



# System-Management IC with Programmable Quad Voltage Monitoring and Supervisory Functions

Preliminary Technical Data

**AD5100**

## FEATURES

- **Two Device-Enabling Outputs with Six Programmable Monitoring Inputs (Table 1)**
  - **Two 30V Monitoring Inputs with Shutdown Control of External Devices:**
    - **Programmable Over-voltage, Under-voltage, Turn-on, Turn-off Thresholds, and Shutdown timings**
    - **Shutdown Warning with Fault Detection**
  - **Two 5V Monitoring Inputs with Reset Control of External Devices:**
    - **Programmable Reset Thresholds and Hold Time**
  - **Two Supervisory Functions:**
    - **Watchdog Reset Controller with Programmable Timeout and Selectable Floating Input**
    - **Manual Reset Control for External Devices**
- **Digital Interface and Programmability:**
  - **I<sup>2</sup>C<sup>®</sup> Compatible Interface**
  - **OTP<sup>1</sup> for Permanent Threshold and Timing Settings**
  - **OTP Overwritten Capable for Dynamic Adjustments**
  - **Power Up by Edge Triggered Signal**
  - **Power Down by I<sup>2</sup>C Software**
- **Operating Range:**
  - **Supply Voltage 6.0V to 30V**
  - **Temp Range -40°C to +125°C**
  - **Low Shutdown Current: 10μA**
- **High-Voltage-Input Anti-migration Shielding Pinouts**

## APPLICATIONS

- **Automotive Systems**
- **Network Equipment**
- **Computers, Controllers, and Embedded Systems**

## GENERAL DESCRIPTION

The AD5100 is a programmable system-management IC that combines 4-channel of voltage monitoring and a watchdog supervision that can be used to shutdown external supplies, reset processors, or disable any other system electronics when the systems malfunction. The AD5100 can also be used to protect system under faulty condition of improper devices power up sequencing. The AD5100 can monitor two 30V inputs with shutdown and reset controls, one 2.5V-5.0V and one 0.9V-3.3V monitoring inputs with reset control, a robust watchdog reset controller. Most monitoring input thresholds and timing settings can be programmed on the fly or permanently set in the factory with the OTP feature.

The AD5100 is versatile for system-monitoring applications where critical μP, DSP, and embedded systems operate under harsh conditions such as automotive, industrial, or communications network environments.

The AD5100 is available in compact QSOP-16 and can operate in an extended automotive temperature range from -40°C to +125°C.

<sup>1</sup>One Time Programmable EPROM – Unlimited Adjustment Before OTP Execution.  
<sup>2</sup>With Programmable Threshold and Programmable Delay.

Table 1. AD5100 General Inputs and Output Information

Input	Monitoring Range <sup>2</sup>	Shutdown Control	Reset Control	Fault Detection
V <sub>1MON</sub>	6 – 30 V	√	√	√
V <sub>2MON</sub>	3 – 30 V	√	√	√
V <sub>3MON</sub>	2.5 – 5.0 V		√	√
V <sub>4MON</sub>	0.9 – 3.3 V		√	√
WDI	0 – 5 V	√	√	
MR	0 – 5 V		√	

### Rev. PrJ

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FUNCTIONAL BLOCK DIAGRAM

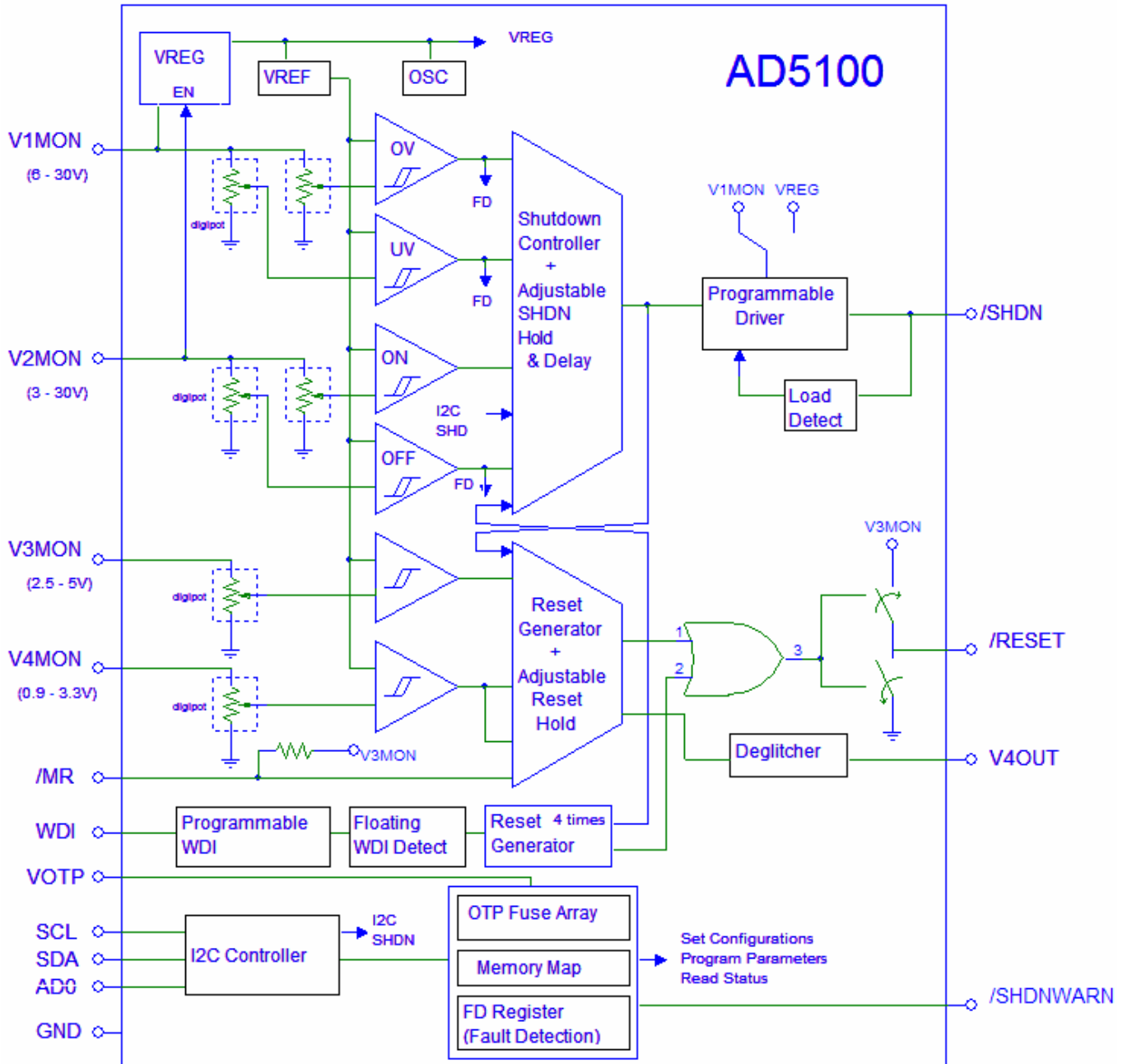


Figure 1. Functional Block Diagram

## Electrical Characteristics

6V ≤ V<sub>1MON</sub> ≤ 30V and 3V ≤ V<sub>2MON</sub> ≤ 30V, -40°C ≤ T<sub>A</sub> ≤ +125°C, unless otherwise noted.

Table 2.

Parameter	Symbol	Conditions	Min	Typ <sup>1</sup>	Max	Unit
<b>HIGH-VOLTAGE MONITORING INPUTS V<sub>1MON</sub>, V<sub>2MON</sub> AND SHDN, SHDNWARN OUTPUT</b>						
Input Resistance	R <sub>IN_V1MON</sub> , R <sub>IN_V2MON</sub>			60		KΩ
<b>V<sub>1MON</sub></b>						
OV, UV Threshold Tolerance (Figure 5 and Table 5a)	ΔOV, ΔUV	T <sub>A</sub> = 25°C T <sub>A</sub> = -40°C to 85°C T <sub>A</sub> = -40°C to 125°C	-1.5 -2 -3		+1.5 +2 +3	% % %
Hysteresis				1.5		%
Programmable Shutdown Hold Time Tolerance (Figure 5 and Table 6a)	Δt <sub>1SD_HOLD</sub>	Does not apply to code 0x7	-10		+10	%
Programmable Shutdown Delay Tolerance (Figure 4 and Table 6a)	Δt <sub>1SD_DELAY</sub>	Does not apply to code 0x7	-10		+10	%
Fault Detection Delay	t <sub>FD_DELAY</sub>			70		μs
Glitch-Immune Time	t <sub>GLITCH</sub>			50		μs
<b>V<sub>2MON</sub></b>						
On, Off Threshold Tolerance <sup>2</sup> (Figure 5 and Table 5a)	ΔOn, ΔOff	T <sub>A</sub> = 25°C T <sub>A</sub> = -40°C to 85°C T <sub>A</sub> = -40°C to 125°C	-1.5 -2 -3		+1.5 +2 +3	% % %
Hysteresis				1.5		%
Turn-On Programmable SHDN Hold Time Tolerance (Figure 5 and Table 6a)	Δt <sub>2SD_HOLD</sub>	Does not apply to code 0x7	-10		+10	%
Turn-Off Programmable SHDN Delay Time Tolerance (Figure 5 and Table 6a)	Δt <sub>2SD_DELAY</sub>	Does not apply to code 0x7	-10		+10	%
Fault Detection Delay	t <sub>FD_DELAY</sub>	V <sub>2MON_OFF</sub> only		70		μs
Glitch Immune Time	t <sub>GLITCH</sub>			50		μs
<b>SHDN</b>						
SHDN Output High	V <sub>OH</sub>	V <sub>RAIL</sub> =V <sub>REG</sub> , I <sub>SOURCE</sub> =40uA	2.4			V
SHDN Output High	V <sub>OH</sub>	V <sub>RAIL</sub> =V <sub>1MON</sub> , I <sub>SOURCE</sub> =600uA	V <sub>1MON</sub> -0.5			V
SHDN Output Low	V <sub>OL</sub>	I <sub>SINK</sub> =1.6mA			0.4	V
SHDN Output Low	V <sub>OL</sub>	V <sub>1MON</sub> =12V, I <sub>SINK</sub> =40mA		1.7	3	V
SHDN Sink Current	I <sub>SINK</sub>	V <sub>1MON</sub> =12V, SHDN forced to 12V		10	15	mA
<b>SHDNWARN (Open Drain Output)</b>						
SHDNWARN Inactive Leakage Current	I <sub>OH_SHDNWARN</sub>			1		μA
SHDNWARN Active	V <sub>OL_SHDNWARN</sub>	I <sub>sink</sub> = 3mA			0.4	V
<b>LOW-VOLTAGE MONITORING INPUTS V<sub>3MON</sub>, V<sub>4MON</sub> AND RESET OUTPUT</b>						
Voltage Range	V <sub>3MON</sub> , V <sub>4MON</sub>		-0.3		5.5	V
Input Resistance	R <sub>IN_V1MON</sub> , R <sub>IN_V2MON</sub>			50		KΩ
<b>V<sub>3MON</sub>, V<sub>4MON</sub></b>						
V <sub>3MON</sub> Threshold Tolerance (Figure 6 and Table 5a)	ΔV <sub>3MON</sub>	T <sub>A</sub> = 25°C T <sub>A</sub> = -40°C to 85°C T <sub>A</sub> = -40°C to 125°C	-1.5 -2 -3		+1.5 +2.7 +3.5	% % %
V <sub>3MON</sub> Hysteresis	V <sub>3_HYSTERESIS</sub>			1.5		%

Parameter	Symbol	Conditions	Min	Typ <sup>1</sup>	Max	Unit
$V_{4MON}$ Threshold Tolerance (Figure 7 and Table 5a)	$\Delta V_{4MON}$	$T_A = 25^\circ\text{C}$	-2.5		+2.5	%
		$T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$	-3		+3	%
		$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	-3.5		+3.5	%
$V_{4MON}$ Hysteresis	$V_{4\_HYSTERESIS}$			6		%
Reset Hold Time Tolerance (Figures 6, 7, and Table 6a)	$\Delta t_{RS\_HOLD}$	Does not apply to codes 0x6 and 0x7	-10		+10	%
$V_{3,4MON}$ -to- $\overline{\text{RESET}}$ Delay	$t_{RS\_DELAY}$			70		$\mu\text{s}$
$\overline{\text{RESET}}$ Output Voltage	$V_{OH}$	$V_{3MON} \geq 4.38\text{V}$ , $I_{SOURCE} = 120\mu\text{A}$	$V_{3MON}-1.5$			V
		$2.7\text{V} < V_{3MON} \leq 4.38\text{V}$ , $I_{SOURCE} = 30\mu\text{A}$	$0.8 \times V_{3MON}$			V
		$2.3\text{V} < V_{3MON} \leq 2.7\text{V}$ , $I_{SOURCE} = 20\mu\text{A}$	$0.8 \times V_{3MON}$			V
		$1.8\text{V} \leq V_{3MON} \leq 2.3\text{V}$ , $I_{SOURCE} = 8\mu\text{A}$	$0.8 \times V_{3MON}$			V
		$V_{3MON} > 4.38\text{V}$ , $I_{SINK} = 3.2\text{mA}$			0.4	V
$\overline{\text{RESET}}$ Output Short-Circuit Current <sup>3</sup>	$I_{SOURCE}$	$V_{3MON} < 4.38\text{V}$ , $I_{SINK} = 1.2\text{mA}$			0.3	V
		$\overline{\text{RESET}} = 0$ , $V_{3MON} = 5.5\text{V}$			800	$\mu\text{A}$
Glitch Immune Time	$t_{GLITCH}$	$\overline{\text{RESET}} = 0$ , $V_{3MON} = 3.6\text{V}$			400	$\mu\text{A}$
				50		$\mu\text{s}$
$V_{4OUT}$ Maximum Output	$V_{4OUT\_MAX}$	Open Drain			5.5	V
$V_{4OUT}$ Propagation Delay	$t_{V4OUT\_Delay}$			70		$\mu\text{s}$
$V_{4OUT}$ Maximum Frequency	$f_{V4OUT}$	Apply to $\overline{\text{RESET}}$ disabled only		10		KHz

