



The MPM3695 Family: High-Power Module Solutions with Flexible Output Voltage Configurations

By Niliana Carrero, Sr. Applications Engineer

Abstract

Powering modern applications requires high currents, precise transient control, and a flexible voltage set-up. In particular, field-programmable gate array (FPGA) power specifications often come with rigid requirements regarding output voltage (V_{OUT}) accuracy, where the absolute V_{OUT} accuracy must be around $\pm 1.5\%$, regardless of temperature variations and aging. Some manufacturers' load regulation specifications may be significantly more stringent.

The most commonly used method to configure V_{OUT} is to use external or internal voltage dividers. This method provides flexibility for V_{OUT} configuration while fulfilling demanding requirements.

The MPM3695 family ([MPM3695-10](#), [MPM3695-20](#), [MPM3695-25](#), and [MPM3695-100](#)) was introduced to deliver up to 800A of current with ultra-fast transient response and excellent voltage tolerance. Depending on the application, designers can use either external or internal voltage dividers to provide excellent flexibility. The internal resistor divider offers compactness, integration, and ease of use. These features make the device suitable for designs with stringent space and performance requirements; meanwhile, the external resistor dividers provide flexibility, customization, and improved thermal management.

Introduction

In recent years, fast-paced advancements in technology have required power supplies with higher output current (I_{OUT}) capabilities. Unfortunately, delivering a significant I_{OUT} with high efficiency in a compact package is a complex task for modern design solutions.

The MPM3695 family is a fully integrated power module solution with a PMBus interface that features paralleled connections, delivering outstanding I_{OUT} delivery capabilities of up to 800A (see Table 1). MPS's proprietary, multi-phase constant-on-time (MCOT) control provides ultra-fast transient response and simple loop compensation.

Table 1: MPM3695 Family

Part Number	MPM3695-10	MPM3695-20	MPM3695-25	MPM3695-100
I_{OUT} (Max per Phase) (A)	10	25	20	100
Slave Phases (Max)	5	5	5	7
Total I_{OUT} (A)	60	150	120	800
Package Size	LGA-45 (8mmx8mmx 2mm)	ECLGA-29 (5mmx6mmx 4.4mm)	QFN-59 (10mmx12mmx 4mm)	BGA (15mmx30mmx 5.18mm)

The PMBus interface enables simple module configuration and monitoring of key parameters, while the comprehensive protections ensure reliable operation. The MPM3695 can easily set V_{OUT} margins, fault levels, and power good (PG) thresholds relative to V_{OUT} . This flexibility allows for dynamic adjustments as V_{OUT} changes, eliminating the need for manual updates and accelerating the design process.

Setting the Output Voltage

The MPM3695 family offers two possible methods to adjust V_{OUT} . The first option is to use the internal resistor voltage divider. The second option is to change V_{OUT} via the external resistor divider.

Figure 1 shows the typical application circuit with an internal resistor divider.

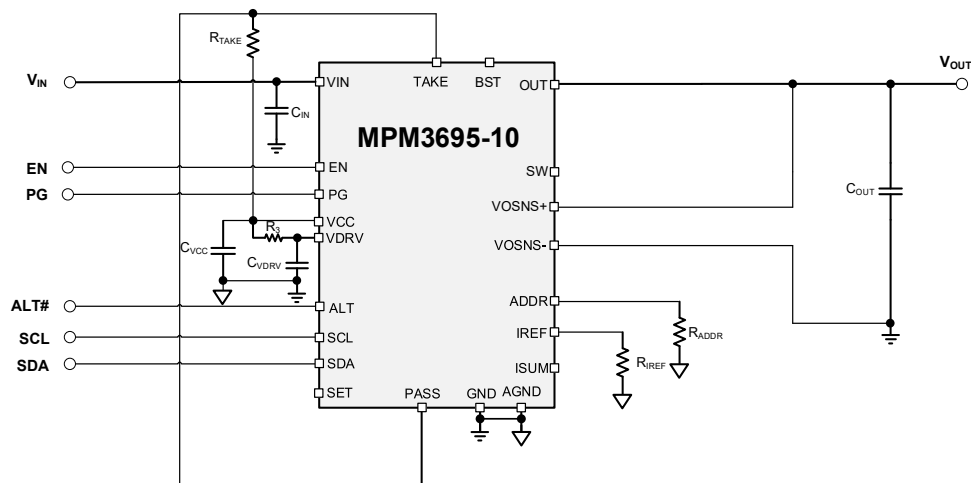


Figure 1: Typical Application Circuit Using an Internal Resistor Divider (Single-Module Operation)

Figure 2 shows the typical application circuit with an external resistor divider.

