC} 5V$  4.5V to 5.5V

$V_{CC} 12V$  10V to 18V

Junction Temperature Range  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$

**Electrical Characteristics**

$V_{CC5V} = 5V$ ,  $V_{CC12V} = 12V$  unless otherwise specified. Typical and limits appearing in plain type apply for  $T_A = T_J = +25^{\circ}\text{C}$ . Limits appearing in **boldface** type apply over the entire operating temperature range.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$V_{DACOUT}$	5-bit DAC Output Voltage	(Note 3)	<b><math>N-1.5\%</math></b>	<b><math>N</math></b>	<b><math>N+1.5\%</math></b>	V
$I_{CC12V}$	Quiescent $V_{CC12V}$ Current	Enable = 5V, VID = 00001, DRV Outputs Floating		1	2	mA
$I_{CC5V}$	Operating $V_{CC5V}$ Current	$V_{OUT} = 2.00V$		4.3	8	mA
$V_{REF}$	Rref Pin Voltage			1.225		V
$V_{INL}$	Vid0:4, Clksel, Divsel, and	Logic Low (Note 4)		1.8	1.5	V
$V_{INH}$	Enable Pins Logic Threshold	Logic High (Note 5)	3.5	2.8		V
$I_{INL}$	Vid0:4 and Enable Pins Internal Pullup Current	The Corresponding Pin = 0V	60	100	140	$\mu\text{A}$
	Clksel, Divsel Pins Internal Pullup Current		-10	0	10	
	Gate Driver Resistance When Sinking Current	$I_{SINK} = 50 \mu\text{A}$ , $V_{CC12V} = 14V$		12		$\Omega$
$V_{DRV}$	DRV0:3 Output Voltage	$I_{DRV} = 10 \text{ mA}$ , $V_{CC12V} = 14V$	$V_{CC12V} - 1.5V$	$V_{CC12V} - 1.0V$		V
$t_{fall}$	DRV0:3 Fall Time	(Note 6)		7		ns
$I_{SRC}$	DRV0:3 Source Current	DRV0:3 = 0V, $V_{CC12V} = 14V$	40	60		mA
$I_{SINK}$	DRV0:3 Sink Current	DRV0:3 = 5V, $V_{CC12V} = 14V$	90	160	250	mA
$V_{B_{gOUT}}$	$B_{gOUT}$ Voltage	Current Limit Not Activated		4		V
		Current Limit Activated		0		
$I_{B_{gOUT}}$	$B_{gOUT}$ Sink Current	$B_{gOUT} = 1V$	1.0	2.4	5	mA
$I_{FB}$	FB Pin Bias Current	FB = 2V		30		nA
$F_{OSC}$	Oscillator Frequency	8.02k $\Omega$ from Rref Pin to Ground	7.0	8.0	8.7	MHz
$\Delta_D$	DRV0:3 Duty Cycle Match	Duty Cycle = 50%	-1		+1	%
$\Delta_{ph}$	DRV0:3 Phase Accuracy	Duty Cycle = 50%, $F_{clock} = 8 \text{ MHz}$	-1		+1	Deg
$T_{off}$	PWM Off time	Divide by 4		22		%
		Divide by 3		22		
$V_{PWRGD}$	Power Good Detection Window, $\Delta V_{OUT}$	$1.3V \leq V_{OUT} \leq 1.9V$		$\pm 100$		mV
	Hysteresis			50		
	Power Good Detection Window, $\Delta V_{OUT}$	$2V \leq V_{OUT} \leq 3.5V$		$\pm 150$		
	Hysteresis			50		