**WDI (WATCHDOG INPUT)**

WDI Programmable-Timeout Tolerance (Figure 8 and Table 6a)	$\Delta t_{WD}$		-10		+10	%
WDI Pulse Width	$t_{WDI}$		50			ns
Watchdog-Initiated $\overline{\text{RESET}}$ Pulse Width	$t_{WDR}$	When no WDI		$t_{WD}/50$		ms
Watchdog-Initiated $\overline{\text{SHDN}}$	$t_{WD\_SHDN}$	When no WDI activity $> 4 t_{WD}$		1		s
WDI Input Voltage	$V_{IL\_WD}$				$0.3 \times V_{3MON}$	V
	$V_{IH\_WD}$		$0.7 \times V_{3MON}$			V
WDI Input Current		WDI = $V_{3MON}$ , time average			160	$\mu\text{A}$
		WDI = 0, time average	-20			$\mu\text{A}$

**MR (MANUAL RESET) INPUT**

MR Input Voltage	$V_{IL\_MR}$				$0.3 \times V_{3MON}$	V
	$V_{IH\_MR}$		$0.7 \times V_{3MON}$			V
MR Pulse Width	$t_{MR}$		1			$\mu\text{s}$
MR Deglitching	$t_{MR\_GLITCH}$			100		ns
MR -to-Reset Delay	$t_{MR\_DELAY}$			1		$\mu\text{s}$
MR Pullup Resistance (internal to $V_{3MON}$ )				50		$\text{k}\Omega$
Reset Hold-Time Tolerance (Figure 9 and Table 6a)	$\Delta t_{RS\_HOLD}$	Do not apply to codes 0x6 and 0x7	-10		+10	%

**SERIAL INTERFACES**

Input Logic High (SCL, SDA) <sup>4</sup>	$V_{IH}$	External $R_{pull-up} = 2.2\text{k}\Omega$	2.0		5.5	V
Input Logic Low (SCL, SDA)	$V_{IL}$	External $R_{pull-up} = 2.2\text{k}\Omega$	0		0.8	V
Output Logic High (SDA)	$V_{OH}$	$V_{RAIL} = 3.3\text{V}$ , External $R_{pull-up} = 2.2\text{k}\Omega$	3.0		3.3	V
Output Logic Low (SDA)	$V_{OL}$	$V_{RAIL} = 3.3\text{V}$ , External $R_{pull-up} = 2.2\text{k}\Omega$	0		0.4	V
Input Capacitance	$C_i$			5		pF

**POWER SUPPLY**

Supply Voltage Range	$V_{1MON}$		6.0		30	V
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Parameter	Symbol	Conditions	Min	Typ <sup>1</sup>	Max	Unit
Sleep Mode Supply Current	$I_{SLEEP\_V1MON}$	$V_{2MON} = 0V$			10	$\mu A$
Active Mode Supply Current	$I_{POWER\_V1MON}$	$V_{2MON} = 12V$			3	mA
		$V_{2MON}$ Edge Triggered Mode Selected			3	mA
Device Power On Threshold	$V_{2MON,IH}$ $V_{2MON,IL}$		2.2			V V
Device Power Up $V_{2MON}$ Minimum Pulse Width (Figure 14)	$t_{V2MON\_PW}$		4			ms
Device Power Down Delay		$V_{2MON} < 0.4V$ (Normal Mode) I2C Initiated Power Down		2 10		s $\mu s$
OTP Supply Voltage <sup>6</sup>	$V_{OTP}$	For OTP only	6		6.5	V
OTP Supply Current	$I_{VOTP}$	For OTP only	200			mA
OTP Settling Time <sup>7</sup>	$t_{S\_OTP}$			12		ms

**TIMING CHARACTERISTICS<sup>8</sup>**

Parameter	Symbol	Conditions	Min	Typ <sup>1</sup>	Max	Unit
Parameter Adjustment Time	$t_{S1}$			1		$\mu s$
<b>I2C Interface Timing Characteristics</b>						
SCL Clock Frequency	$f_{SCL}$				400	KHz
$t_{BUF}$ Bus Free Time between Start and Stop	$t_1$		1.3			$\mu s$
$t_{HD,STA}$ Hold Time after (Repeated) START condition. After this period, the first clock is generated	$t_2$		0.6			$\mu s$
$t_{LOW}$ Low Period of SCL Clock	$t_3$		1.3			$\mu s$
$t_{HIGH}$ High Period of SCL Clock	$t_4$		0.6		50	$\mu s$
$t_{SU,STA}$ Setup Time for Start Condition	$t_5$		0.6			$\mu s$
$t_{HD,DAT}$ Data Hold Time	$t_6$				0.9	$\mu s$
$t_{SU,DAT}$ Data Setup Time	$t_7$		0.1			$\mu s$
$t_F$ Fall Time of Both SDA and SCL Signals	$t_8$				0.3	$\mu s$
$t_R$ Rise Time of Both SDA and SCL Signals	$t_9$				0.3	$\mu s$
$t_{SU,STO}$ Setup Time for Stop Condition	$t_{10}$		0.6			$\mu s$

Notes:

1. Represent typical values at 25°C,  $V_{1MON} = 12V$ , and  $V_{2MON} = 12V$ .
2. Does not apply if  $V_{2MON}$  is a digital signal.
3. The  $\overline{RESET}$  short-circuit current is the maximum pullup current when  $\overline{RESET}$  is driven low by a  $\mu P$  bidirectional reset pin.
4. It is typical for the SCL and SDA have resistors to be pulled up to  $V_{3MON}$ . However, care must be taken to ensure that the minimum  $V_{IH}$  is met when the SCL and SDA are driven directly from a low voltage logic controller without pull-up resistors.
5. Initial  $V_{2MON}$  ON minimum remains as 2.2V but the -0.3V to 30V specifications apply afterwards.
6.  $V_{OTP}$  can be furnished by Factory 6V power supply, rather than on-board power supply, when performing factory programming. A 10 $\mu F$  tantalum capacitor is required on  $V_{OTP}$  during operation regardless of whether the OTP fuses are programmed.
7. The OTP settling time occurs only once if OTP function is used.
8. Guaranteed by design and not subject to production test.

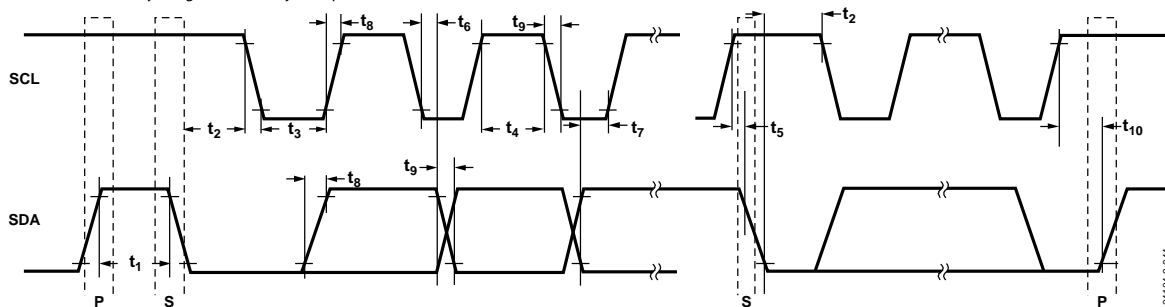


Figure 2. Digital Interface Timing Diagram

## Absolute Maximum Ratings

Table 3.

Parameter	Rating
V <sub>1MON</sub> to GND	−0.3 V, +33 V
V <sub>2MON</sub> to GND	−0.3 V, +33 V
V <sub>3MON</sub> to GND	−0.3 V, +7 V
V <sub>4MON</sub> to GND	−0.3 V, +7 V
V <sub>OTP</sub> to GND	−0.3 V, +7 V
Digital Input Voltage to GND ( $\overline{\text{MR}}$ , WDI, SCL, SDA, AD0)	0 V, +7V
Digital Output Voltage to GND ( $\overline{\text{RESET}}$ , V <sub>4OUT</sub> , $\overline{\text{SHDNWARN}}$ )	0 V, +7V
Digital Output Voltage to GND ( $\overline{\text{SHDN}}$ )	0 V, +33V
Operating Temperature Range	−40°C to +125°C
HBM ESD (All Pins)	2KV
Maximum Junction Temperature (T <sub>Jmax</sub> )	140°C
Storage Temperature	−65°C to +150°C
Lead Temperature (Soldering, 10 s – 30 s)	245°C
Thermal Resistance Junction-to-Ambient <sup>1</sup> $\theta_{JA}$	105°C/W
Thermal Resistance Junction-to-Case $\theta_{JC}$	39°C/W

<sup>1</sup> Package power dissipation = (T<sub>Jmax</sub> – T<sub>A</sub>) /  $\theta_{JA}$ .

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

### PIN CONFIGURATION AND FUNCTIONAL DESCRIPTION

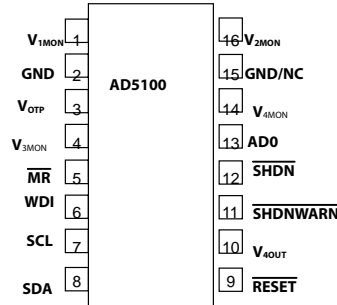


Figure 3a. AD5100 Pin Configuration

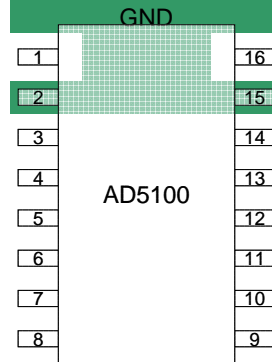


Figure 3b. Recommended PCB Layout for Shielded High-Voltage Inputs

Table 4. AD5100 Pin Function Descriptions

Pin No.	Mnemonic	Description
1	V <sub>1MON</sub>	High-voltage monitoring input. AD5100 internal supply is derived from V <sub>1MON</sub> .
2	GND	Ground.
3	V <sub>OTP</sub>	One-time supply voltage for EPROM. Can be floating when it is not performing fuse programming
4	V <sub>3MON</sub>	Low-voltage monitoring-input
5	$\overline{\text{MR}}$	Manual-Reset Input. Active-low.
6	WDI	Watch-Dog Input.
7	SCL	I2C Serial-Input Register Clock. If it is driven directly from a logic driver without the pull-up resistor, ensure that V <sub>IH</sub> min is 3.3V.
8	SDA	I2C Serial Data Input/Output. If it is driven direct from a logic driver without the pull-up resistor, ensure that V <sub>IH</sub> min is 3.3V.
9	$\overline{\text{RESET}}$	$\overline{\text{RESET}}$ , Push-Pull Output with rail voltage of V <sub>3MON</sub>
10	V <sub>4OUT</sub>	Open-drain output. Triggered by V <sub>4MON</sub>
11	$\overline{\text{SHDNWARN}}$	Shutdown Warning. Active-Low, Open-drain output.
12	$\overline{\text{SHDN}}$	Shutdown output. Push-Pull Output with selectable rail voltage of V <sub>1MON</sub> or V <sub>REG</sub> . 30V maximum
13	AD0	I2C Slave-Address Configuration.
14	V <sub>4MON</sub>	Low-voltage monitoring Input.
15	GND/NC	Ground/No Connect. Can be grounded or left floating but do not connect to any other potentials.
16	V <sub>2MON</sub>	High-voltage monitoring input. It is also the internal-supply-voltage enabling input.

Table 5a. Available Programmable-Threshold at  $T_A = 25\text{ }^\circ\text{C}$  (All values are typical ratings; see Table 2 for tolerances)

	$V_{1MON}$ OV Threshold	$V_{1MON}$ UV Threshold	$V_{2MON}$ ON Threshold	$V_{2MON}$ OFF Threshold	$V_{3MON}$ Threshold	$V_{4MON}$ Threshold
	7.92	6.00	3.00	3.00	2.32	Disabled*
	9.00	6.49	3.30	3.30	2.64	0.86
	9.90	6.95	4.50	4.50	2.93	1.15
	11.00	7.47	4.77	4.77	3.10	1.37
	12.00	7.92	6.00	6.00	4.36*	1.43
	13.20	8.43*	6.49	6.49	4.65	1.66
	14.14	9.00	6.95	6.95*	4.75	2.30
	15.23	9.43	7.47*	7.47	4.97	3.10
	15.84	9.90	7.92	7.92	Reserved	Reserved
	17.22	10.42	8.43	8.43	Reserved	Reserved
	18.00*	11.00	9.00	9.00	Reserved	Reserved
	18.86	11.65	9.43	9.43	Reserved	Reserved
	19.80	12.00	9.90	9.90	Reserved	Reserved
	22.00	12.38	15.23	15.23	Reserved	Reserved
	24.75	13.20	19.80	19.80	Reserved	Reserved
	28.29	13.66	24.75	Rising Edge Trigger/Pseudo CAN Wake Up Mode	Reserved	Reserved

\* Default.  $V_{1MON\_OV}$  must be  $> V_{1MON\_UV}$ .  $V_{2MON\_OFF}$  will be ignored if  $> V_{2MON\_ON}$  but  $V_{2MON\_OFF}$  cannot be  $= V_{2MON\_ON}$ .

