

LM10010

VID Voltage Programmer for Point of Load Regulator

General Description

The LM10010 is a precision, digitally programmed device used to control the output voltage of a DC/DC converter. The LM10010 outputs a DC current inversely proportional to a 6-bit input word. This current DAC output connects to the feedback pin of a regulator in order to adjust its output voltage to a desired range and resolution set by the user. As the 6-bit word counts up, the output voltage is adjusted higher based on the setting of the feedback resistors in the converter.

The LM10010 is designed to program point of load regulators with adjustable resistor feedback networks for VID (Voltage Identification).

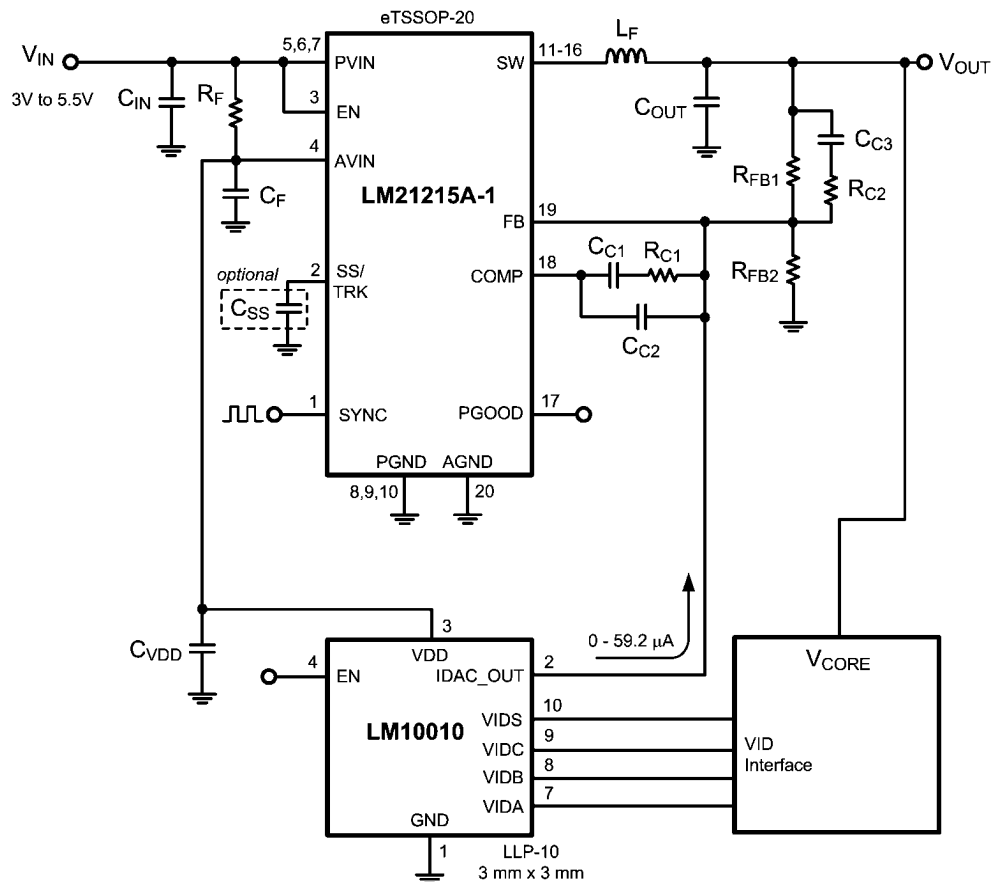
Features

- Output current accuracy (-40°C to +125°C)
- Input voltage range: 3V to 5.5V
- 6-bit current DAC that connects directly to the feedback node of an external regulator to provide output voltage control
- Precision enable to support custom UVLO
- LLP-10 3 mm x 3 mm footprint, 0.5 mm pitch
- Compatible with the TMS320C66XX DSP Smart Reflex Technology

Applications

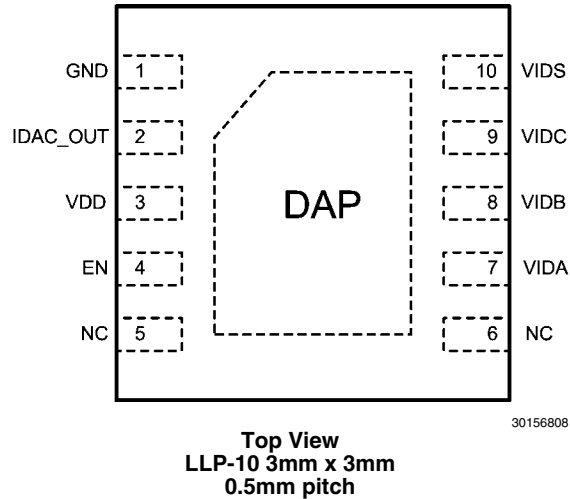
- Broadband, networking, and wireless communications
- Notebook and palmtop computers, PDAs
- Portable instruments
- Battery-powered equipment
- Powering digital loads with a 6-bit, 4 pin VID interface