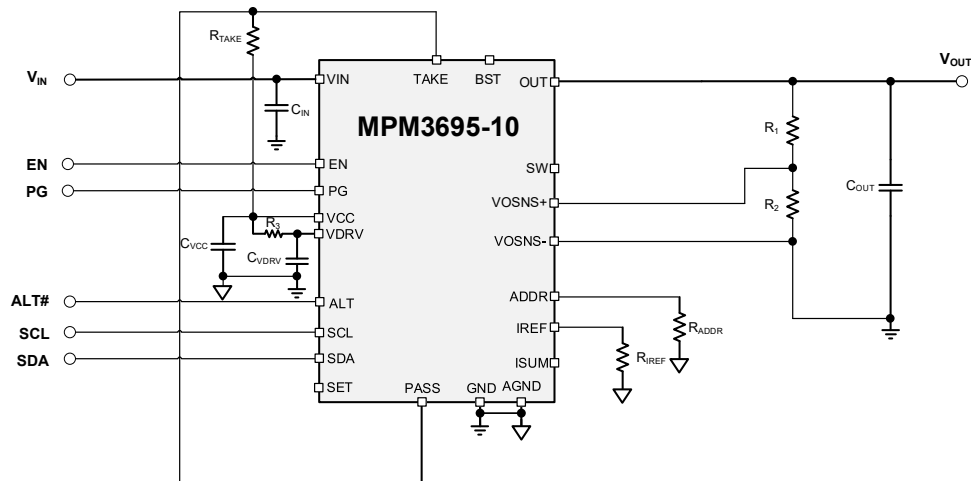


Figure 2: Typical Application Circuit Using an External Resistor Divider (Single-Module Operation)

Based on the design, it can be advantageous to utilize both methods for space-constrained applications with customization requirements. External resistor dividers can also improve thermal management, since the power dissipation can be spread across the PCB. However, one significant drawback of external resistors is that their tolerance can compromise V_{OUT} accuracy. Furthermore, resistor dividers have a temperature coefficient, which means their resistance can fluctuate with changes in temperature. This variation can lead to slight deviations in the feedback voltage (V_{FB}) and, consequently, V_{OUT} .

The MPM3695 family supports the PMBus protocol for the V_{OUT} configurations. Table 2 shows the commands that can be used to change V_{OUT} . The margin voltage commands verify the application's robustness and ensure that the device meets the application's specifications and can tolerate small changes in power supply voltages across time and temperature changes.

Once the selected voltage value is determined, it is compared to the V_{OUT} limits set by the V_{OUT_MAX} and V_{OUT_MIN} commands. This ensures that V_{OUT} remains within safe upper and lower thresholds. Finally, a scaling factor is applied to match a reference voltage.

Table 2: PMBus Output Voltage Commands

Command	Code	Description
VOUT_COMMAND	0x21	Sets the device's target V_{OUT} during normal operation.
VOUT_MARGIN_HIGH	0x25	Sets the upper voltage limit so that V_{OUT} can be adjusted during margin testing (temporary margin testing and performance verification).
VOUT_MARGIN_LOW	0x26	Sets the lower voltage limit so that V_{OUT} can be adjusted during margin testing (temporary margin testing and performance verification).
VOUT_MAX	0x24	Sets the maximum allowable V_{OUT} . This is a permanent upper voltage limit that triggers a fault if exceeded, which could potentially damage the load or the power supply itself.
VOUT_MIN	0x2B	Sets the minimum allowable V_{OUT} . This is a permanent lower voltage limit that triggers a fault if exceeded, which could potentially damage the load or the power supply itself.
VOUT_SCALE_LOOP	0x29	Adjusts the feedback (FB) loop's gain, which can be necessary for stabilizing the power supply or archiving the target voltage regulation performance.
OPERATION	0x01	Controls the power supply's on/off state and the basic source of the V_{OUT} command (VOUT_COMMAND, VOUT_MARGIN_HIGH, or VOUT_MARGIN_LOW).

The V_{OUT} command process for the MPM3695-10 involves using the OPERATION command to select one of the three inputs as the source of the nominal voltage (VOUT_COMMAND, VOUT_MARGIN_HIGH, or VOUT_MARGIN_LOW) (see Figure 3).