Table 5b. Look Up Table of Programming Code versus Typical Thresholds Shown in Table 5a

Code	$V_{1MON}$ OV Threshold	$V_{1MON}$ UV Threshold	$V_{2MON}$ ON Threshold	$V_{2MON}$ OFF Threshold	$V_{3MON}$ Threshold	$V_{4MON}$ Threshold
0000	18.00*	8.43*	7.47*	6.95*	4.36*	Disabled*
0001	18.86	7.92	6.95	7.47	4.65	0.86
0010	15.84	9.43	6.49	6.00	4.75	1.15
0011	17.22	9.00	6.00	6.49	4.97	1.37
0100	24.75	6.49	4.77	4.50	2.32	1.43
0101	28.29	6.00	4.50	4.77	2.64	1.66
0110	19.80	7.47	3.30	3.00	2.93	2.30
0111	22.00	6.95	3.00	3.30	3.10	3.10
1000	9.90	12.38	24.75	19.80	Reserved	Reserved
1001	11.00	12.00	19.80	Rising Edge Trigger/Pseudo CAN Wake Up Mode	Reserved	Reserved
1010	7.92	13.66	15.23	9.90	Reserved	Reserved
1011	9.00	13.20	9.90	15.23	Reserved	Reserved
1100	14.14	10.42	9.43	9.00	Reserved	Reserved
1101	15.23	9.90	9.00	9.43	Reserved	Reserved
1110	12.00	11.65	8.43	7.92	Reserved	Reserved
1111	13.20	11.00	7.92	8.43	Reserved	Reserved



Table 6a. Available Programmable Hold Time and Delay (All values are typical ratings; see Table 2 for tolerances)

	t <sub>1SD_HOLD</sub> (ms)	t <sub>1SD_DELAY</sub> (ms)	t <sub>2SD_HOLD</sub> (ms)	t <sub>2SD_DELAY</sub> (ms)	t <sub>RS_HOLD</sub> (ms)	t <sub>WD</sub> (ms)
	0.07	0.07	0.07	0.07	0.1	100
	20	50	10*	50	1	250
	40	100	20	100*	15	500
	60	200	30	200	30	750
	80	400	40	400	50	1000
	100	800	50	800	100	1250
	150	1000	100	1000	150	1500*
	200*	1200*	200	1200	200*	2000

\* Default

Table 6b. Look Up Table of Programming Code versus Typical Timings Shown in Table 6a

Code	t <sub>1SD_HOLD</sub> (ms)	t <sub>1SD_DELAY</sub> (ms)	t <sub>2SD_HOLD</sub> (ms)	t <sub>2SD_DELAY</sub> (ms)	t <sub>RS_HOLD</sub> (ms)	t <sub>WD</sub> (ms)
000	200*	1200*	10*	100*	200*	1500*
001	150	1000	20	50	150	2000
010	100	800	30	200	100	1250
011	80	400	40	400	50	1000
100	60	200	50	800	30	750
101	40	100	100	1000	15	500
110	20	50	200	1200	1	250
111	0.07	0.07	0.07	0.07	0.1	100

\* Default

## THEORY OF OPERATION

The AD5100 is a Programmable System Management IC that has four channels of monitoring inputs. Two inputs have high voltage (30V) capability. For example if the AD5100 is used in the automotive application, the  $V_{1MON}$  (Monitoring Input 1) should be the battery and the  $V_{2MON}$  should either be the ignition switch or the pseudo CAN bus wake up signal input. Two other inputs,  $V_{3MON}$  and  $V_{4MON}$ , are low voltage for 0.9V, 1.8V, 2.5V, 3.3V, or 5V monitoring. The two high voltage inputs control the shutdown signal,  $\overline{SHDN}$ , while the two low voltage inputs control the reset signal,  $\overline{RESET}$ . The  $\overline{SHDN}$  and  $\overline{RESET}$

are both disabling functions for the external devices. The differences are output levels and driving capabilities that will be described later. In some cases the  $\overline{SHDN}$  and  $\overline{RESET}$  may be used interchangeably. The  $\overline{WDI}$  (Watchdog) and  $\overline{MR}$  (Manual Reset) inputs also control  $\overline{RESET}$  output for external digital processor. Figure 4 shows the general flow chart and Table 7 summarizes the AD5100 functions and features.

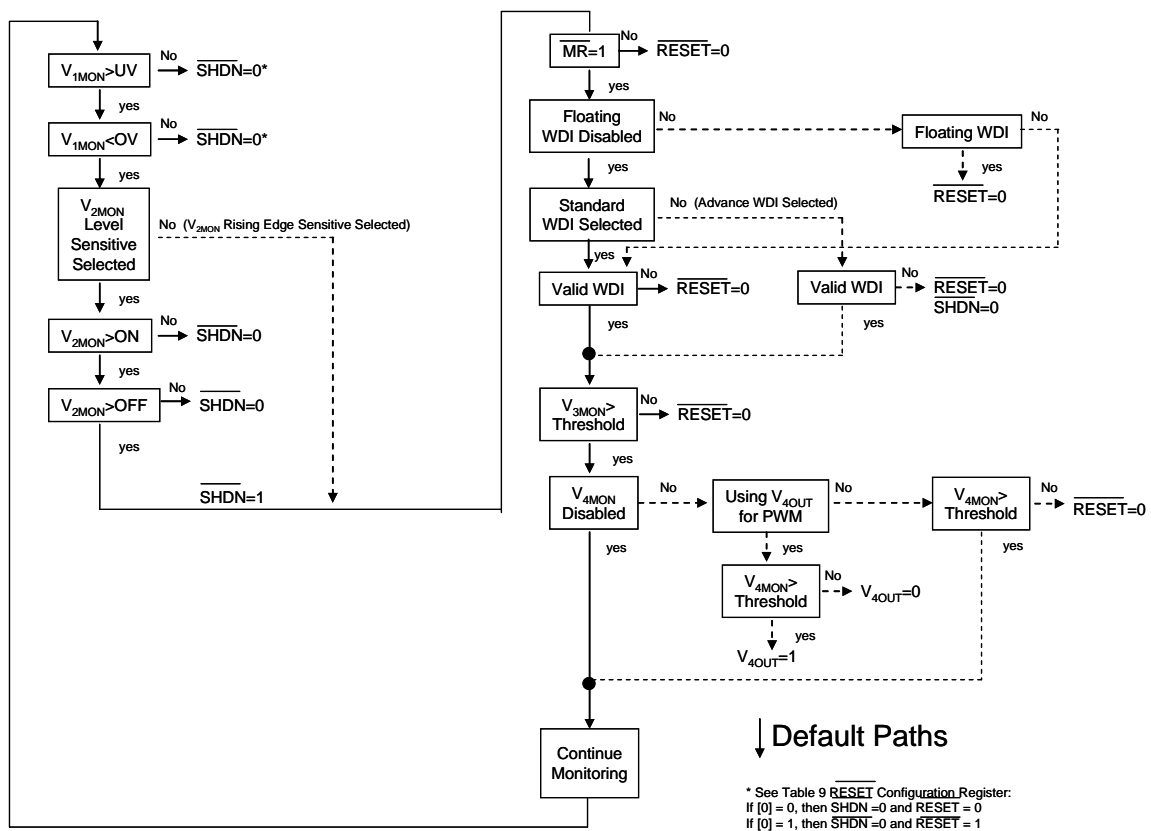


Figure 4. General Flow Chart

Table 7. AD5100 Functions and Features

Input	Monitoring Range	Shutdown Control	Reset Control	Fault Detection	Functions and Features	If Not Used
$V_{1MON}$	6 – 30 V	✓	✓	✓	Over/Under Voltage	Does not apply
$V_{2MON}$	3 – 30 V	✓	✓	✓	On/Off Voltage CAN Bus Wake Up	Tie to $V_{1MON}$ , Min Input
$V_{3MON}$	2.5 – 5.0 V		✓	✓		Connect to VOTP and Threshold to Minimum
$V_{4MON}$	0.9 – 3.3 V		✓	✓	Additional Output	Select Disable in Threshold
WDI	0 – 5 V	✓	✓		Standard, Advance, or Watchdog Selectable	Leave Floating

$\overline{\text{MR}}$

0 – 5 V

√

Highest Priority on  
Other Inputs

Leave Floating

### Monitoring Inputs

#### $V_{1\text{MON}}$

$V_{1\text{MON}}$  is a high-voltage monitoring input that controls the  $\overline{\text{SHDN}}$  and  $\overline{\text{RESET}}$  functions of the external devices. In addition, it also provides a shutdown warning to the system.  $V_{1\text{MON}}$  monitors inputs from 6V to 30V. It has a 16-level programmable over-voltage, under-voltage (OV,UV) shutdown threshold with an 8-step 0.05ms-200ms shutdown hold time and 0.05ms-1200ms shutdown delay. The shutdown hold time means that the shutdown of the external device is held until the programmed-time is reached. On the other hand, the shutdown delay means that shutting down the external device is delayed until the programmed-time is reached.

The OV threshold chosen must be greater than the UV threshold. When the shutdown is triggered either because the input has reached OV or UV threshold, such fault condition will be temporarily recorded in the Fault Detection Register. The  $\overline{\text{SHDNWARN}}$  output will transition low for signaling before shutdown occurs. The occurrence of Shutdown is

depending on how long the shutdown programmed-delay is set relative to the  $\overline{\text{SHDNWARN}}$  propagation delay, this feature attempts to allow the system to finish any critical house keeping tasks before shutting down the external device. The  $V_{1\text{MON}}$ , shutdown, and shutdown warning timing diagrams are shown in Figure 5. The ranges of OV and UV Thresholds are shown in Table 5a and the programming codes of the selected-thresholds are found in Table 5b. The defaulted OV threshold is 18.00V and UV threshold is 8.43V. Similarly, the ranges of shutdown hold and delay times are shown in Table 6a and the programming codes of the selected-timings are found in Table 6b. The defaulted shutdown hold time is 200ms delay time is 1200ms. The voltage at  $V_{1\text{MON}}$  provides the power for the AD5100 but valid signal at  $V_{2\text{MON}}$  must be present before the internal  $V_{\text{REG}}$  starts operation. Details will be explained in the power section.

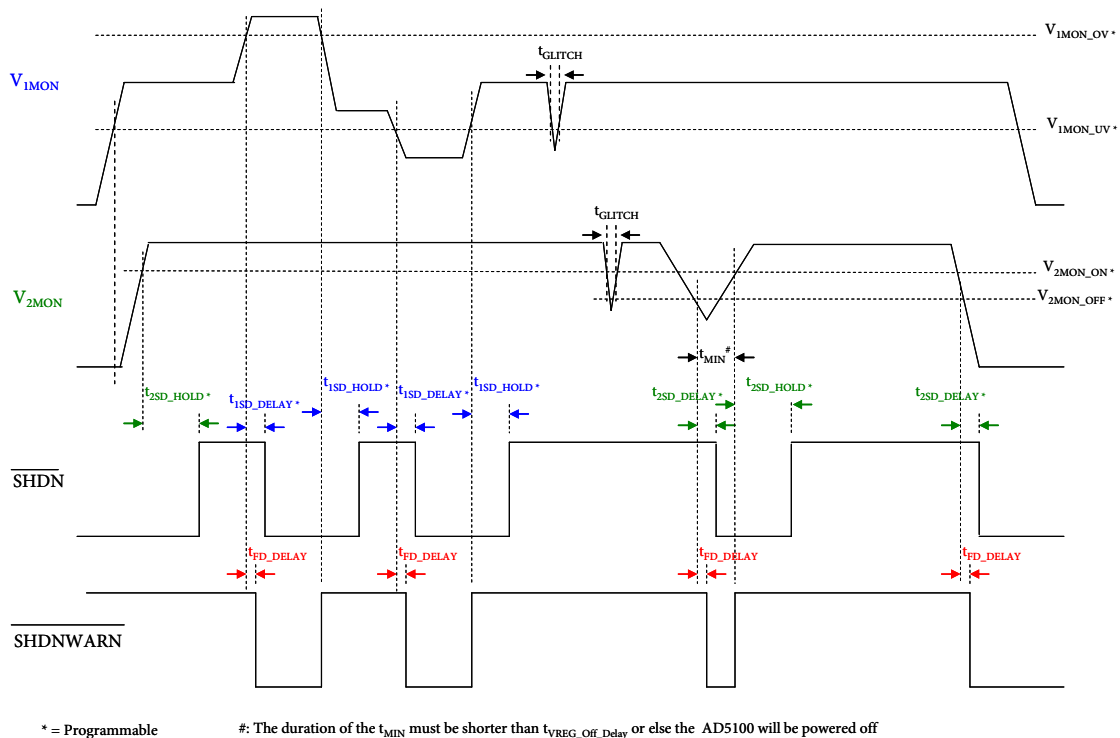


Figure 5.  $V_{1\text{MON}}$  and  $V_{2\text{MON}}$  Shutdown Timing Diagrams (Note  $\overline{\text{RESET}}$  follows  $\overline{\text{SHDN}}$ ).

The  $V_{1\text{MON}}$  pin is monitored by two comparators, one for over-voltage, and one for under-voltage detection. Both are designed with 1.5% hysteresis.

When the  $V_{1\text{MON}}$  input goes above the programmed OV threshold, the comparator will become active immediately,

indicating an OV condition has occurred. Due to hysteresis, the  $V_{1\text{MON}}$  input must be brought below the programmed OV threshold by 1.5% before the comparator will be in-active, indicating the OV condition has gone away, see Figure 6.

When the  $V_{1MON}$  input drops below the programmed UV threshold, the comparator will become active immediately, indicating a UV condition has occurred. Similarly due to hysteresis, the  $V_{1MON}$  input must be brought above the programmed UV threshold by 1.5% before the comparator will be in-active, indicating the UV condition has gone away. Both  $V_{1MON}$  comparators are used (in conjunction with hold and delay timers) to control the  $SHDN$  and  $RESET$  pins.

$V_{1MON}$  exhibits typical input resistance of  $60K\Omega$  that users should account the loading effect.

The default  $V_{1MON}$  OV and UV thresholds are 18.00V and 8.43V respectively. The default  $V_{1MON}$  Shutdown Hold time and Shutdown Delay are 200ms and 1200ms respectively. User should refer to Tables 5b and 6b if they want to program different settings.

### $V_{2MON}$

$V_{2MON}$  is a high-voltage monitoring input that controls the  $SHDN$  and  $RESET$  functions of the external devices.  $V_{2MON}$  monitors inputs from 3V to 30V. It has a 16-level programmable Turn-on, Turn-off (ON,OFF) hysteresis threshold with an 8-step 0.05ms-200ms shutdown hold time and 0.05ms-1200ms shutdown delay.

By default,  $V_{2MON}$  is level-sensitive that the ON and OFF thresholds are both monitored. The ON threshold chosen must be greater than the OFF threshold. When the shutdown function is triggered by the input reaching  $V_{2MON\_OFF}$  threshold, such fault condition will be temporarily recorded in the Fault Detection Register. The  $SHDNWARN$  output will transition low for signaling before shutdown occurs. The occurrence of shutdown is depending on how long the shutdown programmed-delay is set relative to the  $SHDNWARN$  propagation delay, this feature attempts to allow the system to finish any critical house keeping tasks before shutting down the external device. The  $V_{2MON}$ , shutdown, and shutdown warning pins timing diagrams are also shown in Figure 5. The ranges of ON and OFF Thresholds are shown in Tables 5a and the programming codes of the selected-thresholds are found in Table 5b. The defaulted ON threshold is 7.47V and OFF threshold is 6.95V. Similarly, the ranges of shutdown hold and delay times are shown in Table 6a and the programming codes of the selected-timings are found in Table 6b. The defaulted shutdown hold time is 10ms and delay time is 100ms.