**Electrical Characteristics** (Continued)

$V_{CC5V} = 5V$ ,  $V_{CC12V} = 12V$  unless otherwise specified. Typical and limits appearing in plain type apply for  $T_A = T_J = +25^\circ C$ . Limits appearing in **boldface** type apply over the entire operating temperature range.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$I_{PWRGD}$	Power Good Sink Current	$V_{PWRGD} = 0.4V$	0.8	1		mA
$V_{OCC\_CM}$	Over-current Comparator Common Mode Range		<b>3</b>		<b>12</b>	V
$IB_{OC+}$	OC+ Input Bias Current	$V_{IN} = 5V$ , $OC+ = 5V$ , $OC- = 4V$	100	145	200	$\mu A$
$IB_{OC-}$	OC- Input Bias Current	$V_{IN} = 5V$ , $OC+ = 6V$ , $OC- = 5V$	85	120	165	$\mu A$
$V_{OS\_OCC}$	Over-current Comparator Input Offset Voltage	$V_{IN} = 5V$	2	16	42	mV
		$V_{IN} = 12V$		21		
$D_{MAX}$	Maximun Duty Cycle	$FB = 0V$		78		%
gm	Error Amplifier Transconductance			1.36		mmho
$V_{ramp}$	Ramp Signal Peak-to-Peak Amplitude			2		V
$I_{comp}$	COMP Pin Source Current		250	360	550	$\mu A$
$I_{comp}$	COMP Pin Sink Current		160	260	400	$\mu A$
$V_{comp\_hi}$	COMP Pin High Clamp			2.9		V
$V_{comp\_lo}$	COMP Pin Low Clamp			0.19		V
$V_{POR}$	Power On Reset Trip Point	Vcc5V Pin Voltage Rising		4.0		V
		Vcc5V Pin Voltage Falling		3.6		
	Vcc12V Minimum Working Voltage	(Note 7)		3.8		V
$t_{SS}$	Soft Start Delay	$F_{OSC} = 8MHz$		1.6		ms

**Note 1:** **Absolute Maximum Ratings** are limits beyond which damage to the device may occur. **Operating ratings** do not imply guaranteed performance limits.

**Note 2:** Maximum allowable power dissipation is a function of the maximum junction temperature,  $T_{JMAX}$ , the junction-to-ambient thermal resistance,  $\theta_{JA}$ , and the ambient temperature,  $T_A$ . The maximum allowable power dissipation at any ambient temperature is calculated using:  $P_{MAX} = (T_{JMAX} - T_A)/\theta_{JA}$ . The junction-to-ambient thermal resistance,  $\theta_{JA}$ , for LMS1145 is  $78^\circ C/W$ . For a  $T_{JMAX}$  of  $150^\circ C$  and  $T_A$  of  $25^\circ C$ , the maximum allowable power dissipation is 1.6W.

**Note 3:** The letter **N** stands for the typical output voltages appearing in **italic boldface** type in Table 1.

**Note 4:** **Max** value of logic low means any voltage below this value is guaranteed to be taken as logic low whereas a voltage higher than this value is not guaranteed to be taken as a logic low.

**Note 5:** **Min** value of logic high means any voltage above this value is guaranteed to be taken as logic high whereas a voltage lower than this value is not guaranteed to be taken as a logic high.