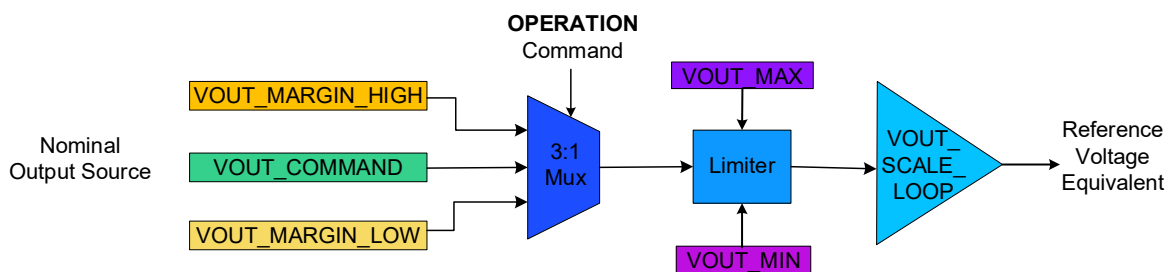


Figure 3: MPM3695-10 PMBus Output Voltage Command Processing

Internal Voltage Divider

V_{OUT} is sensed through the VOSNS+ and VOSNS- pins. The internal resistor divider reduces V_{OUT} to match the reference voltage (V_{REF}). Figure 4 shows how to configure the internal voltage divider.

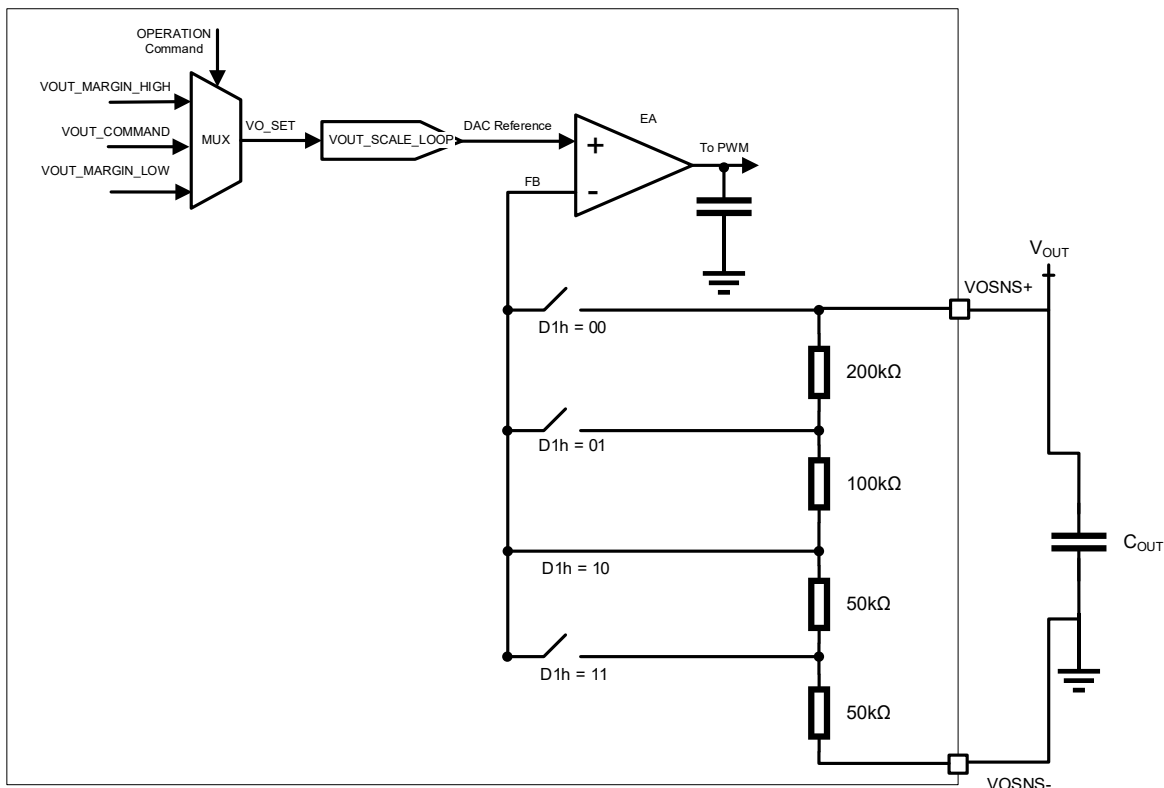


Figure 4: V_{OUT} Set by the Internal Resistor Divider

Table 3 shows the V_{OUT} range using the internal voltage divider option through $VOUT_SCALE_LOOP$ (29h) and MFR_CTRL_VOUT (D1h). While using the internal voltage divider, it is important to completely disconnect the external feedback (FB) resistors and select the appropriate voltage range according to the desired application.