$V_{2MON\_OFF}$  will be ignored if  $V_{2MON\_OFF} > V_{2MON\_ON}$  but  $V_{2MON\_OFF}$  cannot be =  $V_{2MON\_ON}$ .

If the  $V_{2MON}$  is selected with Rising Edge Triggered, only the ON threshold is monitored and the OFF Threshold is ignored.

The voltage at  $V_{1MON}$  provides the power for the AD5100 but valid signal at  $V_{2MON}$  must be present before the internal  $V_{REG}$  starts operation. Details will be explained in the power section.

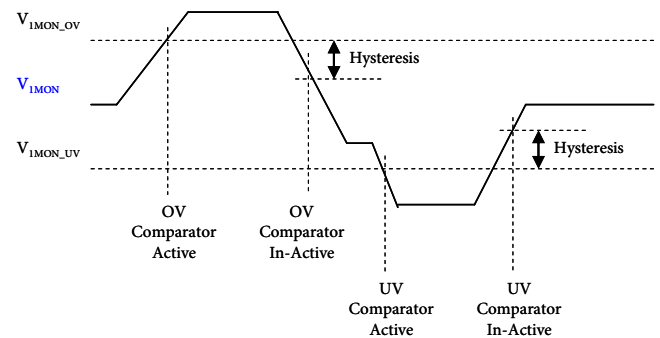


Figure 6.  $V_{1MON}$  Hysteresis.

The  $V_{2MON}$  pin is monitored by 2 comparators, 1 for turn-on, and 1 for turn-off detection in the level sensitive power-up mode. Both are designed with 1.5% hysteresis. On the other hand, the turn-on monitoring comparator is used only if the rising edge trigger power-up mode is selected.

When the  $V_{2MON}$  input goes above the programmed  $T_{on}$  threshold, the comparator will become active immediately, indicating an OV condition has occurred. Due to hysteresis, the  $V_{2MON}$  input must be brought below the programmed threshold by 1.5% before the comparator will be in-active, indicating the OV condition has gone away, see Figure 7.

When the  $V_{2MON}$  input drops below the programmed threshold, the comparator will become active immediately, indicating a UV condition has occurred. Similarly due to hysteresis, the  $V_{2MON}$  input must be brought above the programmed threshold by 1.5% before the comparator will be in-active, indicating the UV condition has gone away.

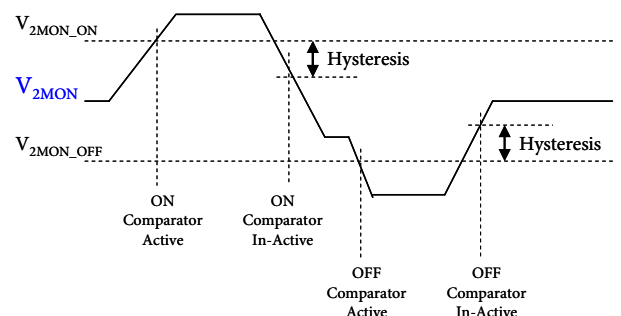


Figure 7.  $V_{2MON}$  Hysteresis.

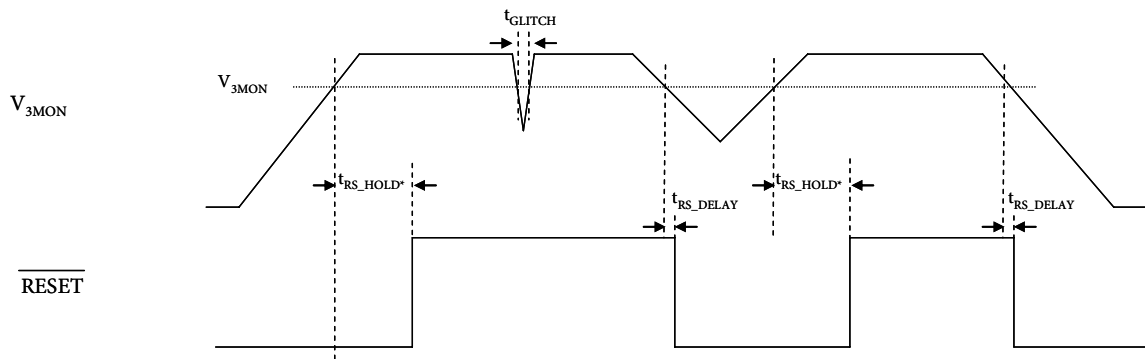
$V_{2MON}$  exhibits typical input resistance of  $60K\Omega$  that users should account the loading effect.

The default  $V_{2MON}$  ON and OFF thresholds are 7.47V and 6.95V respectively. The default  $V_{2MON}$  Shutdown Hold time and Shutdown Delay are 10ms and 100ms respectively. User should refer to Tables 5b and 6b if they want to program different settings.

**V<sub>3MON</sub>**

V<sub>3MON</sub> is a low-voltage monitoring input that controls the RESET function of an external device. V<sub>3MON</sub> monitors inputs from 2.5V to 5.5V. It has an 8-step programmable reset threshold with an 8-step 0.1ms-200ms reset hold time. The reset hold time means that the reset of the external device is held until the programmed-time is reached. The V<sub>3MON</sub> and reset timing diagrams are shown in Figure 8. The range of

thresholds is shown in Table 5a and the programming code of the selected-threshold is found in Table 5b. The defaulted monitoring threshold is 4.36V. Similarly, the range of reset hold time is shown in Tables 6a and the programming code of the selected-timing is found in Table 6b. The defaulted reset hold time is 200ms.



\* Programmable

Figure 8. V<sub>3MON</sub> RESET Timing Diagrams

The V<sub>3MON</sub> pin is monitored by a comparator to detect an under-voltage condition. It is designed with 1.5% hysteresis. When the V<sub>3MON</sub> input drops below the programmed UV threshold, the comparator will become active immediately, indicating a UV condition has occurred. Due to hysteresis, the V<sub>3MON</sub> input must be brought above the programmed UV threshold by 1.5% before the comparator will be in-active, indicating the UV condition has gone away, see Figure 9. The V<sub>3MON</sub> comparator is used (in conjunction with a hold timer) to control the RESET pin.

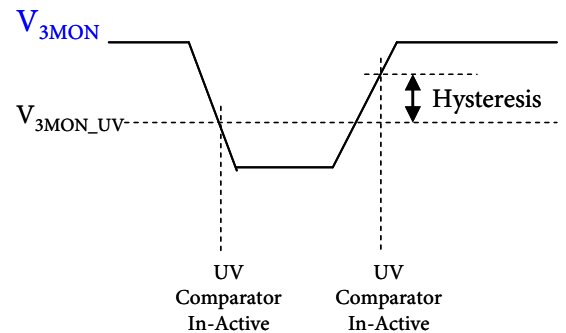


Figure 9. V<sub>3MON</sub> Hysteresis.

V<sub>3MON</sub> exhibits typical input resistance of 50KΩ that users should account the loading effect.

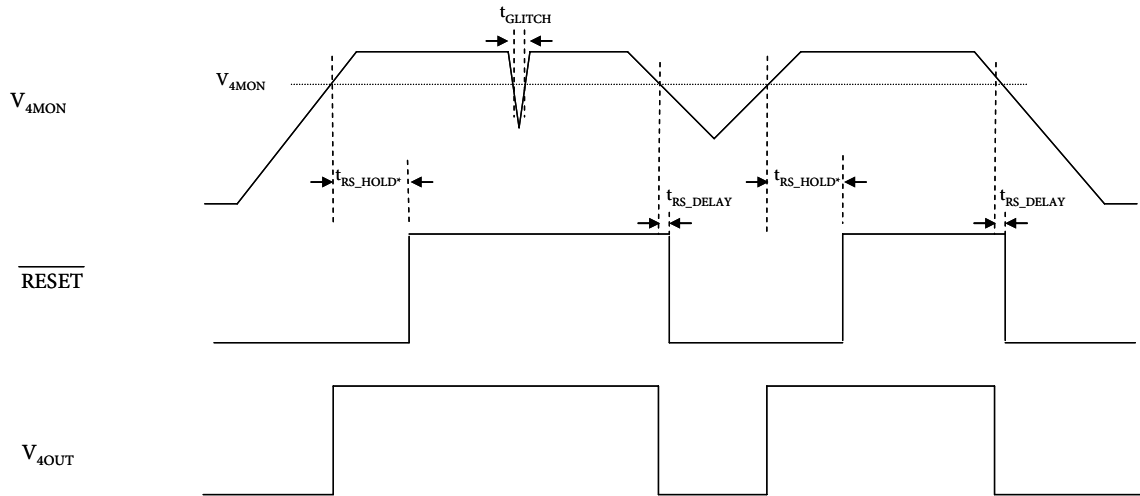
The default V<sub>3MON</sub> threshold is 4.36V. User should refer to Table 5b if they want to program different setting.

The MR input has an internal resistor pull-up to V<sub>3MON</sub>. The RESET output are push-pull configured between V<sub>3MON</sub> and GND.

**V<sub>4MON</sub>**

V<sub>4MON</sub> is the lowest voltage monitoring input that controls the RESET function of an external device or provides a comparator output, V<sub>4OUT</sub>. V<sub>4MON</sub> monitors input from 0.9V to 3.3V. It has an 8-step programmable reset threshold with an 8-step 0.1ms to 200ms reset hold time. The V<sub>4MON</sub>, reset, and V<sub>4OUT</sub> timing diagrams are shown in Figure 10. The range of

thresholds is shown in Table 5a and the programming code of the selected-threshold is found in Tables 5b. The defaulted monitoring threshold is Disabled. Similarly, the range of reset hold time is shown in Tables 6a and the programming code of the selected-timing is found in Table 6b.



•Programmable  
Most Applications using  $V_{4OUT}$  require disabling of  $V_{4MON}$  triggered reset

Figure 10.  $V_{4MON}$ ,  $\overline{RESET}$ , and  $V_{4OUT}$  Timing Diagrams

The  $V_{4MON}$  pin is monitored by a comparator to detect an under-voltage condition. It is designed with 6% hysteresis. When the  $V_{4MON}$  input drops below the programmed UV threshold, the comparator will become active immediately, indicating a UV condition has occurred. Due to hysteresis, the  $V_{4MON}$  input must be brought above the programmed UV threshold by 6% before the comparator will be in-active, indicating the UV condition has gone away, See Figure 11. The  $V_{4MON}$  comparator is used to control the  $V_{4OUT}$  pin and also (in conjunction with a hold timer) to control the  $\overline{RESET}$  pin.  $V_{4MON}$  exhibits typical input resistance of 50K $\Omega$  that users should account the loading effect.

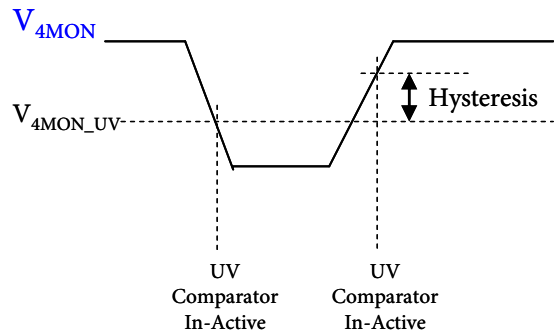


Figure 11.  $V_{4MON}$  Hysteresis.

The default  $V_{4MON}$  is Disabled. User should refer to Table 5b if they want to program a different setting.

**Watchdog Input**

The Watch-Dog Input (WDI) circuit attempts to reset the system to a known good state if a software or hardware glitch renders the system processor inactive for a duration that is longer than the timeout period. There is an 8-step programmable timeout period from 100ms to 2000ms. The watchdog circuit is independent of the CPU clock that the watchdog is monitoring.

Watchdog is disabled during power-up. WDI starts monitoring once the  $\overline{\text{RESET}}$  is high. Unique to AD5100, it

provides a Standard or Advance Watchdog monitoring function. In the defaulted Standard Watchdog mode, if WDI remains either high or low for longer than the timeout period, a reset pulse is generated in an attempt to allow the system processor to re-establish the WDI signal. The reset pulses continue indefinitely until a valid watchdog signal, a rising or falling edge signal at the WDI, is received. The internal watchdog timer clears whenever reset is asserted. The Standard WDI and  $\overline{\text{RESET}}$  timing diagrams are shown in Figure 12.

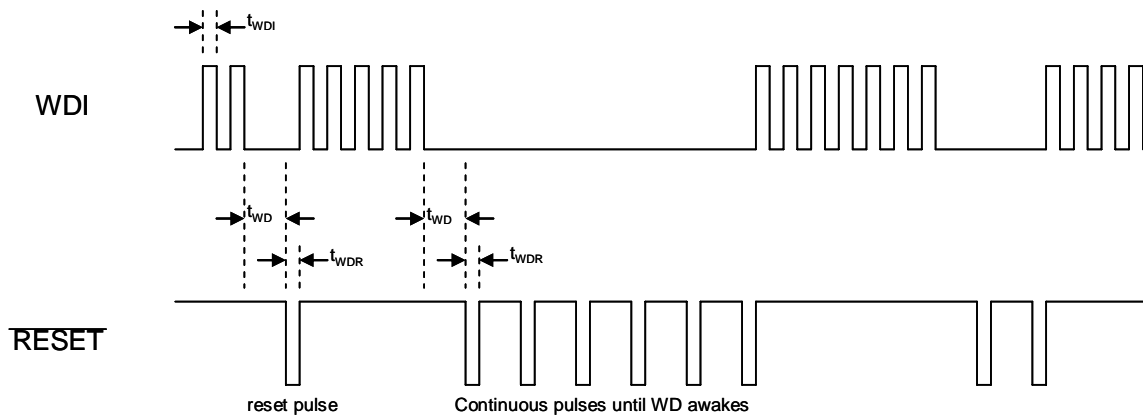


Figure 12. Standard Watchdog – Pulsing Reset Until Watchdog Awakes.

On the other hand, the AD5100 can be programmed to an Advance Watchdog mode such that when the watchdog remains inactive longer than three times the watchdog timeout period, at the fourth time the  $\overline{\text{SHDN}}$  and  $\overline{\text{RESET}}$  will be

asserted and released after 1 second. These actions repeat indefinitely, unless it is interferred by the user, if the processor is not responding. The Advance WDI and  $\overline{\text{RESET}}$  timing diagrams are shown in Figure 13.

