Digital Power Monitor (DPM) Basics

Understanding the Current and Power Calculations of the ISL28022

This application note discusses the internal calculation procedure of the digital power monitor (DPM) ISL28022. It explains the bit formats of the data registers and illustrates the procedural steps of the internal math-processor to derive the current and power values from the measured shunt and bus voltages. This application note serves as a short compendium to be used in conjunction with the *ISL28022 Datasheet*.

Contents

1. Current and Power Calculation

The ISL28022 calculates the load current, I_L, by multiplying the measured and stored shunt voltage, Vshunt, with a user-defined calibration value, CAL. When the current value is available, the ISL28022 calculates the Power, by multiplying the measured and stored bus voltage, Vbus, with the calculated current value I_L (Figure 1).

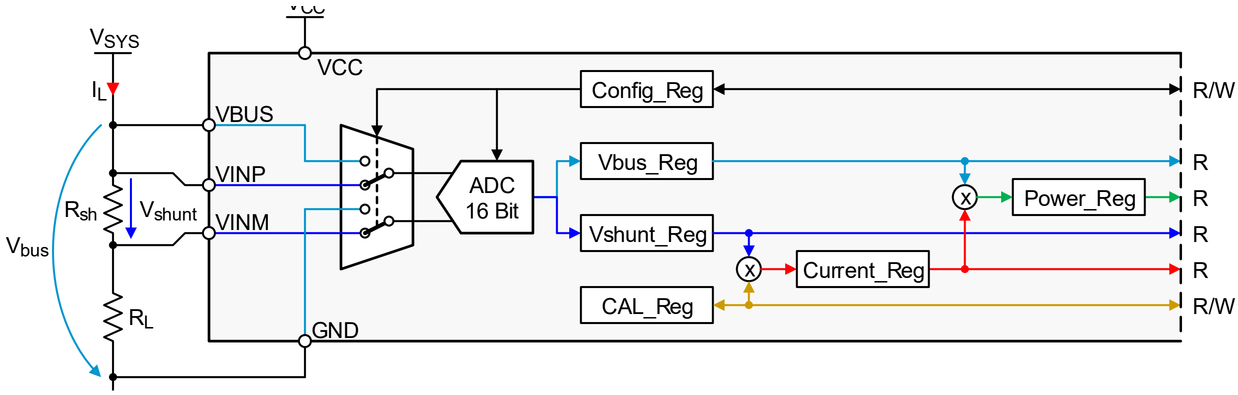

Figure 1. Current and Power Calculation within the ISL28022

Before any measurement, the user must store the device configurations in the configuration register (Figure 2).

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
RST	BRNG1	BRNG0	PG1	PG0	BADC3	BADC2	BADC1	BADC0	SADC3	SADC2	SADC1	SADC0	MODE2	MODE1	MODE0

Defaults & Calibration

RST	Reset Function
0	No Reset
1	Reset*

Bus Voltage Range

BRNG1	BRNG0	FSR (V)
0	0	16
0	1	32
1	0	60
1	1	60

Shunt Voltage Range

PG1	PG0	FSR (mV)
0	0	±40
0	1	±80
1	0	±160
1	1	±320

Bus ADC and Shunt ADC Settings

BADC3 / SADC3	BADC2 / SADC2	BADC1 / SADC1	BADC0 / SADC0	Resolution # Samples	Conversion Time
0	X	0	0	12-bit	72µs
0	X	0	1	13-bit	132µs
0	X	1	0	14-bit	258µs
0	X	1	1	15-bit	508µs
1	0	0	0	15-bit	508µs
1	0	0	1	2	1.01ms
1	0	1	0	4	2.01ms
1	0	1	1	8	4.01ms
1	1	0	0	16	8.01ms
1	1	0	1	32	16.01ms
1	1	1	0	64	32.01ms
1	1	1	1	128	64.01ms

Operating Mode Settings

MODE2	MODE1	MODE0	MODE
0	0	0	Power-down
0	0	1	V_{SH} triggered
0	1	0	V_B triggered
0	1	1	V_{SH} & V_B triggered
1	0	0	ADC off (disabled)
1	0	1	V_{SH} continuous
1	1	0	V_B continuous
1	1	1	V_{SH} & V_B continuous

Figure 2. Configuration Register Content and Format

The user selects

- One of eight possible operating modes by setting the bits MODE0: MODE2
- One of twelve ADC conversion modes for the shunt voltage by setting the bits SADC0: SADC3
- One of twelve ADC conversion modes for the bus voltage by setting the bits BADC0: BADC3
- One of four full-scale ranges for the shunt voltage by setting the bits PG0: PG1
- One of three full-scale ranges for the bus voltage by setting the bits BRNG0: BRNG1

2. Bit Formats of the Data Registers

Besides the configuration register, the registers required for the current and power calculations are the calibration register and the data registers for shunt- and bus voltage, current and power (Table 1).