Typical Application Circuit



30156807

Connection Diagram



Ordering Information

Order Number	Package Type	NSC Package Drawing	Package Marking	Supplied As
LM10010SD	LLP-10	SDA10A	L254B	1000 Units / Tape and Reel
LM10010SDX	LLP-10	SDA10A	L254B	4500 Units / Tape and Reel

Pin Descriptions

Pin No.	Name	Description
1	GND	Ground.
2	IDAC_OUT	Output current DAC that connects to the feedback node of the regulator.
3	VDD	Positive supply input.
4	EN	Precision enable input.
5	NC	No Connect.
6	NC	No Connect.
7	VIDA	VID digital input: Bit 0 when VIDS transitions low; Bit 3 when VID transitions high.
8	VIDB	VID digital input: Bit 1 when VIDS transitions low; Bit 4 when VID transitions high.
9	VIDC	VID digital input: Bit 2 when VIDS transitions low; Bit 5 when VID transitions high.
10	VIDS	VID select line: Transition low selects lower 3 bits, Transition high selects upper 3 bits.
DAP	DAP	Die Attach Pad. Not electrically connected to device, connect to system ground plane for reduced thermal resistance.

Absolute Maximum Ratings *(Note 1)*

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

VDD, EN, IDAC_OUT	-0.3V to 6V
VIDA, VIDB, VIDC, VIDS	-0.3V to 6V
ESD Rating <i>(Note 2)</i>	2 kV
Human Body Model	
Storage Temperature	-65°C to +150°C
Junction Temperature	+150°C

Operating Ratings

VDD	3.0V to 5.5V
IDAC_OUT	-0.3V to VDD-1.75V
VIDA, VIDB, VIDC, VIDS	-0.3V to 5.5V
EN	-0.3V to 5.5V
Junction Temperature	-40°C to +125°C
Ambient Temperature	-40°C to +125°C
LLP-10 Thermal Resistance (θ_{JA})	40°C/W

(Note 3)

Electrical Characteristics Limits in standard type are for $T_J = 25^\circ\text{C}$ only. Limits appearing in **boldface** type apply over the full operating junction temperature range ($-40^\circ\text{C} < T_J < +125^\circ\text{C}$). Unless otherwise noted, specifications apply to the Typical Application Circuit. See *(Note 4)*.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
Supply, UVLO, and Enable						
I_Q	Quiescent current	VDD=5.0V, $V_{EN}=2.0\text{V}$		250	280	μA
		VDD=5.0V, $V_{EN}=2.0\text{V}$, I_{FS}		340		μA
		VDD=5.0V, $V_{EN}=0.0\text{V}$		45	70	μA
UVLO	Under voltage rising threshold			2.65	2.95	V
	Under voltage falling threshold		2.2	2.45		V
	Hysteresis		100	200	300	mV
V_{EN}	Enable rising threshold		1.20	1.34	1.45	V
	Enable hysteresis		50	100	180	mV
I_{EN}	Enable pullup current			2		μA
IDAC						
ACC	Accuracy	Measured at full scale	2		-2	%
LSB	DAC step size	$I_{FS}/(2^6-1)$		940		nA
Default	Output code	At startup		46d		Code
	Output current	At startup		16		μA
I_{FS}	Full-scale output current	VID[5:0] = 000000b		59.2		μA
INL	Integral non-linearity		-1	0.15	1	LSB
DNL	Differential non-linearity		-0.25	0.06	0.25	LSB
Offset	Offset current	VID[5:0] = 111111b		60		nA
V_{OUT_MAX}	Output compliance	VDD- V_{IDAC_OUT} , VDD=3V		1.3	1.75	V
VID Logic Inputs <i>(Note 5)</i>						
V_{IL}	Input voltage low				0.4	V
V_{IH}	Input voltage high		1.1			V
I_{IL}	Input current low		-5			μA
I_{IH}	Input current high				5	μA
$t_{DEGLITCH}$	Input deglitch time			3.4		μs
t_1	VIDS delay time to VID latch	VIDS rising edge	1			μs
t_2	Input hold time VIDA, VIDB, VIDC valid	VIDS edge	20			μs
t_3	VIDS delay time to VID latch	VIDS falling edge	1			μs
t_4	Input hold time VIDA, VIDB, VIDC valid	VIDS edge	20			μs
t_5	Delay to beginning of IDAC_OUT transition	Measured from VIDS rising edge		10	17	μs
t_6	IDAC_OUT transition time	Time constant for exponential rise		40		μs

Note 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 do not guarantee specific performance limits. For guaranteed specifications and conditions, see the Electrical Characteristics.