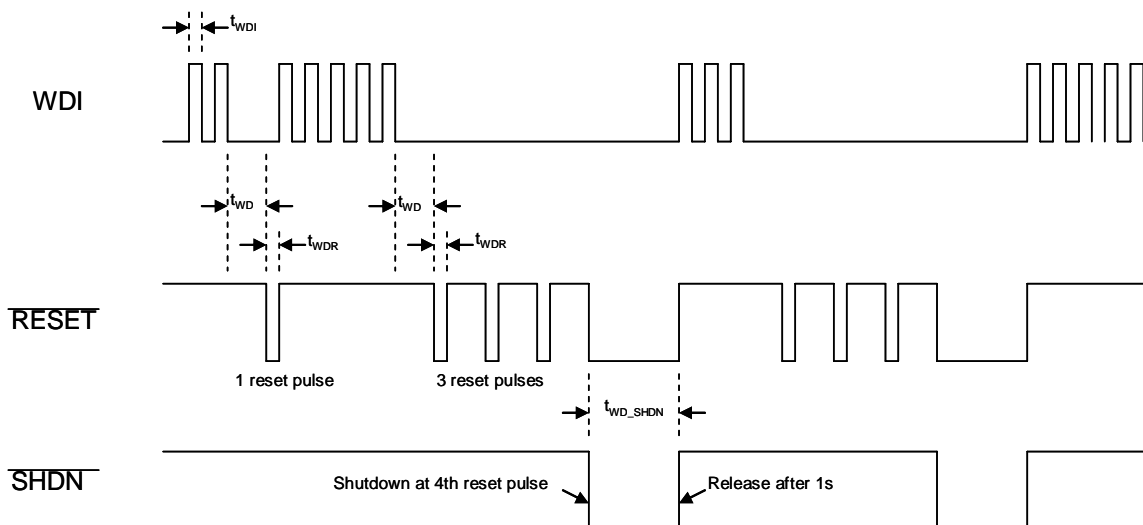


Figure 13. Advance Watchdog – SHDN Asserted After Three Trials of Resetting the Watchdog. SHDN Released After 1 second and the cycle repeats.

The range of Watchdog Timeout is shown in Table 6a and the programming code of the selected-timeout is found in Table 6b. The default timeout is 1500ms.

If WDI is floating, the watchdog is disabled by default. However, floating watchdog can be enabled through I2C

programming such that a broken WDI connection or any unusual condition that makes WDI float will trigger the reset.

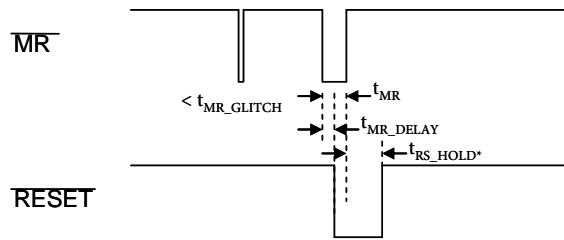
Enabling or disabling floating WDI can be changed dynamically provided that the OTP fuse of such function is not programmed or the OTP overridden function is selected.

**Manual Reset**

Manual Reset  $\overline{MR}$  is active low and it has an internal pull-up resistor to  $V_{3MON}$ .  $\overline{MR}$  can be driven from a CMOS logic signal. The  $\overline{MR}$  and  $\overline{RESET}$  timing diagrams are shown in

The default Watchdog Timeout is 1500ms. User should refer to Table 6b if they want to program a different setting.

Figure 14.  $\overline{MR}$  has the highest priority in triggering the  $\overline{RESET}$  over any other monitoring inputs.



•Programmable

Figure 14. Manual Reset Timing Diagrams



## Outputs

### Shutdown Generator

The shutdown output,  $\overline{\text{SHDN}}$ , is triggered by the abnormal inputs of  $V_{1\text{MON}}$  or  $V_{2\text{MON}}$ . It can also be the result of a failed watchdog input.  $\overline{\text{SHDN}}$  control can also be asserted low by users through I2C programming at anytime.

To be explicit, the shutdown generator asserts a logic-low  $\overline{\text{SHDN}}$  signal based on the following conditions:

1. During power-up.
2. When  $V_{1\text{MON}}$  goes over or under the threshold, Figure 5.
3. When  $V_{2\text{MON}}$  is below the turn-on threshold during the rising edge or the turn-off threshold during the falling edge in the default level sensitive mode, Figure 5.
4. When the external monitoring processor cannot issue the necessary WDI signal and an Advanced WDI mode is selected, Figures 8 and 9.
5. I2C programmed-shutdown.

The  $\overline{\text{SHDN}}$  signal is released after the programmable hold time. The  $\overline{\text{SHDN}}$  output is push-pull configured with I<sup>2</sup>C selectable rail voltage of either  $V_{1\text{MON}}$  in default or internal  $V_{\text{REG}}$ . Figure 15 shows the  $\overline{\text{SHDN}}$  output configurations, Pull-down resistor R1 ensures  $\overline{\text{SHDN}}$  is pulled to ground when the AD5100 is not powered. When AD5100 is powered, M2a and M2b are both on. M2a has relatively lower impedance than M2b and R1 that the  $\overline{\text{SHDN}}$  remains low at shutdown. When the AD5100 settles, sw1 will be on. M1 is stronger than M2a that  $\overline{\text{SHDN}}$  will be pulled to the rail that makes AD5100 out of the shutdown mode.

The AD5100 is likely be used to monitor and control power regulators in some applications where some regulators have the input and enable pins next to each other in fine pitch that may pose reliability concern under some abnormal conditions. To prevent this may happen, the AD5100 shutdown output features a smart-load detection that ensures the shutdown to respond for maximum protection. For example, if the car battery has not been started for an extensive period of time and a resistive dendrite may have formed across the  $\overline{\text{SHDN}}$  and the battery terminal ( $V_{1\text{MON}}$ ), the dendrite will be blown immediately as the M2a is designed with adequate current sinking capability and remains in the on position to offer such protection. In another situation where the  $\overline{\text{SHDN}}$  pin may be hard-short to any sub-30V source, the short-circuit detector will open sw2 and therefore limit the current by the high impedance M2b.

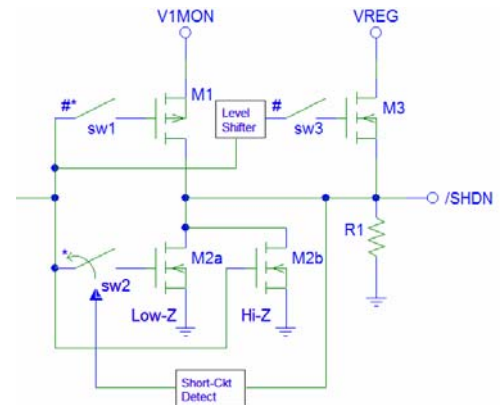


Figure 15. Shutdown Output. # = I<sup>2</sup>C Selectable, \* = Default.

### Reset Generator

The Reset output,  $\overline{\text{RESET}}$ , is triggered by the abnormal input of  $V_{3\text{MON}}$  or  $V_{4\text{MON}}$ .  $\overline{\text{RESET}}$  activation can also be the result of the processor that is not generating the proper watchdog signal or the Manual Reset is triggered.

To be explicit, the Reset generator asserts a logic-low  $\overline{\text{RESET}}$  signal based on the following conditions

1. During power up
2. When  $V_{3\text{MON}}$  drops below the threshold, Figure 8.
3. When  $V_{4\text{MON}}$  drops below the threshold, Figure 10.
4. When  $\overline{\text{SHDN}}$  output is asserted, Figures 5 and 13.
5. When the external monitoring processor cannot issue the necessary WDI signal, Figures 12 and 13.
6. When  $\overline{\text{MR}}$  is asserted, Figure 14.

The  $\overline{\text{RESET}}$  signal is asserted and maintained except when it is triggered by the WDI that will be described in the watchdog section. The  $\overline{\text{RESET}}$  signal is released after the programmable hold time.

As shown in Figure 16, The  $\overline{\text{RESET}}$  output is push-pull configured with the the rail voltage of  $V_{3\text{MON}}$ .

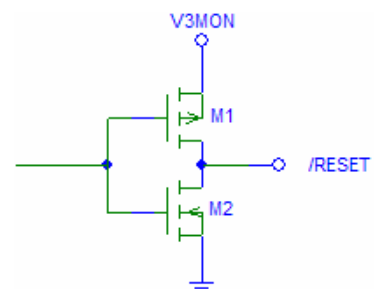


Figure 16. Reset Output.

**Fault Detection with Shutdown Warning**

An early shutdown warning is available for the system processor to identify the source of failure and take appropriate action before shutting down the external devices. Whenever the voltage at  $V_{1MON}$  is detected as over-voltage or under-voltage, or the voltage at  $V_{2MON}$  falls below the threshold,  $\overline{SHDNWARN}$  outputs a logic 0. If the processor sees a logic-low on this pin, the processor may issue an I2C read command to identify the cause of failure reported in the Fault Detect/Status Register. The processor may store the information in the external EEPROM as a record of failure history.

 **$V_{4OUT}$** 

$V_{4OUT}$  is an open-drain output triggered by  $V_{4MON}$  with minimum propagation delay and the programmable delay does not apply.  $V_{4OUT}$  can be used as a PWM control over an external device or used as a monitoring signal. Most applications using  $V_{4OUT}$  require disabling  $V_{4MON}$  triggered reset with an I2C command.

**Power Requirements**

**Internal Power**

The AD5100 internal power  $V_{REG}$  is derived from  $V_{1MON}$  and  $V_{2MON}$  is used to turn AD5100 on and off with a different behavior depending on the  $V_{2MON}$  monitoring mode selection. By default, in the  $V_{2MON}$  level sensitive mode, the AD5100 turns on when the voltage at  $V_{2MON}$  rises above the logic threshold  $V_{2MON\_ON}$ , When  $V_{2MON}$  falls below the

threshold  $V_{2MON\_OFF}$ , AD5100 will turn off 2 seconds after  $\overline{SHDN}$  is deasserted. Note that AD5100 requires 5 us to start up and that  $V_{1MON}$  must be applied before  $V_{2MON}$ . The extension of the AD5100 turn-off attempts to allow the system to complete any housekeeping tasks before the system is powered off. Figure 17 shows the defaulted  $V_{2MON}$  and  $V_{REG}$  waveforms.

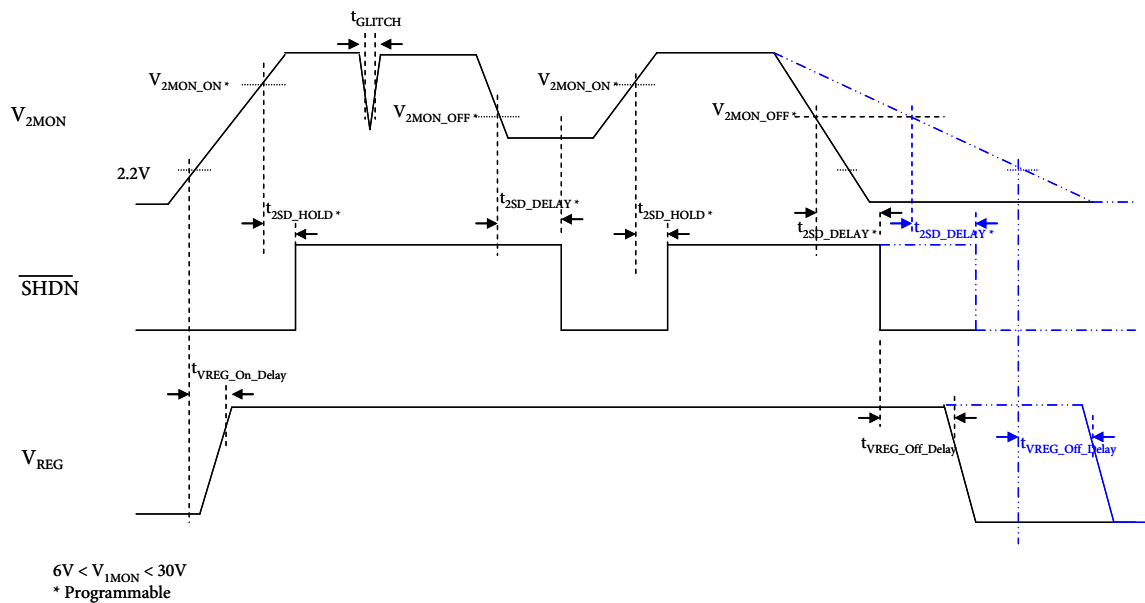


Figure 17. Internal Power  $V_{REG}$  versus  $V_{2MON}$  Timing Diagrams (Default)

If the Pulse-Sensitive  $V_{2MON}$  Mode is selected instead, the AD5100 will not turn off when  $V_{2MON}$  returns to a logic low. In this mode, once the part has been powered on, it can only

be power-down by an I2C power down instruction or by eliminating the supply on  $V_{1MON}$  pin. This feature is for the applications that use a wake up signal.

**$V_{OTP}$**

A 6V supply voltage is needed only during OTP fuse programming. This voltage should be provided by an external source during factory programming and should have 6V/200mA driving capability. The OTP programming duration depends on the numbers of programming fuses with maximum duration of 10ms.  $V_{OTP}$  is not required for normal operation. The  $V_{OTP}$  has dual functions, it is used for programming the non-volatile memory fuse arrays as well as serving as a compensation network for internal power stability. As a result, a bypass capacitor must be connected at  $V_{OTP}$  pin at all times. A low ESR 10uF tantalum capacitor is recommended.

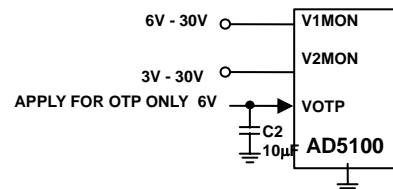


Figure 18. Power Supply Requirement

AD5100 achieves the OTP function through blowing internal fuses. Users should always apply the 6 V one-time program voltage requirement at the first fuse programming attempt. Failure to comply with this requirement may lead to a change in the fuse structures, rendering programming inoperable.

Care should be taken when SCL and SDA are driven from a low voltage logic driver.

Poor PCB layout introduces parasitic inductance that may affect the fuse programming voltage droop. Therefore, it is mandatory that a 10 $\mu$ F tantalum capacitor be placed as close as possible to the  $V_{OTP}$  pin. The value and the type of C2 chosen are important. It should provide both a fast response and larger supply current handling with minimum supply droop during programming, see Figure 18.