Table 1. Relevant Registers for Current and Power Calculations

Address	Register Name	Register Content	Default	Access
00h	Config_Reg	POR, Vsh and Vb full-scale ranges, ADC acquisition time, ADC operating mode	799Fh	R/W
01h	Vshunt_Reg	Measured shunt voltage in binary form	0000h	R
02h	Vbus_Reg	Measured bus voltage in binary form	0000h	R
03h	Power_Reg	Result of DPM internal calculation of Equation 4	0000h	R
04h	Current_Reg	Result of DPM internal calculation of Equation 3	0000h	R
05h	CAL_Reg	User-calculated calibration value of Equation 2	0000h	R/W

Their differing data formats and weighted bit locations are shown in Figure 3.

Vshunt Register, 01h	**PG**	**FSR (mV)**	**D15**	**D14**	**D13**	**D12**	**D11**	**D10**	**D9**	**D8**	**D7**	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**
	11	±320	-2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
	10	±160		-2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
	01	±80			-2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
	00	±40				-2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
Calibration Register, 05h	**User Program.**		**D15**	**D14**	**D13**	**D12**	**D11**	**D10**	**D9**	**D8**	**D7**	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**
	Equation 2		2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	0
Current Register, 04h	**DPM Internal Calc.**		**D15**	**D14**	**D13**	**D12**	**D11**	**D10**	**D9**	**D8**	**D7**	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**
	Equation 3		-2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
Vbus Register, 02h	**BRNG**	**FSR (V)**	**D15**	**D14**	**D13**	**D12**	**D11**	**D10**	**D9**	**D8**	**D7**	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**
	11, 10	60	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	CNVR	OVF
	01	32	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}		CNVR	OVF
	00	16		2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}		CNVR	OVF
Power Register, 03h	**DPM Internal Calc.**		**D15**	**D14**	**D13**	**D12**	**D11**	**D10**	**D9**	**D8**	**D7**	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**
	Equation 4		2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

Figure 3. Differing Data Formats of the Data Registers

To convert a binary register content into the appropriate units of V, A, and W, the register content must be multiplied with corresponding LSB, that is:

$$Vshunt[V] = Vshunt\_Reg \times Vshunt\_LSB$$

$$Vbus[V] = Vbus\_Reg \times Vbus\_LSB$$

$$Current[A] = Current\_Reg \times Current\_LSB$$

$$Power[W] = Power\_Reg \times Power\_LSB$$

3. Programming Procedure

1. Determine your application-specific maximum expected values for bus voltage, load current, shunt voltage, and shunt resistance.
2. Program the configuration register accordingly to the required full-scale voltage ranges, and ADC operating modes.
3. Calculate the Current LSB using Equation 1:

(EQ. 1) $$Current\_LSB = \frac{Maximum\ Expected\ Current}{ADC_{Res}}$$

4. Calculate the calibration register content with:

(EQ. 2) $$CAL\_Reg = TRUNC\left(\frac{0.04096}{Current\_LSB \times R_{SHUNT}}\right)$$

5. When the calibration register is programmed, the DPM calculates the load current using Equation 3:

(EQ. 3) $$Current\_Reg = \frac{Vshunt\_Reg \times CAL\_Reg}{4096}$$

6. When the current register content is available, the DPM calculates the power value using Equation 4:

(EQ. 4) $$Power\_Reg = \frac{Current\_Reg \times Vbus\_Reg}{5000}$$

4. Application Example

A power supply system with a nominal supply of **V_{SYS} = 12V** supplies a load resistance of R_L = 6Ω. This makes the nominal load current I_L = 2A. However, due to changes in R_L, a maximum current of **I_{max} = 3A** is expected. This current creates a power dissipation in the shunt resistor, which shall be ≤250mW. Therefore, the shunt resistor value is calculated with: $R_{SH} = P/I^2 = 0.25W/(3A)^2$ = 27.8mΩ. In this case, chose the next lower standard value of **R_{SH} = 25mΩ**. Then, at 3A, the maximum shunt voltage is **V_{SH-max}** = 3A x 25mΩ = **75mV**.

Note: The bolded values represent the information required to set the full-scale ranges for shunt and bus voltage and to calculate the calibration register.

5. Programming the Configuration Register (see Figure 2)

Assuming the bus and shunt voltages are to be sampled continuously requires [MODE0: MODE1 = 111].

Assuming the A-to-D conversion should use the highest ADC resolution without averaging for both shunt voltage and bus voltage requires [SADC3: SADC0 = 1000] and [BADC3: BADC0 = 1000].

The V_{SH-max} of 75mV requires the shunt voltage FSR to be 80mV; therefore, requiring [PG1: PG0 = 01].

The V_{SYS} of 12V requires the bus voltage FSR to be 16V; therefore, requiring [BRNG1: BRNG0 = 00].

The above requirements lead to the configuration bit pattern in Figure 4.