A higher FB gain typically leads to faster response times to load transients. However, excessively high gains can introduce instability or overshoot. A lower FB gain can lead to slower settling times and reduced overshoot.

Table 3: MPM3695 Family V_{OUT} Range with an Internal Resistor Divider

FB Divider	$VOUT_SCALE_LOOP$ (29h)	MFR_CTRL_VOUT (D1h, Bits[1:0])
Internal	29h = 0x01F4	If D1h, bits[1:0] = 2'b01: $V_{REF} / V_{OUT} = 0.5$ $V_{OUT} = 0.4V$ to $1.344V$
	29h = 0x00FA	If D1h, bits[1:0] = 2'b10: $V_{REF} / V_{OUT} = 0.25$ $V_{OUT} = 0.7V$ to $2.688V$
	29h = 0x007D	If D1h, bits[1:0] = 2'b11: $V_{REF} / V_{OUT} = 0.125$ $V_{OUT} = 1.3V$ to $5.376V$

External Voltage Divider

When using an external voltage divider, the device's V_{OUT} is scaled using two resistors ($R1$ and $R2$) connected in series to form a voltage divider configuration. V_{FB} is sensed through the $VOSNS+$ and $VOSNS-$ pins. Figure 5 shows an external voltage divider configuration.

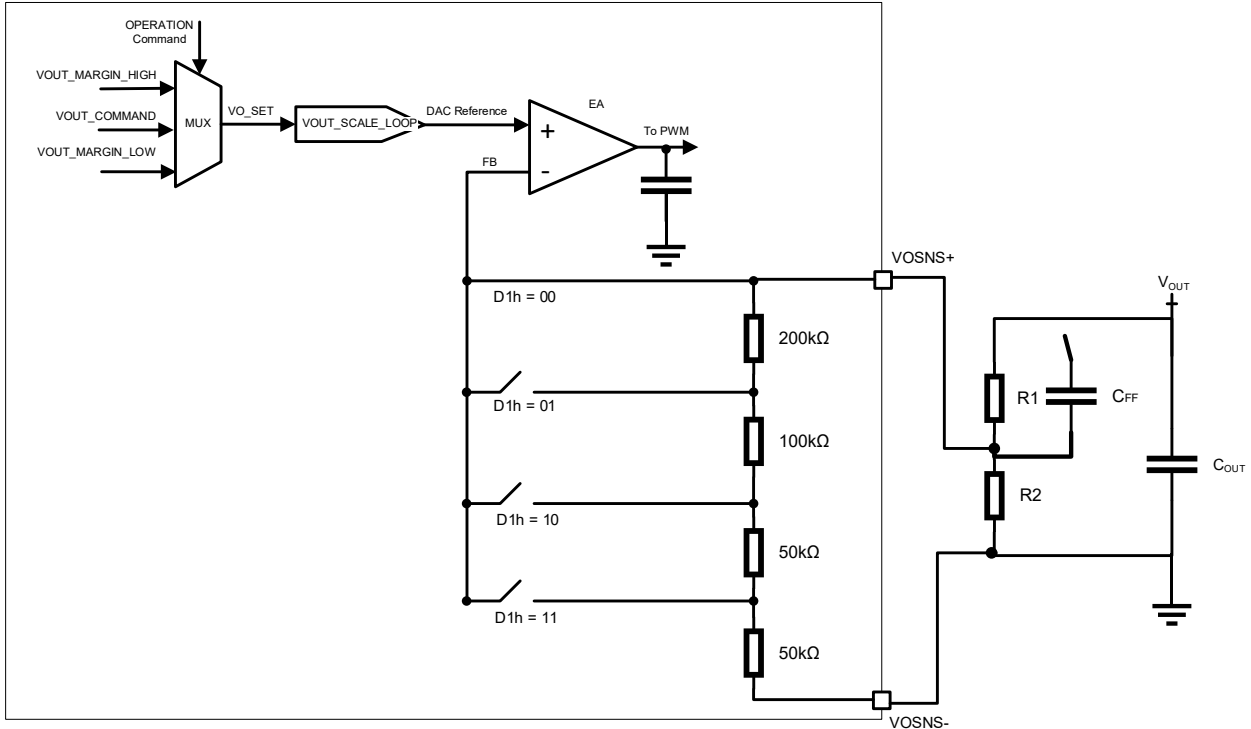


Figure 5: V_{OUT} Set by an External Resistor Divider

The values of the FB resistors (R_2 and R_1) can be calculated with Equation (1):

$$R_2(k\Omega) = \frac{V_{REF}}{V_{OUT} - V_{REF}} \times R_1(k\Omega) \quad (1)$$

Where V_{REF} is the reference voltage, which has a default value of 0.6V (and can be adjusted to be between 0.5V and 0.672V); and V_{OUT} is the target output voltage.