## Protection

### Over-Current Protection

If the  $V_{1MON}$  is shorted internally in the AD5100 to GND, the short-circuit protection kicks in and limits subsequent current to 150mA in normal operation or 50mA when the  $V_{OTP}$  is executed.

### Thermal Shutdown

When the AD5100 junction temperature is near the junction temperature limit, it will automatically shutdown and cut out the power from  $V_{1MON}$ . The part will resume operational when the device junction temperature returns to normal.

For automotive applications, proper external protections on the AD5100 are needed in order to ensure reliable operation. The  $V_{1MON}$  will likely be used for battery monitoring. The  $V_{2MON}$  will likely be used for ignition switch or other critical inputs. As a result, these inputs may need additional protections such as EMI, load dump, and ESD protections. In addition, battery input also requires reverse battery protection and short circuit fuse protection, see Figure 19.

### ESD Protection

It is common to require a contact rating of  $\pm 8$ kV and a non-contact or air rating of  $\pm 15$ kV ESD protection for the automotive electronics. As a result, an ESD rated protection device must be used such as MMBV27VCL, a dual 40W TVS (Transient Voltage Suppressor) at the  $V_{1MON}$  and  $V_{2MON}$ .

### Load Dump Protection

A load dump is a severe overvoltage surge that occurs when the car battery is being disconnected from a spinning alternator and the resulting long-duration, high-voltage surge introduced into the supply line. As a result, external load dump protection is recommended. Typically the load dump overvoltage lasts for few hundreds milliseconds and peaks at around 40V to 70V while current can be as high as 1A. As a result, a load dump rated TVS D1 and D2 such as SMCJ17 are used to handle the surge energy. A series R is an in-line current limiting resistor, it should be adequate to limit the current without significant drop and yet small enough to not affect the input monitoring

accuracy drop

### Reverse Battery Protection

Reverse battery protection can be provided by a regular diode if the battery monitoring accuracy can be relaxed. Otherwise, a 60V P-Ch Power MOSFET, like NDT2955, can be used. Because of the MOSFET internal diode, the battery will first conduct through P1's body diode, as soon as the voltage reaches its source terminal, the voltage divider provides adequate gate-to-source voltage to turn on P1 and the voltage drop across the FET will be negligible. The resistor divider values are chosen such that the P1's maximum  $V_{GS}$  is not violated and the current drawn through the battery is only a few  $\mu$ A.

### EMI Protection

For EMI protection, ferrite bead or EMC rated inductor such as DR331-7-103 can be used.

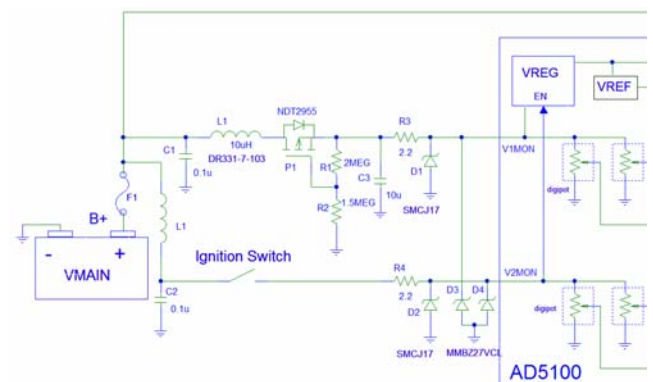


Figure 19. Protection Circuits

**Digital Interface**

All programmable parameters are set through a 2-wire I<sup>2</sup>C protocol with read/write access to the registers. All programmable parameters can be set permanently by blowing the OTP fuses at users' factories. Analog Devices offers device programming software, which effectively replaces the need for external I<sup>2</sup>C controllers or host processors for OTP programming in the factories.

**SCL**

Serial Input Register Clock Pin. Shifts in one bit at a time on positive clock edges. External 1k-2.2kΩ pull-up resistor is needed. The pull-up resistor should tie to V<sub>3MON</sub> if it is used to monitor a sub-5V source.

**SDA**

Serial Data Input/Output Pin. Shifts in one bit at a time on positive clock edges. MSB loaded first. External 1k-2.2kΩ pull-up resistor is needed. The pull-up resistor should tie to V<sub>3MON</sub> if it is used to monitor a sub-5V source.

**AD0**

I2C Slave Address Pin. AD5100 is a slave device that will communicate with a master if the AD0 bit in the protocol matches with the logic state of the AD5100's AD0 pin. Table 8 and Figure 20 show the example with two AD5100 devices operate on the same serial bus independently.

Table 8. Slave Address Decoding Scheme

AD0 Program ming Bit	AD0 Device Pin	Device Address
0	0V	0x2E (U1)
1	5V	0x2F (U2)

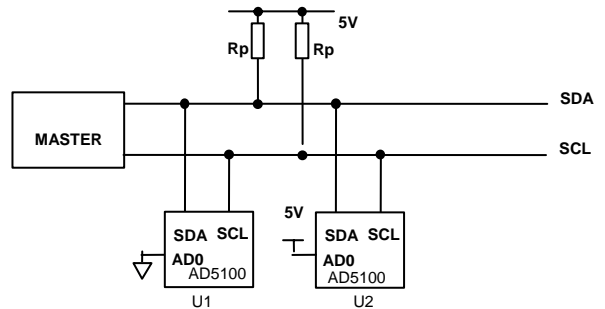


Figure 20. Two AD5100 Devices on One Bus

The master-device output bus-line drivers are open-drain pull-downs in a fully I<sup>2</sup>C compatible interface.

**AD5100 Register Map**

Table 9 outlines the Address Pointer Registers used to configure and control all parameters and functions in the AD5100. Table 10 shows the Address Pointer Register Structure. Table 9 also outlines if registers are writable, readable, or permanently settable. All registers are single-port, meaning they have the same address for read and write operations. The AD5100 ships from its manufacturing factory with default power-up values as listed in the last column. The user can experiment with different settings in the various threshold, delay and configuration registers. Once enough evaluation is done, the user can program their own power-up default values via a one time program (OTP) feature. When all desired settings have been programmed (or the user is satisfied with the manufacturers defaults), a lock-out bit can be set to prevent further/erroneous settings from being programmed.

Some users will use the AD5100 as a 'set and forget' device, i.e. program some default values and never need to change these over the life of the application. However some users will require 'On the Fly' flexibility, i.e. the ability to change settings to values other than those they choose as their defaults. An additional feature of the AD5100 is the ability to temporarily over-ride the OTP executed settings and still allows users to program the parts dynamically in the field. All over-ride values will revert back to OTP executed settings once the AD5100 is power cycled.

Register Writing, Reading, OTP & Over-Ride are explained later in the I2C section.

Table 9. AD5100 Register Map

Register Address	Read / Write	Permanently settable	Register Name & Bit Description	Pre-OTP Power On Default <sup>(1)</sup>
0x01	R/W	Y	<b>V<sub>1MON</sub> Over-Voltage Threshold</b> [3:0] – 4 bits used to program V <sub>1MON</sub> OV Threshold [7:4] – Reserved	0x00 (18.00 V)
0x02	R/W	Y	<b>V<sub>1MON</sub> Under-Voltage Threshold</b> [3:0] – 4 bits used to program V <sub>1MON</sub> UV Threshold [7:4] – Reserved	0x00 (8.43 V)
0x03	R/W	Y	<b>V<sub>2MON</sub> Turn-On Threshold</b> [3:0] – 4 bits used to program V <sub>2MON</sub> TON Threshold [7:4] – Reserved	0x00 (7.47 V)
0x04	R/W	Y	<b>V<sub>2MON</sub> Turn-Off Threshold</b> [3:0] – 4 bits used to program V <sub>2MON</sub> TOFF Threshold [7:4] – Reserved	0x00 (6.95 V)
0x05	R/W	Y	<b>V<sub>3MON</sub> <math>\overline{\text{RESET}}</math> Threshold</b> [2:0] – 3 bits used to program V <sub>3MON</sub> $\overline{\text{RESET}}$ Threshold [7:3] – Reserved	0x00 (4.36 V)
0x06	R/W	Y	<b>V<sub>4MON</sub> <math>\overline{\text{RESET}}</math> Threshold</b> [2:0] – 3 bits used to program V <sub>4MON</sub> $\overline{\text{RESET}}$ Threshold [7:3] – Reserved	0x00 (Disabled)
0x07	R/W	Y	<b>V<sub>1MON</sub> OV/UV Triggered <math>\overline{\text{SHDN}}</math> Hold</b> [2:0] – 3 bits used to program V <sub>1MON</sub> OV/UV Triggered $\overline{\text{SHDN}}$ Hold time [7:3] – Reserved	0x00 (200 mS)
0x08	R/W	Y	<b>V<sub>1MON</sub> OV/UV Triggered <math>\overline{\text{SHDN}}</math> Delay</b> [2:0] – 3 bits used to program V <sub>1MON</sub> OV/UV Triggered $\overline{\text{SHDN}}$ Delay time [7:3] – Reserved	0x00 (1200 mS)
0x09	R/W	Y	<b>V<sub>2MON</sub> Turn-On Triggered <math>\overline{\text{SHDN}}</math> Hold</b> [2:0] – 3 bits used to program V <sub>2MON</sub> TON Triggered $\overline{\text{SHDN}}$ Hold time [7:3] – Reserved	0x00 (10 mS)
0x0A	R/W	Y	<b>V<sub>2MON</sub> Turn-Off Triggered <math>\overline{\text{SHDN}}</math> Delay</b> [2:0] – 3 bits used to program V <sub>2MON</sub> TOFF Triggered $\overline{\text{SHDN}}$ Delay time [7:3] – Reserved	0x00 (100 mS)
0x0	R/	Y	<b><math>\overline{\text{RESET}}</math> Hold</b>	0x00

B	W		[2:0] – 3 bits used to program $\overline{\text{RESET}}$ Hold time [7:3] – Reserved	(200 mS)
0x0C	R/W	Y	<b>Watchdog Timeout</b> [2:0] – 3 bits used to program Watchdog timeout time [7:3] – Reserved	0x00 (1500 mS)
0x0D	R/W	Y	<b><math>\overline{\text{RESET}}</math> Configuration</b> [0] – 0 - $\overline{\text{RESET}}$ is active when $\overline{\text{SHDN}}$ is active 1 - $\overline{\text{RESET}}$ is not active when $\overline{\text{SHDN}}$ is active [1] – Reserved [2] – 0 - Enable $V_{4\text{MON}}$ over threshold to cause $\overline{\text{RESET}}$ 1 - Prevent $V_{4\text{MON}}$ over threshold to cause $\overline{\text{RESET}}$ (For $V_{4\text{OUT}}$ Application) [3] – 0 - Prevent floating WDI to cause $\overline{\text{RESET}}$ 1 - Enable floating WDI to cause $\overline{\text{RESET}}$ [7:4] – Reserved	0x00
0x0E	R/W	Y	<b><math>\overline{\text{SHDN}}</math> Rail Voltage Configuration</b> [2:0] – Reserved [3] – 0 - $\overline{\text{SHDN}}$ rail = $V_{1\text{MON}}$ 1 - $\overline{\text{SHDN}}$ rail = Vreg [7:4] – Reserved	0x00
0x0F	R/W	Y	<b>Watchdog Mode</b> [2:0] – Reserved [3] – 0 – Standard Mode 1 – Advanced Mode [7:4] – Reserved	0x00
0x15	R/W	Y	<b>Program Lock Fuse (Inhibit Further Programming)</b> [2:0] – Reserved [3] – 0 – Fuse Programming allowed 1 – Fuse Programming Disabled [7:4] – Reserved	0x00
0x16	R/W	N	<b>Special Functions 1</b> [0] – 0 – OTP Enable A Inactive 1 – OTP Enable A Active [1] – 0 - OTP Enable B Inactive 1 - OTP Enable B Active [2] – 0 – Software assertion of $\overline{\text{SHDN}}$ Inactive	0x00

			<p>1 – Software assertion of <math>\overline{\text{SHDN}}</math> Active</p> <p>[3] – 0 – Over-ride of permanent settings Inactive</p> <p>1 – Over-ride of permanent settings Active</p> <p>[7:4] – Reserved</p>	
0x17	R/ W	N	<p><b>Special Functions 2</b></p> <p>[0] – 0 – Software Power-down of AD5100 Inactive</p> <p>1 – Software Power-down of AD5100 Active<sup>(2)</sup></p> <p>[7:1] – Reserved</p>	0x00
0x18	R/ W	N	<p><b>Disable Special Functions</b> <sup>(3)</sup></p> <p>[0] – 0 – Allow Over-ride Function</p> <p>1 – Disable Further Over-ride Function</p> <p>[1] – 0 – Allow OTP Function</p> <p>1 – Disable OTP Function</p> <p>[2] – 0 – Allow Manufacturer Test-modes</p> <p>1 – Disable Manufacturer Test-modes</p> <p>[3] – 0 – Allow Software power-down Function</p> <p>1 – Disable Software power-down Function</p> <p>[4] – 0 – Allow Software assertion of <math>\overline{\text{SHDN}}</math> Function</p> <p>1 – Disable Software assertion of <math>\overline{\text{SHDN}}</math> Function</p> <p>[7:5] – Reserved</p>	0x00
0x19	R- on ly	N	<p><b>Fault Detect &amp; Status Register</b></p> <p>[3:0] – These 4 level triggered bits indicate the current state of the comparators monitoring the <math>V_{1\text{MON}}</math> and <math>V_{2\text{MON}}</math> input pins.</p> <p>[0] – A '1' indicates <math>V_{2\text{MON}}</math> input &lt; <math>V_{2\text{MON}}</math> OFF Threshold</p> <p>[1] – A '1' indicates <math>V_{2\text{MON}}</math> input &gt; <math>V_{2\text{MON}}</math> ON Threshold</p> <p>[2] – A '1' indicates <math>V_{1\text{MON}}</math> input &lt; <math>V_{1\text{MON}}</math> UV Threshold</p> <p>[3] – A '1' indicates <math>V_{1\text{MON}}</math> input &gt; <math>V_{1\text{MON}}</math> OV Threshold</p> <p>[6:4] – These are Fault Detection bits can be decoded to indicate one or more conditions were present when a <math>\overline{\text{SHDN}}</math> event occurred. These bits are edge triggered.</p> <p>000 – None</p> <p>001 – <math>V_{1\text{MON}}</math> UV only</p> <p>010 – <math>V_{1\text{MON}}</math> OV only</p> <p>011 – Never Occur</p> <p>100 – <math>V_{2\text{MON}}</math> Below OFF only</p> <p>101 – <math>V_{1\text{MON}}</math> UV AND <math>V_{2\text{MON}}</math> Below OFF Both Occur</p> <p>110 – <math>V_{1\text{MON}}</math> OV AND <math>V_{2\text{MON}}</math> Below OFF Both Occur</p>	0x00



111 – Never Occur  
 [7] – Reserved

Notes

1. Values AD5100 has when shipped from manufacturer’s factory.
2. V<sub>2MON</sub> must be 0V for Software Power down.
3. These register bits are set only. To clear them the AD5100 must be power cycled. In some cases the AD5100 may be connected to an I<sup>2</sup>C bus with lots of activity. Setting these bits is an added means of ensuring any erroneous activity on the bus does not cause AD5100 special functions to become active.