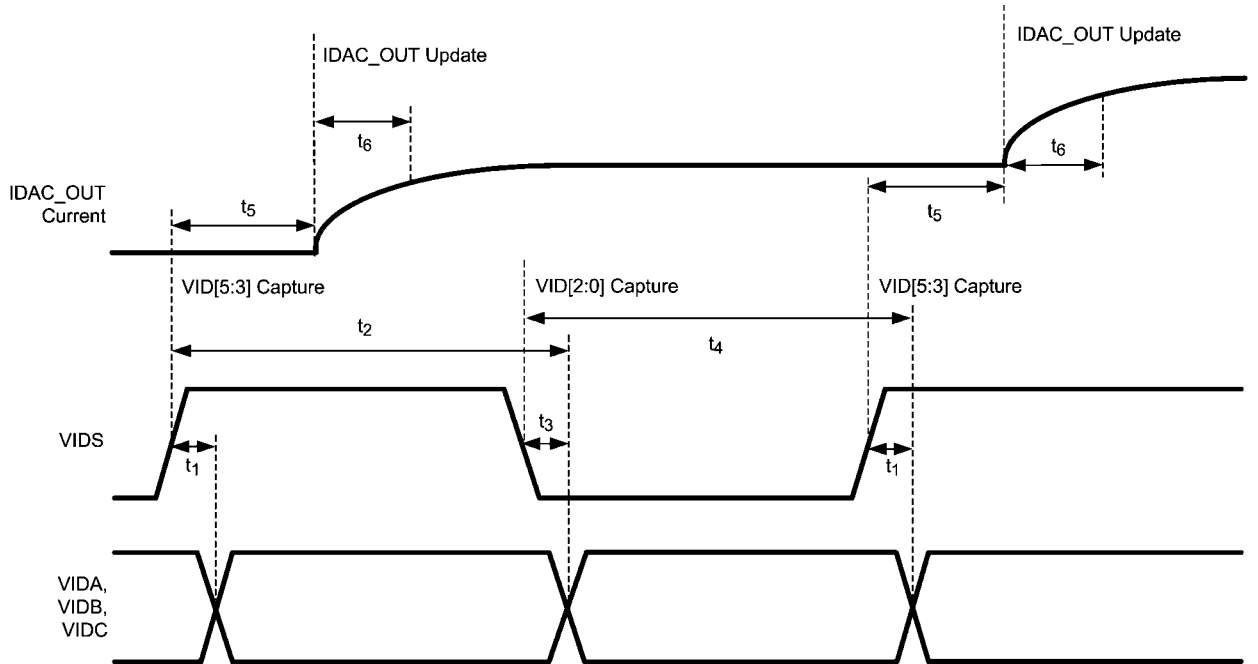
Note 2: The human body model is a 100 pF capacitor discharged through a 1.5 k Ω resistor into each pin.

Note 3: Junction to ambient thermal resistance is highly application and board layout dependent. Specified thermal resistance values for the package specified is based on a 4-layer, 4"x3", 2/1/1/2 oz. Cu board as per JEDEC standards is used.

Note 4: All limits are guaranteed. All electrical characteristics having room temperature limits are tested during production at $T_A = 25^\circ\text{C}$. All hot and cold limits are guaranteed by correlating the electrical characteristics to process and temperature variations and applying statistical process control.

Note 5: For VID timing, see [Figure 1](#)