**Note 6:** When driving bipolar FET drivers in the typical application circuit.

**Note 7:** When Vcc12V pin goes below this voltage, all DRV pins go to 0V.

**Note 8:** ESD ratings is based on the human body model, 100pF discharged through 1.5k $\Omega$ .

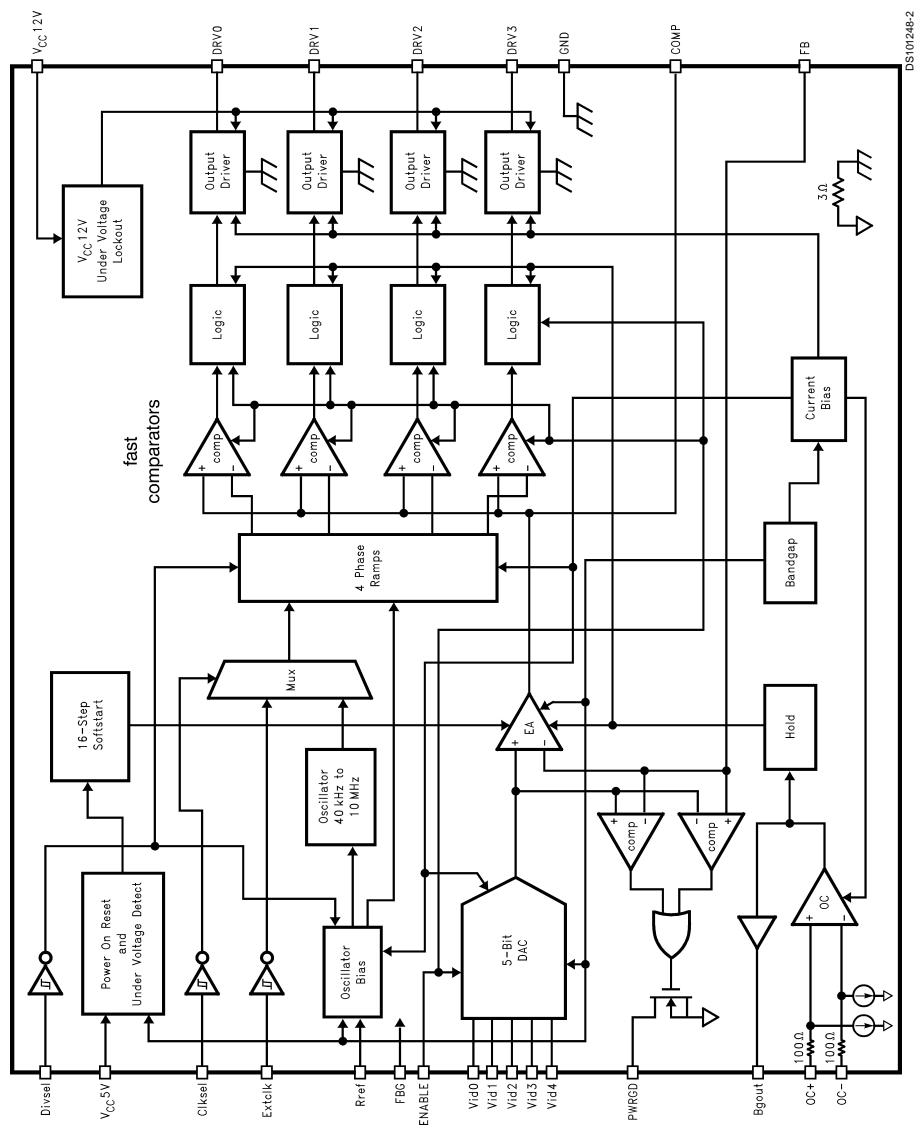
**Electrical Characteristics** (Continued)**TABLE 1. 5-Bit DAC Output Voltage Table**

Symbol	Parameter	Conditions	Typical	Units
V <sub>DACOUT</sub>	5-Bit DAC Output Voltages for Different VID Codes	VID4:0 = 01111	<b>1.30</b>	V
		VID4:0 = 01110	1.35	
		VID4:0 = 01101	<b>1.40</b>	
		VID4:0 = 01100	1.45	
		VID4:0 = 01011	<b>1.50</b>	
		VID4:0 = 01010	1.55	
		VID4:0 = 01001	<b>1.60</b>	
		VID4:0 = 01000	1.65	
		VID4:0 = 00111	<b>1.70</b>	
		VID4:0 = 00110	1.75	
		VID4:0 = 00101	<b>1.80</b>	
		VID4:0 = 00100	1.85	
		VID4:0 = 00011	<b>1.90</b>	
		VID4:0 = 00010	1.95	
		VID4:0 = 00001	<b>2.00</b>	
		VID4:0 = 00000	2.05	
		VID4:0 = 11111	2.0	
		VID4:0 = 11110	2.1	
		VID4:0 = 11101	<b>2.2</b>	
		VID4:0 = 11100	2.3	
		VID4:0 = 11011	2.4	
		VID4:0 = 11010	2.5	
		VID4:0 = 11001	2.6	
		VID4:0 = 11000	2.7	
		VID4:0 = 10111	<b>2.8</b>	
		VID4:0 = 10110	2.9	
		VID4:0 = 10101	3.0	
		VID4:0 = 10100	3.1	
		VID4:0 = 10011	3.2	
		VID4:0 = 10010	<b>3.3</b>	
		VID4:0 = 10001	3.4	
		VID4:0 = 10000	3.5	