I2C Serial Interface

Control of the AD5100 is accomplished via an I<sup>2</sup>C compatible serial bus. The AD5100 is connected to this bus as a slave device (the AD5100 has no master capabilities).

The AD5100 has a 7-bit slave address. The six MSBs are 010111 and the LSB is determined by the state of the A0 pin. Therefore when A0 is low, the AD5100 slave address is 01011110 and 01011111 otherwise. Therefore the A0 pin allows the user to connect two AD5100s to the same I<sup>2</sup>C bus provided the two devices comply with the configurations shown in Figure 20.

The 2-wire serial bus protocol operates as follows:

1. The master initiates data transfer by establishing a START condition, which is when SDA goes from high-to-low while SCL is high. The following byte is the slave address byte, which consists of the 7-bit slave address followed by an R/W bit which determines whether data is read from or written to the slave device
2. Data is transmitted over the serial bus in sequences of nine clock pulses (eight data bits followed by an Acknowledge bit). The transitions on the SDA line must occur during the low period of SCL and remain stable during the high period of SCL.

3. When all data bits have been read or written, a STOP condition is established by the master. A STOP condition is defined as a low-to-high transition on the SDA line while SCL is high. In write mode, the master pulls the SDA line high during the 10<sup>th</sup> clock pulse to establish a STOP condition. In the read mode, the master issues a no Acknowledge for the 9<sup>th</sup> clock pulse, (i.e., the SDA line remains high). The master then brings the SDA line low before the 10<sup>th</sup> clock pulse and then high during the 10<sup>th</sup> clock pulse to establish a STOP condition.

For the AD5100, write operations contain either one or two bytes, while read operations contain one byte. The AD5100 makes use of an **Address Pointer Register**. The Address Pointer Register does not have and does not require an address, because it is the register to which the first data byte of every write operation is written automatically. This data byte is an address pointer that sets up one of the other registers for the second byte of the write operation or for a subsequent read operation. Table 10 shows the structure of the Address Pointer Register. Bits [6:0] signify the address of the register that is to be written to or read from. Bit [7] is used when OTP mode is invoked (use of this bit is explained later in the OTP section), and should be ‘0’ for normal write/read operations.

Table 10 – Address Pointer Register Structure

Bit #	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]
Function	OTP En	AP6	AP5	AP4	AP3	AP2	AP1	AP0

follows with two data bytes. The first data byte is the address of the internal data register to be written to, which is stored in the Address Pointer Register. The second byte is the data to be written to the internal data register. After each byte the AD5100 acknowledges by pulling the SDA line low during the 9<sup>th</sup> clock pulse. Figure 21 illustrated this operation.

Writing Data to AD5100

When writing data to the AD5100, the user begins by writing an address byte followed by the R/W bit set to ‘0’. The AD5100 will acknowledge (if the correct address byte is used) by pulling the SDA line low during the 9<sup>th</sup> clock pulse. The user then

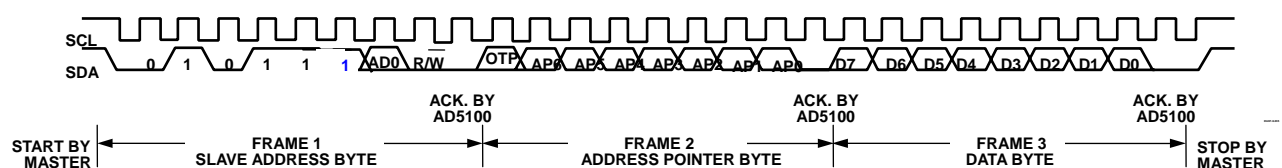


Figure 21 – Writing a register address to the Address Pointer Register, then writing data to the selected register

**Reading Data from AD5100**

When reading data from an AD5100 register there are two possibilities:

1. If the AD5100's Address Pointer Register value is unknown or not at the desired value, it is first necessary to set it to the correct value before data can be read from the desired data register. This is done by performing a write to the AD5100 as before, but only a value containing the register address is sent, because data is not

to be written to the register. This is shown in Figure 22. A read operation is then performed consisting of the serial bus address, R/W bit set to '1', followed by the data byte from the data register. This is shown in Figure 23.

2. If the address pointer is known to be already at the desired address, data can be read from the corresponding data register without first writing to the Address Pointer Register.

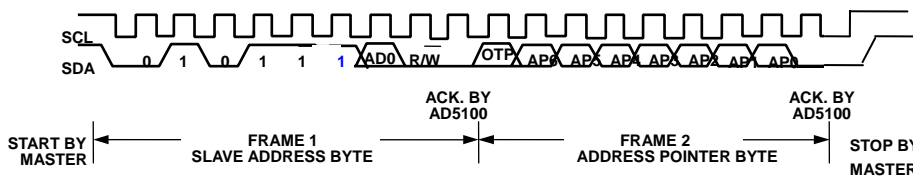


Figure 22. Dummy Write to set proper Address Pointer.

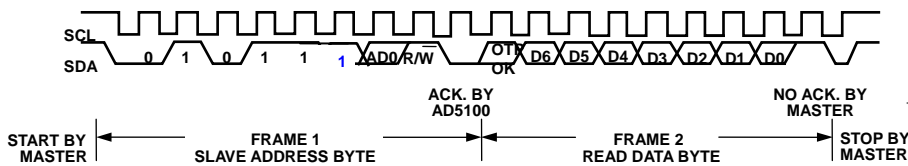


Figure 23. Read Data from the Address Pointer Register.

Table 11 shows the read-back data byte structure. Bits [6:0] contain the data from the register just read. Bit [7] only has significance when OTP mode is being used, and should be ignored for normal

read operations. The majority of AD5100's registers are 4-bits wide, with only the Status/FDR Register and disable Special Function Register by 7 bit and 5 bits wide respectively.

**Table 11 – Read-Back Data Byte Structure**

Bit #	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]
Function	OTP Okay	D6	D5	D4	D3	D2	D1	D0

**Permanent Setting of AD5100 Registers (OTP Function)**

When the user wants to permanently program settings to the AD5100, the one time program (OTP) function is invoked. To complete a permanent program cycle for a particular register, the following sequence should be used:

1. Set bit [0] in register 0x16 using a normal write operation
2. Set bit [1] in register 0x16 using a normal write operation
3. Apply a 6V (200mA) voltage source to the OTP pin. This provides the current for the programming cycle.
4. Write the desired permanent data to the register of choice, using a write operation with the OTP bit set to '1' in the Address Pointer byte.

minimum of 30ms for the AD5100 to perform the permanent setting of the internal register. The user has the opportunity to check whether the AD5100 programmed correctly by performing a read cycle, and monitoring the state of bit [7] (OTP Okay).

**OTP Okay = 1** indicates the AD5100 programmed correctly

**OTP Okay = 0** indicates the AD5100 programmed incorrectly

**Note:** Read-back of the **OTP Okay** bit is only available for the read cycle following immediately after the program cycle. If a write or read of a different register is done immediately after the program cycle, then the opportunity for verifying if the programming was successful will have been missed. Figure 24 shows the recommended way of performing a program then read-back and verify of the  $V_{IMON}$  Over-Voltage Register, (assuming steps 1-3 above have already been done).

When the write cycle has been completed, the user should allow

Programming Sequence	S	0x5C	A	0x01	A	0x8F	A	P	Delay	S	0x
Comment	Start	Slave Addr	Ack	Set V <sub>IMON</sub> OV Thres hold	Ack	OTP at setti ng 15	Ack	Stop	Wait for 30ms	Start	Sl Ac e R

Figure 24. Example of Executing OTP and a Successful Validation

When all default registers have been programmed, the lock bit should be set. User programmed defaults won't become active until the first power cycle after the lock bit is set. Programming the lock bit is done in exactly the same manner as all other registers.

**Temporary Over-Ride of Default Settings (Over-Ride Function)**

As stated previously in the register map section, even with the lock bit set, it is possible to temporarily over-ride the default values of any of the permanently programmable registers. To Over-Ride a permanent setting in a particular register, the following sequence should be used:

1. Set bit [3] in register 0x16 (Special Functions 1)
2. Write the desired temporary data to the register of choice

While the Over-Ride bit is set in register 0x18, the user may over-ride any registers they wish by simply writing to them with new data.

**Controlling the AD5100**

There are two ways to control the AD5100. Users can apply the AD5100 evaluation software for one time programming the devices in the factory without ever reprogramming the parts in

To revert an over-ridden register back to its default setting, the following sequence should be used:

1. Clear bit [3] in register 0x16
2. Write a dummy byte to the register of choice

Clearing the Over-Ride bit in register 0x18 does not cause all over-ridden registers to revert back to their defaults at the same time. For example, imagine the user had over-ridden registers 0x01, 0x02 & 0x03. If the user now cleared the Over-Ride bit in register 0x16 and wrote a dummy byte to register 0x01, it would revert back to its default value. However registers 0x02 & 0x03 would still contain their Over-Ride data. To revert both registers back to their defaults, the user must write dummy data to each register individually.

Power cycling the AD5100 will also revert all registers back to their programmed defaults.

the fields. They can also design or make use of the on-board I<sup>2</sup>C controllers for programming the AD5100. The later is necessary for any dynamic or field programming applications.

## APPLICATIONS

### Car Battery and Infotainment System Supply Monitoring

The AD5100 has two high-voltage monitoring inputs with shutdown and reset controls over external devices. For example, the  $V_{1MON}$  and  $V_{2MON}$  can be used to monitor the signals from a car battery and an ignition key in an automobile, respectively. Such application is shown in Figure 25. The shutdown output can be connected to the shutdown pin of an external regulator

to prevent false conditions such as a weak battery or overcharging battery by an alternator. The reset output can be used to reset the processor in the event of a hardware or software malfunction. An example of the input and output responses of this circuit is shown in Figure 26.

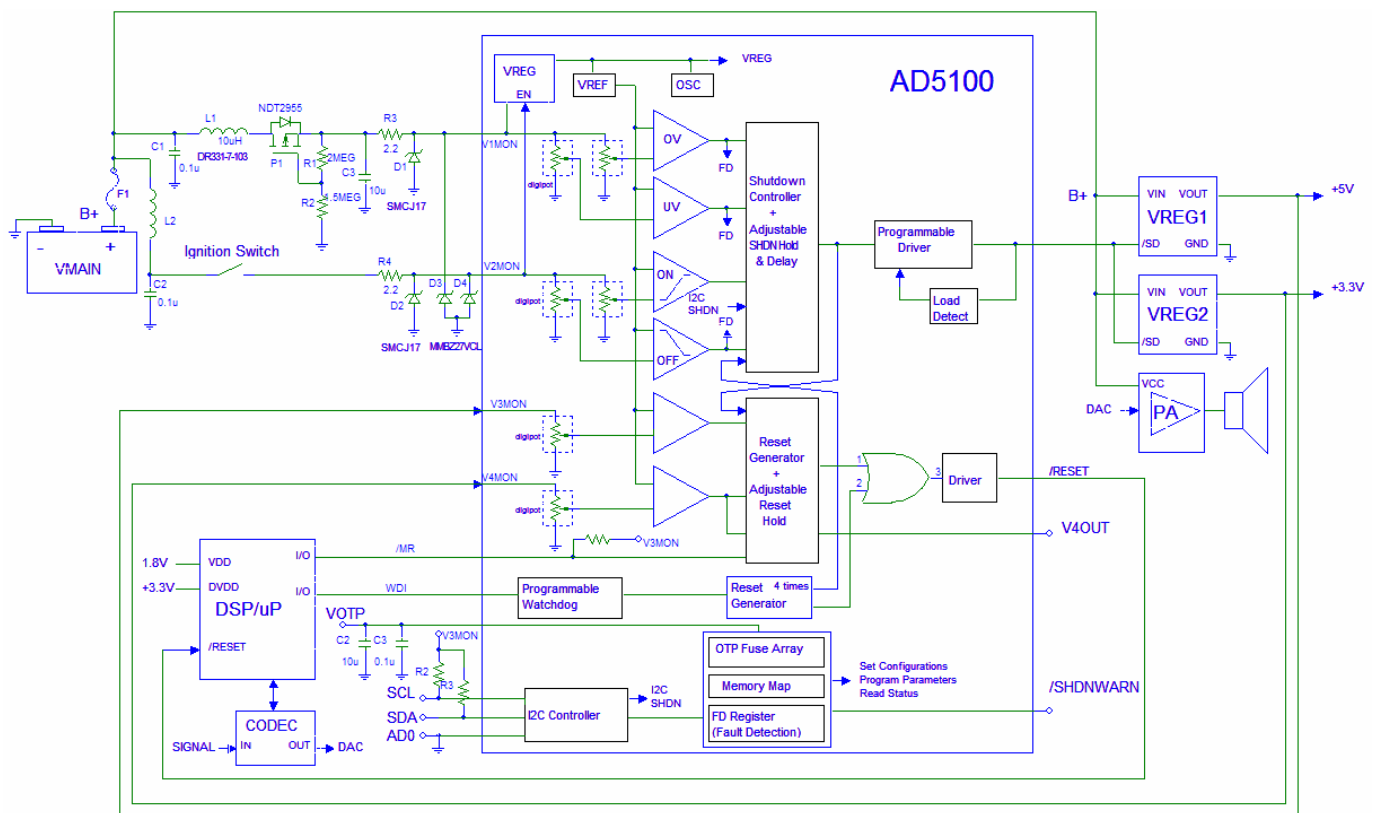


Figure 25. Typical DSP in Car Infotainment Application.