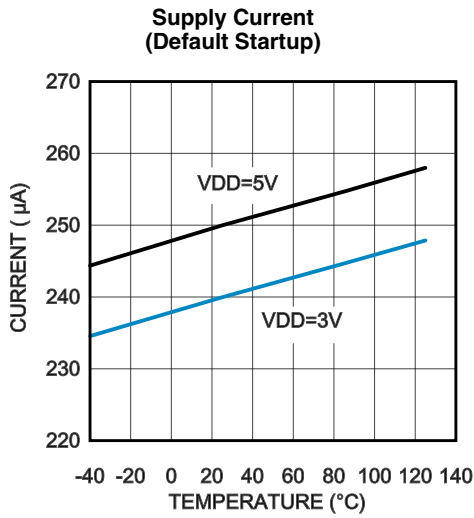
Timing Diagram



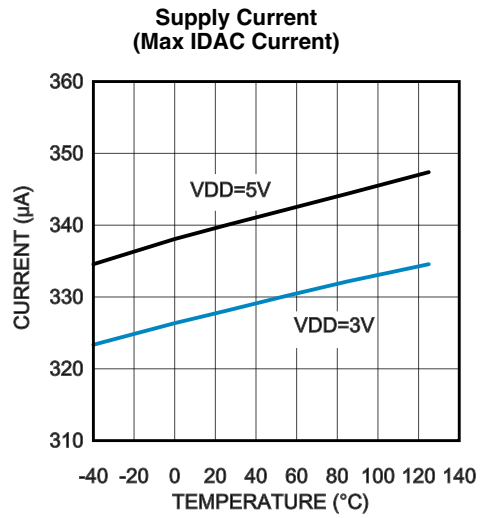
30156809

FIGURE 1. Timing Diagram for LM10010 Communications

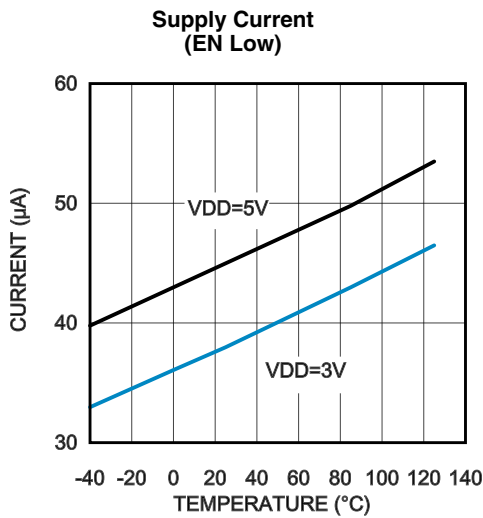
Typical Performance Characteristics Unless otherwise specified, the following conditions apply: $T_J = 25^\circ\text{C}$, $V_{DD} = 5\text{V}$. All graphs show junction temperature.