## Pin Description

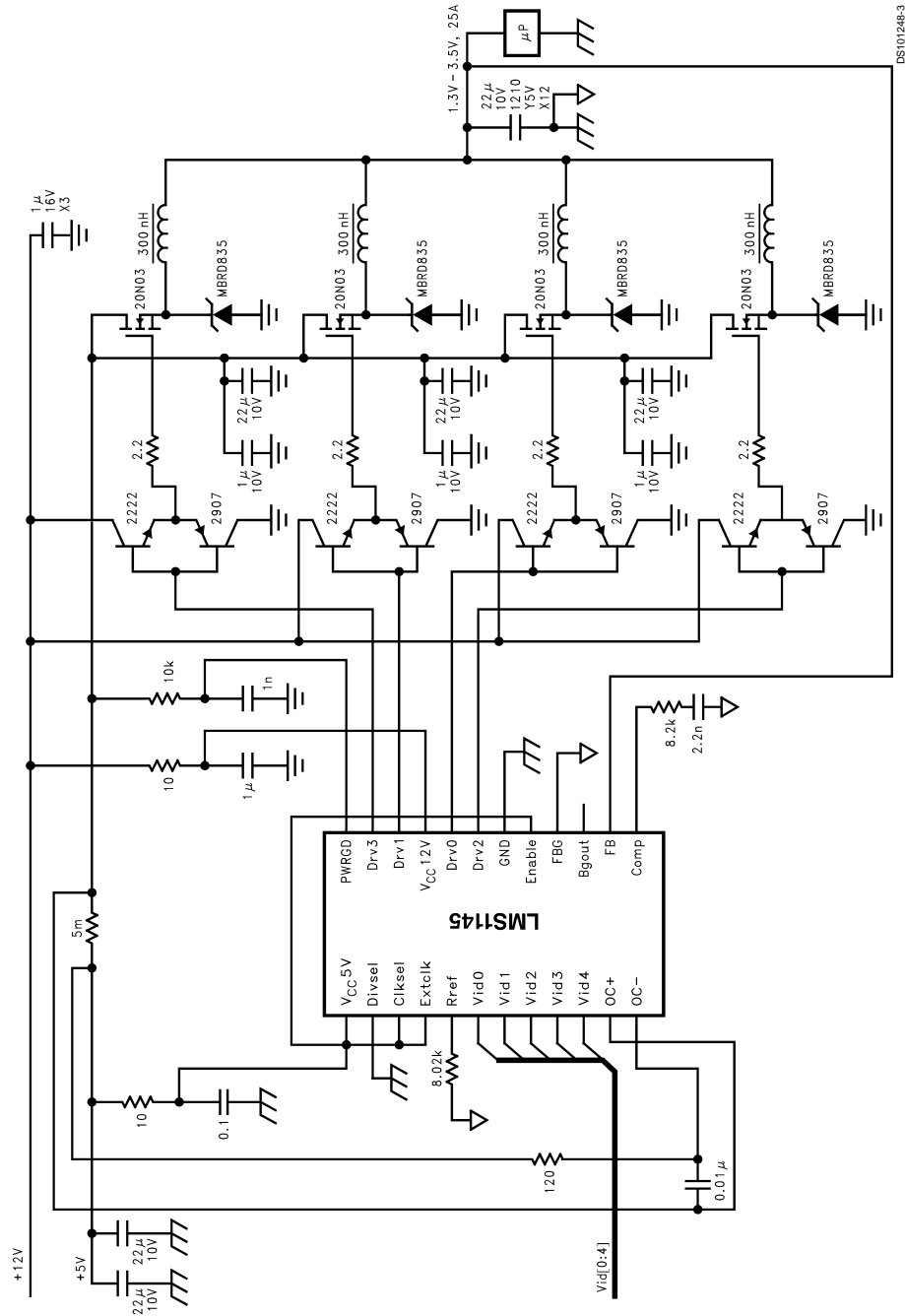
Pin	Pin Name	Pin Function
1	Vcc5V	Supply Voltage Input (5V nominal)
2	Divsel	Selects Phase Mode. Logic low selects 4 phase. Logic high selects 3 phase. 2 phase operation is achieved by using 2 outputs in 4 phase mode.
3	Clksel	Clock Select: Logic high selects internal clock. Logic low selects external clock.
4	Extclk	External Clock Input. Output frequency = Clock Input / No. of Phases. Connect to Vcc5V to select internal clock.
5	Rref	Connects to external reference resistor. Sets the operating frequency of the internal clock and the ramp time for the PWM. Reference voltage at this pin is 1.26V.
6	Vid0	5-Bit DAC Input (LSB).
7	Vid1	5-Bit DAC Input.
8	Vid2	5-Bit DAC Input.
9	Vid3	5-Bit DAC Input.
10	Vid4	5-Bit DAC Input (MSB)
11	OC+	Over-current Comparator. Non-inverting input.
12	OC-	Over-current Comparator. Inverting input.
13	COMP	Compensation Pin. This is the output of the internal transconductance amplifier. Compensation network should be connected between this pin and feedback ground FBG.
14	FB	Feedback Input. Normally Kelvin connected to supply output.
15	Bgout	Current Limit Flag. Goes to logic low when current limit is activated. When over-current condition is removed, this pin is weakly pulled up to Vcc5V.
16	FBG	Feedback Ground. This pin should be connected to the ground at the supply output.
17	ENABLE	Output Enable Pin. Tie to logic high to enable and logic low to disable.
18	GND	Power Ground Pin.
19	DRV2	Phase 2 Output.
20	DRV0	Phase 0 Output.
21	Vcc12V	Supply Voltage for FET Drivers DRV0:3.
22	DRV1	Phase 1 Output.
23	DRV3	Phase 3 Output.
24	PWRGD	Power Good. This is an open-drain output that goes low (low impedance to ground) when the output voltage travels out of the threshold window, and resume to open-drain state when $V_{OUT}$ recovers into the 50mV hysteresis window. The power good window threshold, i.e. $\pm 100\text{mV}$ for $1.3\text{V} \leq V_{OUT} \leq 1.9\text{V}$ or $\pm 150\text{mV}$ for $2\text{V} \leq V_{OUT} \leq 3.5\text{V}$ , is automatically set according to VID code. Connect a 1nF capacitor to ground to filter out the switching noise coupling from DRV3 to this pin.