It is recommended to use 1% tolerance resistors with a low temperature coefficient for the FB divider. The V_{OUT} FB gain can be estimated with Equation (2):

$$G_{FB} = VOUT_SCALE_LOOP = \frac{R_2}{R_1 + R_2} \quad (2)$$

For a given FB resistor network, the upper (V_{OUT_MAX}) and lower limits (V_{OUT_MIN}) of V_{OUT} can be calculated with Equation (3) and Equation (4), respectively:

$$V_{OUT_MAX} = \frac{0.672}{G_{FB}} \quad (3)$$

$$V_{OUT_MIN} = \frac{0.5}{G_{FB}} \quad (4)$$

To optimize the load transient response, a feed-forward capacitor (C_{FF}) must be placed in parallel with R_1 (see Figure 5). Table 4 shows the V_{OUT} range when using the external voltage divider through $VOUT_SCALE_LOOP$ (29h) and MFR_CTRL_VOUT (D1h).

Table 4: MPM3695 Family V_{OUT} Range with an External Resistor Divider

FB Divider	$VOUT_SCALE_LOOP$ (29h)	MFR_CTRL_VOUT (D1h, Bits[1:0])
External	$29h = R_{FB2} / (R_{FB1} + R_{FB2})$	If D1h, bits[1:0] = 2'b00: $V_{REF} / V_{OUT} = 1$ $V_{OUT} = 0.4V \text{ to } 5.5V$

Table 5 lists the values of the FB resistors and the feed-forward capacitor for common output voltages.

Table 5: Common Output Voltages

V _{OUT} (V)	R ₁ (kΩ)	R ₂ (kΩ)	C _{FF} (nF)	VOUT_SCALE_LOOP (29h)
0.9	0.5	1	33	0.66
1.2	1	1	33	0.50
1.8	2	1	33	0.33
3.3	4.53	1	4.7	0.18
5	7.32	1	4.7	0.12

Practical Design Example

External Voltage Divider

The following section gives a practical example on how to set V_{OUT} through the external resistor voltage divider using the MPM3695-25. Table 6 shows all parameters considered for this example.

Table 6: Design Example Parameters

Input Voltage (V _{IN})	12V
Output Voltage (V _{OUT})	1.8V
Maximum Output Current (I _{O MAX})	10A
Switching Frequency (f _{sw})	800kHz

Choose R₁ = 2kΩ and V_{REF} = 0.6V. Estimate R₂ with Equation (5):

$$R_2(k\Omega) = \frac{0.6}{1.8-0.6} \times 2 = 1k\Omega \quad (5)$$

Calculate the resistor divider gain with Equation (6):

$$G_{FB} = VOUT_SCALE_LOOP = \frac{1}{1+2} = 0.33 \quad (6)$$

V_{OUT_MAX} and V_{OUT_MIN} can be estimated with Equation (7) and Equation (8), respectively:

$$V_{OUT_MAX} = \frac{0.672}{0.22} = 2.016V \quad (7)$$

$$V_{OUT_MIN} = \frac{0.5}{0.33} = 1.5V \quad (8)$$

When using the resistor divider described above, failure to adhere to these limits reduces V_{OUT} accuracy.

Table 7 shows the configuration values for the nominal V_{OUT} command (VOUT_COMMAND) and the gain of the external resistor divider (VOUT_SCALE_LOOP) used in this example. It also includes the margin V_{OUT} limit commands (VOUT_MARGIN_HIGH and VOUT_MARGIN_LOW) and the safeguard V_{OUT} limit command (VOUT_MAX and VOUT_MIN) values.