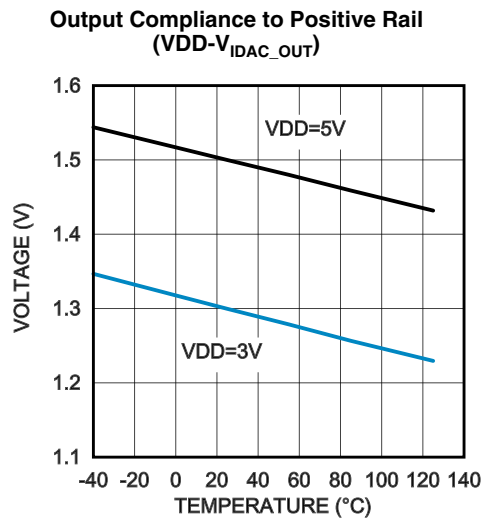
30156813



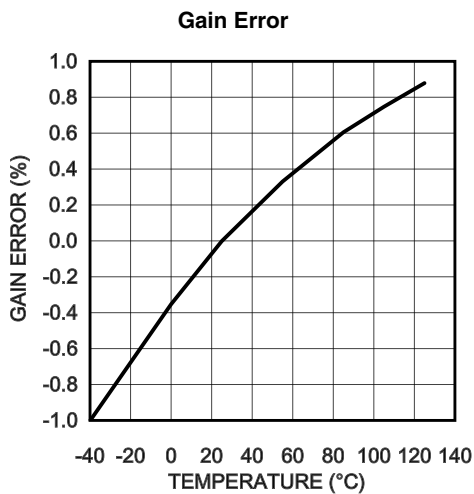
30156815



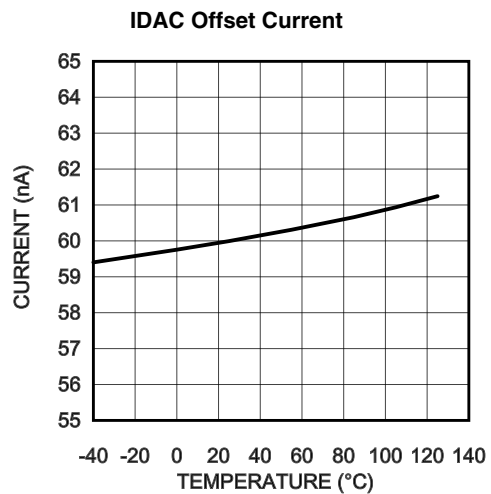
30156814



30156817

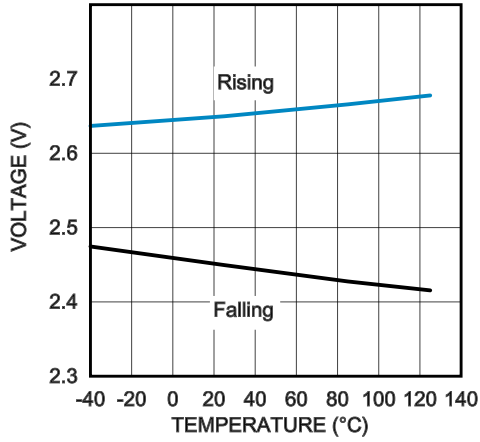


30156819



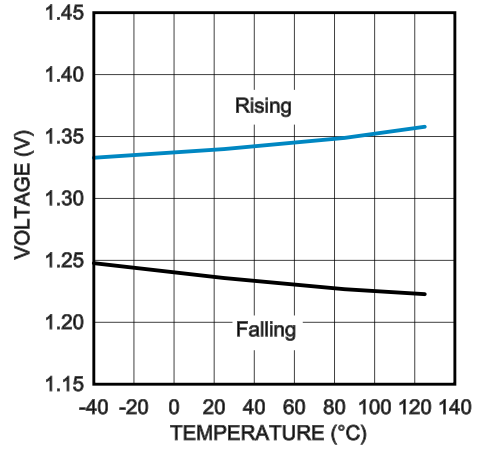
30156818

UVLO Thresholds



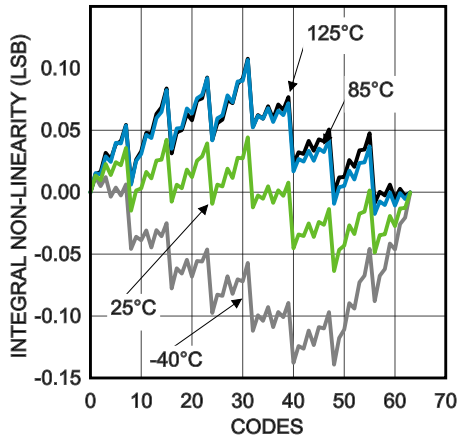
30156812

EN (Enable) Threshold



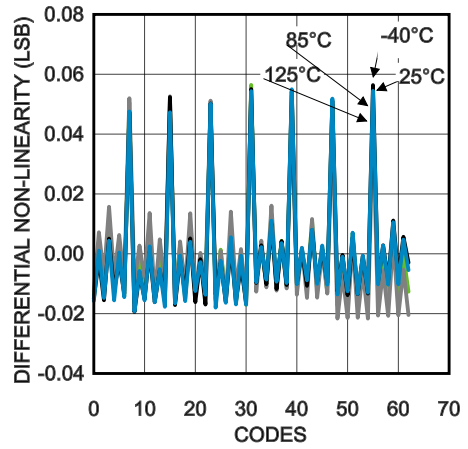
30156816

Integral Non-Linearity



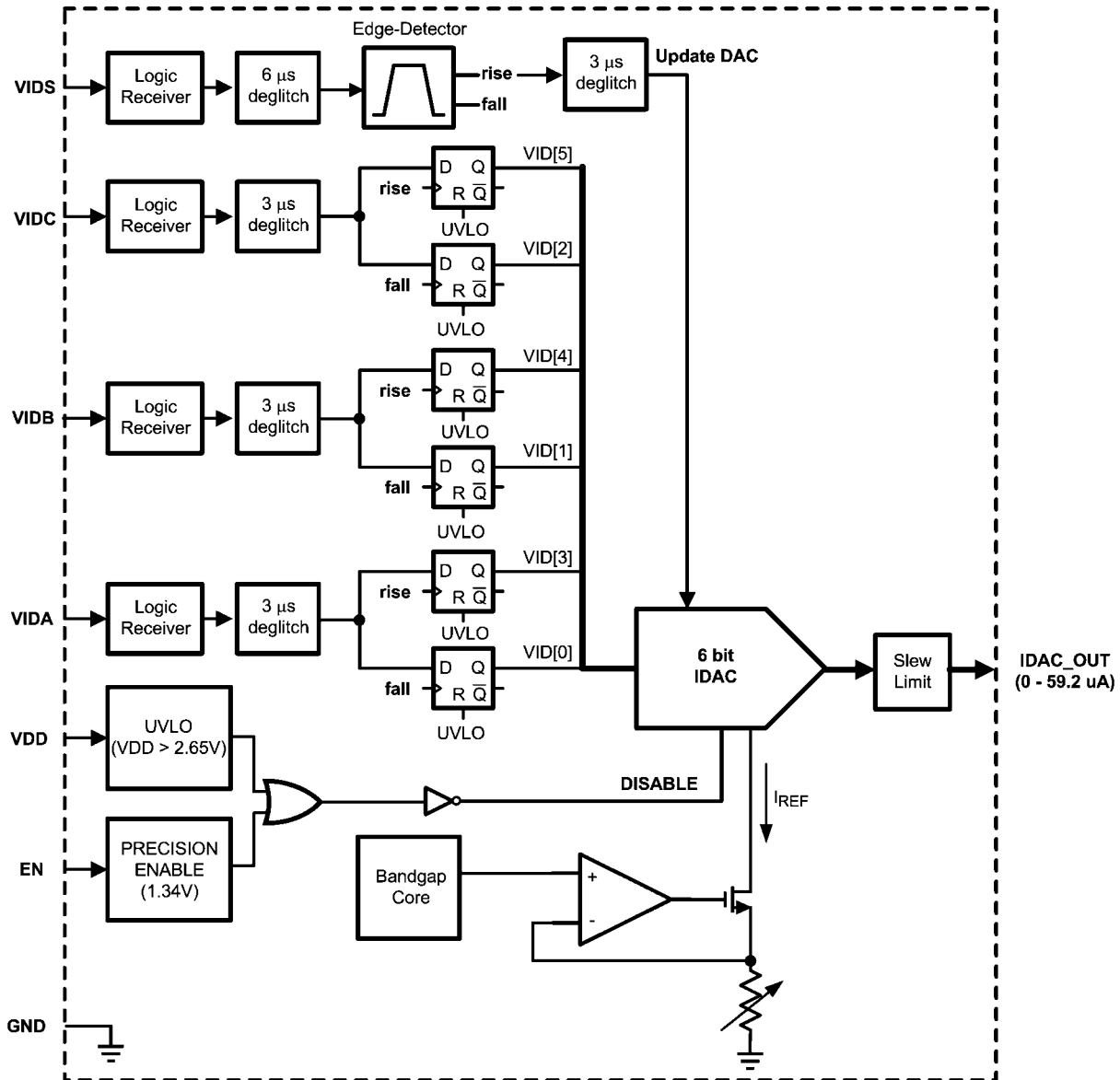
30156820

Differential Non-Linearity



30156821

Block Diagram



30156810

FIGURE 2. LM10010 Block Diagram

Functional Description

GENERAL

The LM10010 is a precision current DAC used for controlling any point of load regulator with an adjustable resistor feedback network. Four communication lines are used to write to a 6-bit IDAC value. The output of the IDAC is used to send current to the feedback node of a regulator, adjusting the output voltage. With this method, it is possible to precisely control the output voltage of the regulator.

An enable pin (EN) is provided to allow for a reduced quiescent current when not in use. Also, the VDD line is monitored so that an under-voltage event will shut down the device.

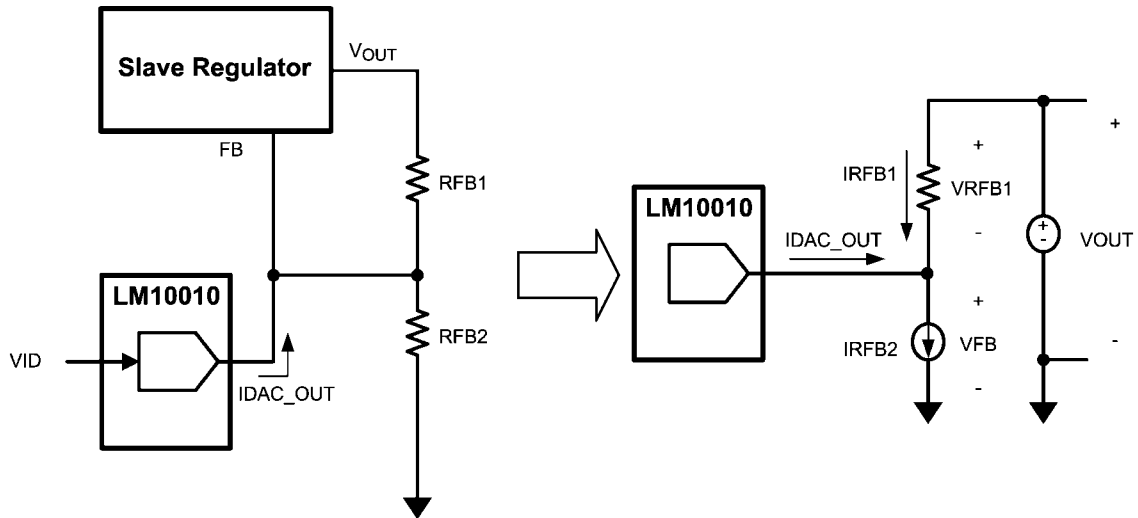
The device is available in a 10-pad No-Pullback Leadless Leadframe Package (LLP-10). The LM10010 can be used in

numerous applications with regulators from 3.0V to 5.5V supplies. A block diagram of the LM10010 is shown in [Figure 2](#) above.

THEORY OF OPERATION