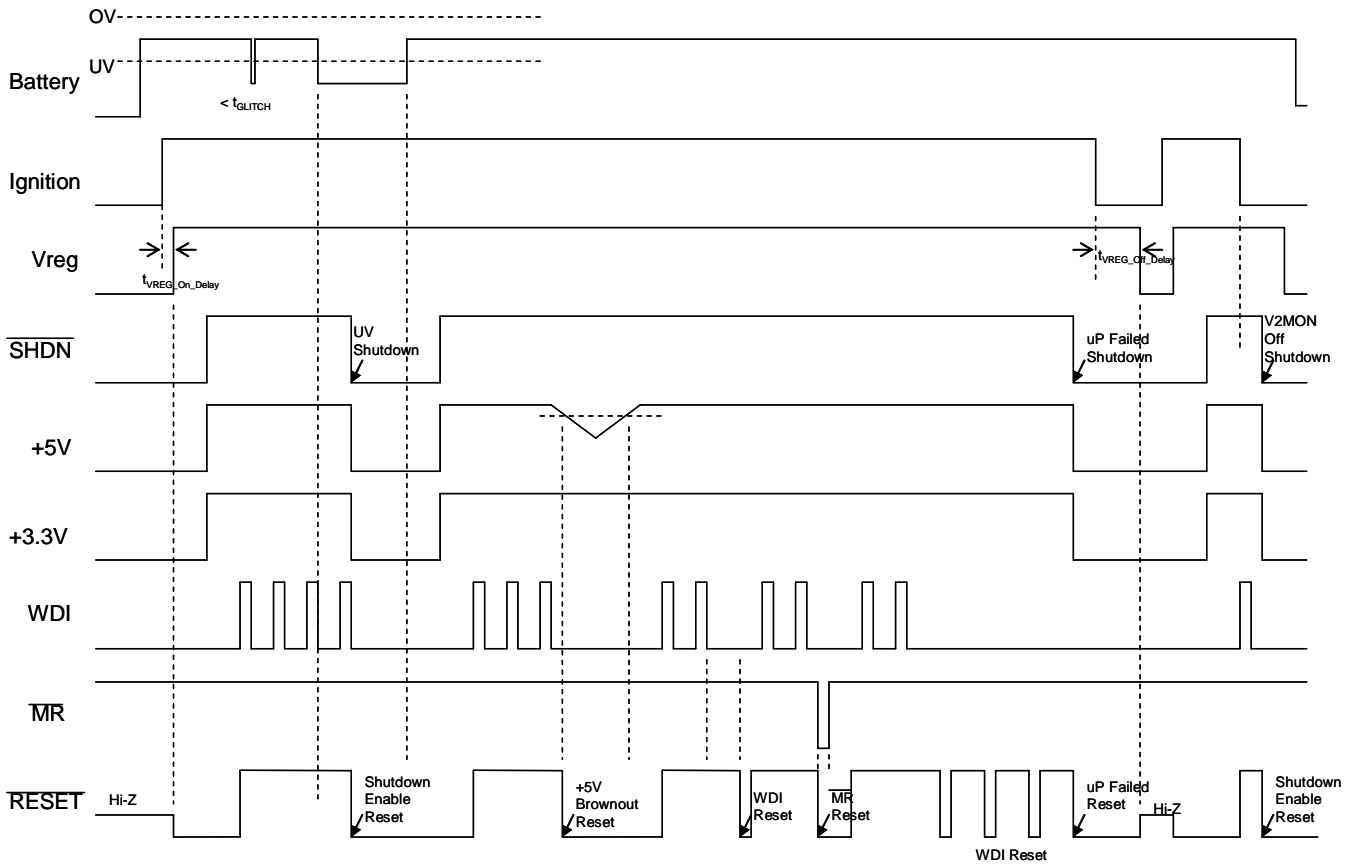


Figure 26. Examples of  $\overline{\text{SHDN}}$  and  $\overline{\text{RESET}}$  Responses of circuit shown in Figure 25.

**Battery Monitoring with Fan Control**

$V_{4MON}$  can be used with  $V_{4OUT}$  in tandem to form a simple PWM control circuit. For example as shown in Figure 27, when a temperature sensor output connects to the  $V_{4MON}$  input, with

the proper threshold level set,  $V_{4OUT}$  outputs high whenever the temperature goes above the threshold. This turns on the FET switch which activates the fan. When  $V_{temp}$  drops below the threshold,  $V_{4OUT}$  decreases which turns off the fan.

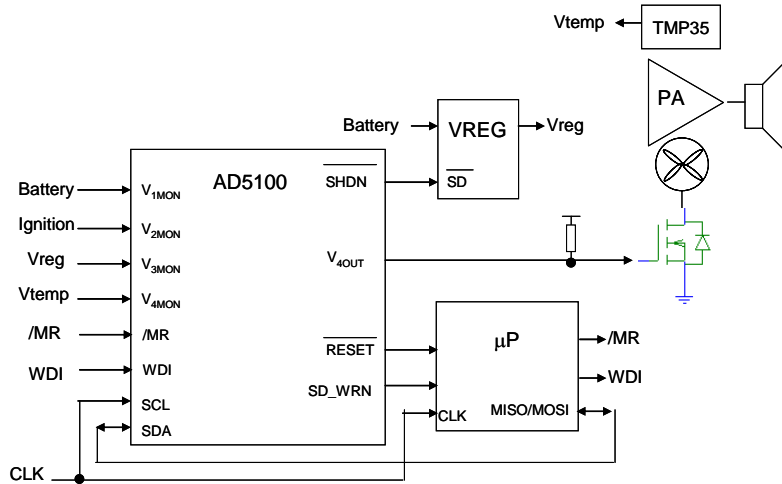
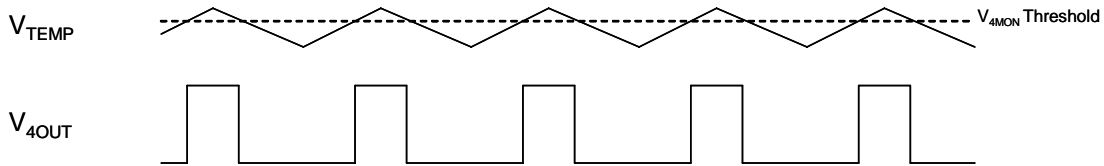


Figure 27. Power Amp Monitoring and Fan Control



Note:  $V_{4MON}$  reset disabled

Figure 28.  $V_{4OUT}$  with respect to  $V_{temp}$  with  $V_{4MON}$  reset disabled in circuit shown in Figure 27.

**Battery State of Charge Indicator and Shutdown Early Warning Monitoring**

In the automotive application, the system designer may set the battery threshold to the lowest level in order to allow an automobile to start at the worst case condition. If the battery

remains at the low voltage level, it is indeed a poor battery. However, there is no way to warn the driver. As a result, the system designer may use  $V_{4OUT}$  as the battery warning indicator. By stepping down the battery voltage monitored at  $V_{4MON}$ , the LED is lit which gives a battery replacement warning. The circuit is shown in Figure 29.

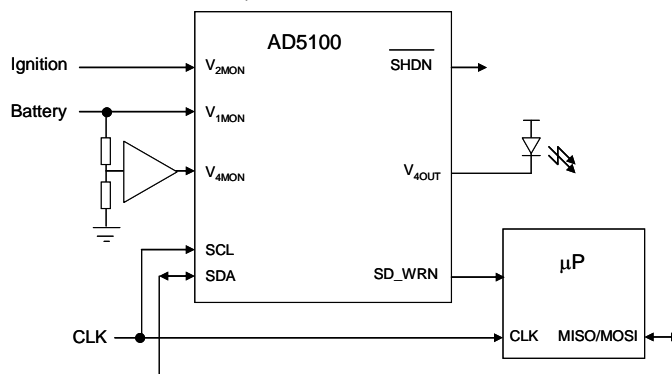


Figure 29. Battery State of Charge Indication

### Psuedo CAN Bus Wake Up Mode

Using the AD5100 as indicated in Figure 30, the microprocessor can control its own power down sequence using the CAN Bus wake up signal. The operator must select the last setting 'Rising Edge Trigger/CAN wake up mode' in the  $V_{2MON}$  Turn Off Threshold parameter (The I2C write command is 5 01011100 A 00000100 A 00001001 A P).

Now when the rising edge of the CAN Bus wake up signal is detected by  $V_{2MON}$ , the AD5100 is powered up with shutdown pulls high. The external regulator is turned on to supply power to the microprocessor. A reset pulse train will be generated at the reset output if there is no watchdog activity. The pulse

continues until the correct watchdog signal appears at the AD5100 WDI pin. The shutdown pin remains high as long as the AD5100 continues to receive the correct watchdog signal.

When the microprocessor finishes its housekeeping tasks or powers down the software routine, it stops sending a watchdog signal. In response, the AD5100 generates a reset. The shutdown pin will be pulled low 2 seconds after and the regulator output drops to 0V, which shuts down the microprocessor. At that point, the AD5100 goes into sleep mode.

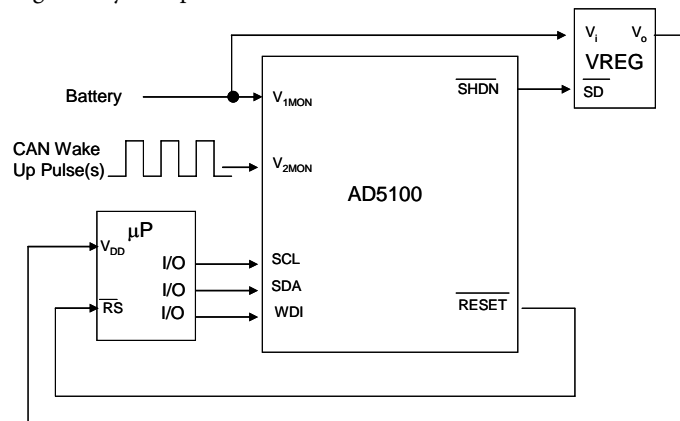
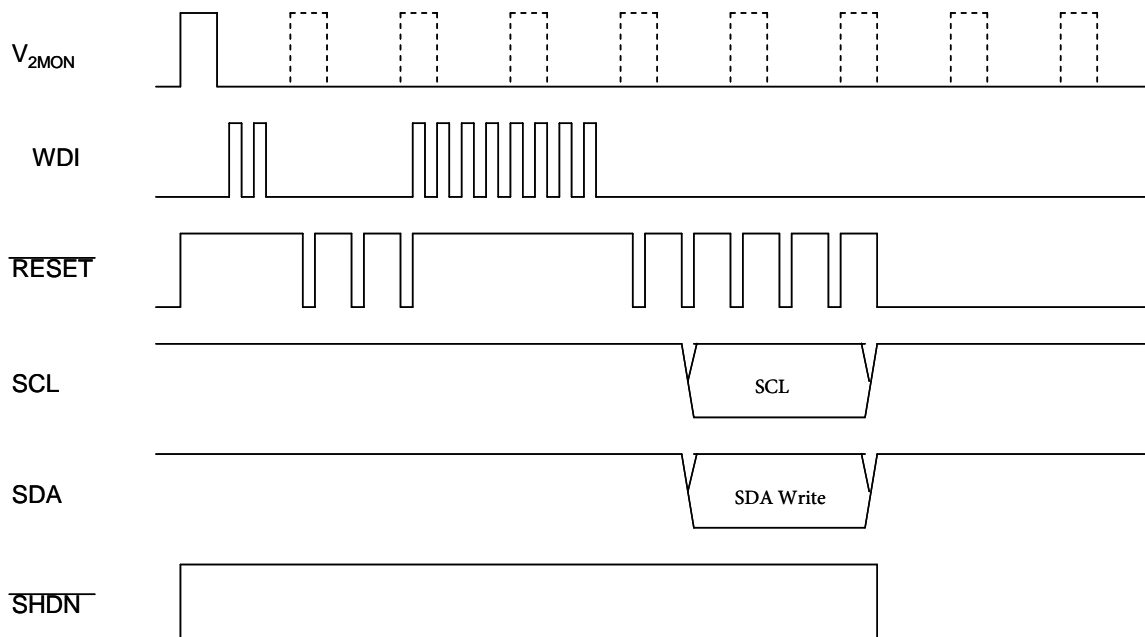


Figure 30. CAN Wake Up Mode



- Notes
- $6V < V_{1MON} < 30V$
  - Select  $V_{2MON\_OFF}$  = Rising Edge Trigger/CAN wake up mode

Figure 31. CAN Bus operation of circuit shown in Figure 30.

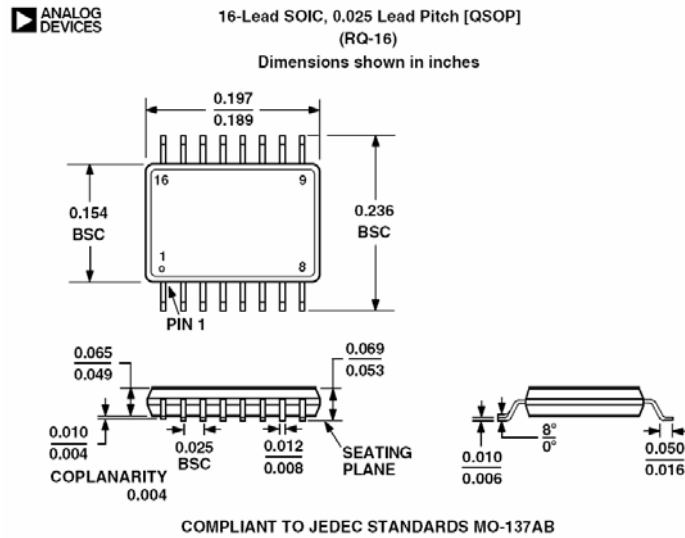


Figure 32. QSOP-16 Mechanical Dimension

ORDERING GUIDE

Model	Temperature Range	Package Code	Package Description	Full Container Quantity	Branding
AD5100YRQZ-RL7 <sup>1</sup>	-40°C to +125°C	RQ-16	QSOP-16	1,000	TBD
A AD5100YRQZ <sup>1</sup>	-40°C to +125°C	RQ-16	QSOP-16	98	TBD
AD5100EVAL			Evaluation Board	1	

<sup>1</sup> Z = Pb-free part.