## Block Diagram



DS101248-2

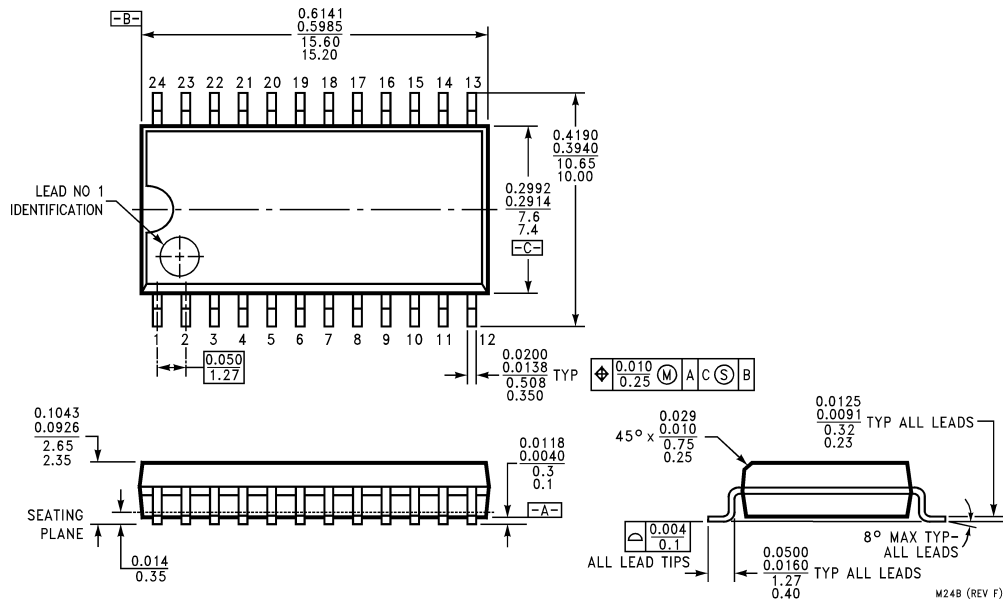
## Typical Application



DS101248-3

LMS1145

## Physical Dimensions inches (millimeters) unless otherwise noted



**24-Lead Small Outline Package**  
**Order Number LMS1145M**  
**NS Package Number M24B**

### LIFE SUPPORT POLICY

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