The LM10010 can be thought of as a D/A converter, converting the VID communication to analog outputs. In this device, the output is a current DAC (IDAC_OUT), which is connected to the feedback node of a slave regulator. Therefore, all VID data words are decoded into a 6-bit current DAC output. The impedance of the feedback node at DC appears as the top feedback resistor. This is because the control loop of the slave regulator effectively maintains a constant current/voltage across the bottom feedback resistor, and creates low impedance at the VOUT node. Therefore, as more current is

sourced into the feedback node, the more the output voltage is reduced. See [Figure 3](#).



30156811

FIGURE 3. Output voltage is controlled via current injection into the feedback node

CURRENT DAC

The LM10010 current DAC is based on a low voltage bandgap reference setting a current through a precision adjustable resistor. This bandgap is trimmed for precision and gives excellent performance over temperature. The output current has a maximum full-scale range of 59.2 μA and is adjustable with the 6-bit VID word. This allows for 64 settings, with a resolution of 940 nA. The current DAC also has a slew limit to prevent abrupt changes in the output. As the VID data lines are set for the output voltage for the regulator, deglitch filters provide a small delay and the output current rises with a 1-e^{-t} function that can be identified by a time constant.

VID PROGRAMMING

Four pins are used to communicate with the LM10010. VIDC, VIDB, and VIDA are data lines, while VIDS is a latching strobe that programs in the LM10010 data. As shown in the Timing Diagram in Figure 1, the falling edge of VIDS latches in the data from VIDC, VIDB, and VIDA as the lower three LSB of the IDAC value. After a minimum hold time, the rising edge of VIDS latches in the data from VIDC, VIDB, and VIDA as the upper three LSB of the IDAC value. Internally, a delay on VIDS allows for the setting of all VID lines simultaneously.