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
RST	BRNG1	BRNG0	PG1	PG0	BADC3	BADC2	BADC1	BADC0	SADC3	SADC2	SADC1	SADC0	MODE2	MODE1	MODE0
0	0	0	0	1	1	0	0	0	1	0	0	0	1	1	1

Figure 4. Configuration Register Content after Programming

6. Calculating the Calibration Register Content

Calculating the calibration register content requires the shunt resistor value (R_{SH} = 25mΩ) and the Current LSB, which is calculated using Equation 1. For this example the current LSB is:

$$\text{Current\_LSB} = \frac{\text{Maximum Expected Current}}{\text{ADC}_{\text{Res}}} = \frac{3A}{2^{15}} = 91.55\mu A$$

Therefore, calculate the CAL_Reg content with Equation 2:

$$\text{CAL\_Reg} = \text{TRUNC}\left(\frac{0.04096}{\text{Current\_LSB} \times R_{\text{SHUNT}}}\right) = \text{TRUNC}\left(\frac{0.04096}{91.55\mu A \times 25m\Omega}\right) = 17896$$

Figure 5 shows the binary content of the Calibration Register.

Calibration Register, 05h	User Program.	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
	Equation 2	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	0
		0	1	0	0	0	1	0	1	1	1	1	0	1	0	0	

Figure 5. Binary Content of Calibration Register

7. Calculating the Current

At the nominal load current of I_L = 2A, the measured shunt voltage is 50mV. With the Shunt voltage LSB = 10µV for all PG settings, calculate the decimal and binary content of the shunt voltage register with:

(EQ. 5) $$\text{Vshunt\_Reg} = \frac{\text{Vshunt[V]}}{\text{Vshunt\_LSB}}$$

In this example, the register content is:

$$\text{Vshunt\_Reg} = \frac{50mV}{10\mu V} = 5000$$

The binary content is shown in Figure 6.

Vshunt Register, 01h	PG	FSR (mV)	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
	01	±80			-2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
					0	1	0	0	1	1	1	0	0	0	1	0	0	0

Figure 6. Binary Content of the Shunt Voltage Register

Now, the DPM internally calculates the current using Equation 3:

$$\text{Current\_Reg} = \frac{\text{Vshunt\_Reg} \times \text{CAL\_Reg}}{4096} = \frac{5000 \times 17896}{4096} = 21846$$

The binary content of the current register is shown in Figure 7.

Current Register, 04h	DPM Internal Calc.	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
	Equation 3	-2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
		0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	0

Figure 7. Binary Content of the Current Register

To get the readout in Amps, simply multiply the decimal register content with the current LSB:

(EQ. 6) $$\text{Current[A]} = \text{Current\_Reg} \times \text{Current\_LSB} = 21846 \times 91.55\mu A = 2.000A$$

8. Calculating the Power

When the current register content is available, the DPM internally calculates the power using Equation 4. Before calculating the power, establish the bus voltage register content. With the bus voltage LSB = 4mV, the content of the bus voltage register for a nominal value of V_{SYS} = 12V is derived with:

$$\text{Vbus\_Reg} = \frac{\text{Vbus[V]}}{\text{Vbus\_LSB}}$$

In this example, the register content is:

$$\text{Vbus\_Reg} = \frac{12V}{4mV} = 3000$$

This results in the binary content of Figure 6.

Vbus Register, 02h	BRNG	FSR (V)	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
	00	16		2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}		CNVR	OVF
				1	0	1	1	1	0	1	1	1	0	0	0			

Figure 8. Binary Content of the Bus Voltage Register

Internally the DPM calculates the content of the power register with Equation 4:

$$\text{Power\_Reg} = \frac{\text{Current\_Reg} \times \text{Vbus\_Reg}}{5000} = \frac{21846 \times 3000}{5000} = 13108$$

Therefore, resulting in the binary content shown in Figure 9.

Power Register, 03h	DPM Internal Calc.	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
	Equation 4	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
		0	0	1	1	0	0	1	1	0	0	1	1	0	1	0	0

Figure 9. Binary Content of the Power Register

To get the readout in watts, simply multiply the power register content with 5000 Power LSB.

$$\text{Power[W]} = \text{Power\_Reg} \times 5000 \times \text{Power\_LSB}$$

With

$$\text{Power\_LSB} = \text{Vbus\_LSB} \times \text{Current\_LSB}$$

follows that

$$5000 \times \text{Power\_LSB} = 5000 \times \text{Vbus\_LSB} \times \text{Current\_LSB}$$

or in numbers

$$5000 \times \text{Vbus\_LSB} \times \text{Current\_LSB} = 5000 \times 4mV \times \text{Current\_LSB} = 20\text{Current\_LSB}$$

Therefore:

$$\text{Power[W]} = \text{Power\_Reg} \times 20\text{Current\_LSB}$$

In this example, the Power (W) is:

$$\text{Power[W]} = 13108 \times 20 \times 91.55\mu A = 24W$$

This results confirms the direct calculation of:

$$\text{Power[W]} = V_{SYS} \times I_L = 12V \times 2A = 24W$$

9. Revision History

Revision	Date	Description
1.00	Dec 19, 2023	Initial release.

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