The VID data word is set so that the lowest output current is seen at the highest VID data word (59.2 μA at a code of 0d). Conversely, the lowest current is seen at the highest VID data word (0 μA at 63d). During VID operation with the regulator, this will translate to the lowest output voltage with the lowest VID word, and the highest output voltage with the highest VID word. The communications pins can be used with a low voltage microcontroller, with a maximum V_{IL} of 0.4V and a minimum V_{IH} of 1.1V.

Upon startup, the IDAC is set at a code of 46d, which translates to approximately 16 μA . This default startup value is

trimmed at final test. For applications with a different default output current at startup, please contact National Semiconductor.

DEGLITCH TIME

The four digital input pins all have deglitch filters which prevent transient noise from affecting the operation of the LM10010. These filters will also impart a small delay to the digital signal. On the VIDS latching signal, there is an additional delay. As mentioned previously, this allows for the VID data lines and the VIDS strobe to be set simultaneously without the need for setup time.

ENABLE PIN AND UVLO

The enable (EN) pin allows the output of the device to be enabled or disabled with an external control signal. This pin is a precision analog input that enables the device when the voltage exceeds 1.34V (typical). The EN pin has 100 mV of hysteresis and will disable the output when the enable voltage falls below 1.24V (typical). If EN is not used, it can be left open, and will be pulled high by an internal 2 μA current source. Since the enable pin has a precise turn-on threshold it can be used along with an external resistor divider network from VIN to configure the device to turn-on at a precise input voltage.

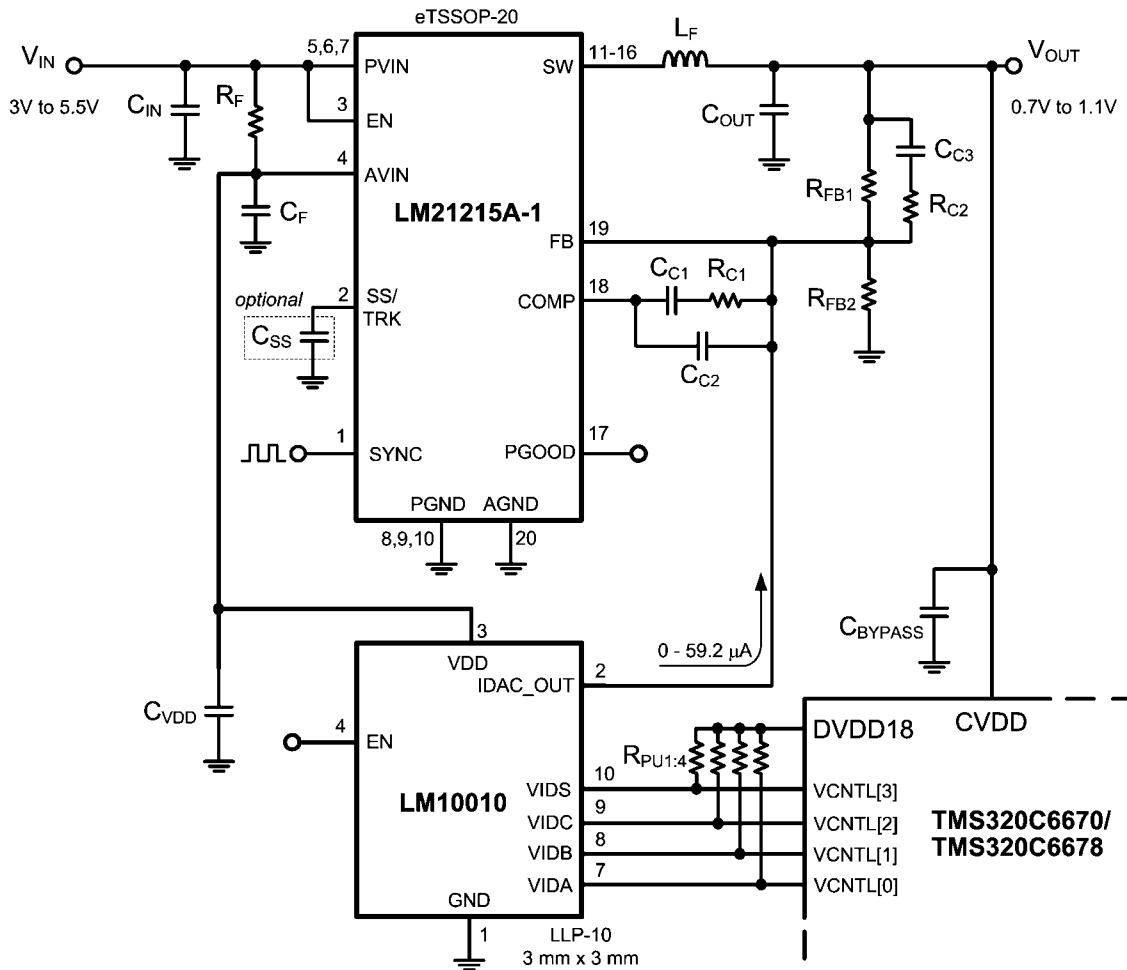
The LM10010 has a built-in under-voltage lockout (UVLO) protection circuit that keeps the device from operating until the input voltage reaches 2.65V (typical). The UVLO threshold has 200 mV of hysteresis that keeps the device from responding to power-on glitches during startup. Note that the enable and the UVLO are functionally the same as a reset. Bringing the device back from a low enable setting or from a VDD under-voltage event will reset the device back to its startup default setting.

Application Information

DESIGN EXAMPLE

In this example, an LM21215A-1 is used as the buck regulator to provide CVDD to the TMS320C6670 or TMS320C6678 from 0.7V to 1.1V and an output current of up to 15A. The LM10010 in conjunction with VID control from the DSP, pro-

vides control of the output voltage within this range with 6 bits of resolution. For this example, the 400 mV of voltage range translates to a 6.4 mV resolution in the control of the regulator output voltage. In this calculation, 1% resistor values are used. A schematic for this example is shown in the circuit of [Figure 4](#).



30156823

FIGURE 4. Typical Application Circuit

SETTING THE V_{OUT} RANGE AND LSB

Looking at the Typical Application Circuit in Figure 4, the following equation defines V_{OUT} of a given regulator (valid for $V_{OUT} > V_{FB}$):

$$V_{OUT} = V_{FB} \cdot \left(1 + \frac{R_{FB1}}{R_{FB2}} \right) - I_{DAC_OUT} \cdot R_{FB1} \quad (1)$$

Here, the output voltage is a function of the resistor divider from R_{FB1} and R_{FB2} . Additionally, there is a current supplied by the LM10010 that helps drive the feedback resistor R_{FB2} , thus lowering the necessary current supplied through R_{FB1} , and lowering V_{OUT} .

The change in the output voltage can be analyzed based on the resolution of the current DAC from the LM10010 compared to the desired resolution of the output swing of the regulator. R_{FB1} is designed to provide the desired LSB for V_{OUT} with the equation:

$$V_{OUT,LSB} = I_{DAC_OUT,LSB} \cdot R_{FB1} \quad (2)$$

Based on the desired default V_{OUT} (with $IDAC_OUT = 0 \mu A$), R_{FB2} can be solved from Eq. 1 above.

EXAMPLE SOLUTION

Assuming a 400 mV output range, 64 VID codes, and an IDAC LSB of 0.940 μA , it is desired to have a V_{OUT} with an LSB of 6.4 mV and a default value of 1.1V using an LM21215A-1 regulator:

$$6.4 \text{ mV} = 0.940 \mu A \cdot R_{FB1} \quad (3)$$

$$R_{FB1} = 6.8 \text{ k}\Omega \quad (4)$$

$$1.103 \text{ V} = 0.6 \text{ V} \cdot \left(1 + \frac{6.8 \text{ k}\Omega}{R_{FB2}} \right) - 0 \text{ V} \quad (5)$$

$$R_{FB2} = 8.1 \text{ k}\Omega \quad (6)$$

Using 1% resistor values, R_{FB1} can be set to 6.81 k Ω and R_{FB2} can be set to 8.06 k Ω . This will yield a regulator output range of 0.704V to 1.107V. At startup, the code of the LM10010 will be 46d (101110b) and will output a 15.97 μ A. This will give an output voltage of approximately 1.0V (0.998V) when power is applied and both the LM10010 and the LM21215A-1 come out of UVLO. Of course, values calculated here will be dependent on the accuracy of the regulator, the LM10010 IDAC, and the resistor values used in the circuit.

Table 1 shows the codes and some of the resultant values of the IDAC current and the corresponding regulator output voltage for the previous example.

TABLE 1. VID Codes with IDAC Current and Regulator Voltage for the Example in Figure 4.

VID Code	IDAC Current (μ A)	Regulator Voltage (V)
000000b	59.20	0.7038
000001b	58.26	0.7102
000010b	57.32	0.7166
000011b	56.38	0.7230
...		
111100b	2.82	1.0878
111101b	1.88	1.0941
111110b	0.94	1.1005
111111b	0.00	1.1069

PC BOARD GUIDELINES

The following guidelines should be followed when designing the PC board for the LM10010:

- Place the LM10010 close to the regulator feedback pin to minimize the FB trace length.
- Place a small capacitor, C_{VDD} , (1 nF) directly adjacent to the VDD and GND pins of the LM10010 to help minimize transients which may occur on the input supply line.
- The high current path from the board's input to the load and the return path should be parallel and close to each other to minimize loop inductance.
- The ground connections for the various components around the LM10010 should be connected directly to each other, and to the LM10010's GND pins, and then connected to the system ground at one point. Do not connect the various component grounds to each other through the high current ground line.
- For additional information about the operation of the regulator, please consult the respective datasheet and application notes on the respective evaluation boards.

Notes

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Mobile Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Automotive and Transportation	www.ti.com/automotive
Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Video and Imaging	www.ti.com/video

TI E2E Community Home Page

e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2012, Texas Instruments Incorporated