Table 7: Example PMBus V_{OUT} Command Values

Command Name	Code	Hexadecimal Value	Decimal Value
VOUT_COMMAND	0x21	0x384	1.8V
VOUT_SCALE_LOOP	0x29	0x14A	0.33
VOUT_MARGIN_HIGH	0x25	0x3E8	2V
VOUT_MARGIN_LOW	0x26	0x320	1.6V
VOUT_MIN	0x2B	0x1F4	1V
VOUT_MAX	0x24	0x4E2	2.5V
MRF_CTRL_VOUT	0xD1	0x00	0

The real output voltage (V_{OUT_REAL}) can be calculated with Equation (9):

$$V_{OUT_REAL} = \left(1 + \frac{R_1}{R_2}\right) \times VOUT_COMMAND \times VOUT_SCALE_LOOP \quad (9)$$

$V_{OUT_REAL} = VOUT_COMMAND$ if the following condition is satisfied, estimated with Equation (10):

$$\left(1 + \frac{R_1}{R_2}\right) \times VOUT_SCALE_LOOP = 1 \quad (10)$$

In our current example, $VOUT_SCALE_LOOP$ matches the resistor divider's real gain, so V_{OUT_REAL} is equal to the value configured via $VOUT_COMMAND$ (21h).

The MPM3695-25's evaluation board ([EVM3695-25-RF-02A](#)) in a single-phase configuration was used for this example. Figure 6 shows the circuit that was built.

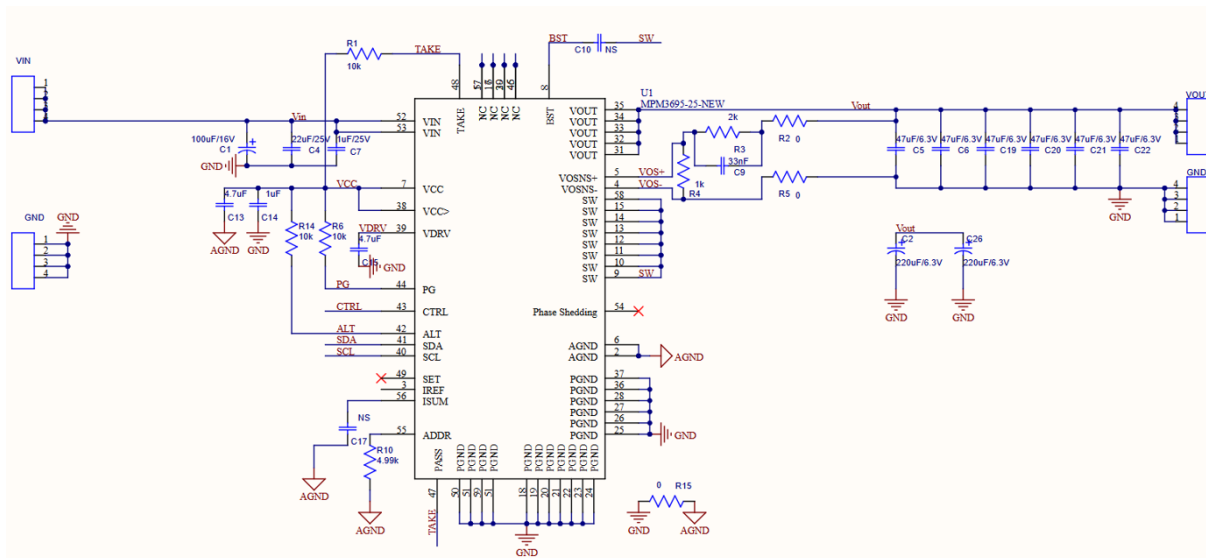


Figure 6: EVM3695-25-RF-02A Schematic

MPS's [Virtual Bench Pro 4.0](#) GUI provides an interface to configure the MPM3695 family. Figure 7 shows the main PMBus V_{OUT} commands used in this example.

The “Parameters” tab is divided into two sections. The basic parameters are found at the top, while more advanced configurations are at the bottom. Box 1 in Figure 7 shows the configurations for $VOUT_COMMAND$ (21h), $VOUT_SCALE_LOOP$ (29h), and MRF_CTRL_VOUT (D1h). Box 2 in Figure 7 shows the following V_{OUT} commands: $VOUT_MAX$ (24h), $VOUT_MIN$ (2Bh), $VOUT_MARGIN_LOW$ (26h), and $VOUT_MARGIN_HIGH$ (25h). The configuration value (in hexadecimal format) for each of these registers can be found in the “Register Map” tab in Box 3 (see Figure 7).

The MPM3695 family of power modules have telemetry commands such as READ_VIN (88h), READ_VOUT (8Bh), READ_IOUT (8Ch), and READ_TEMPERATURE (8Dh). These commands monitor the input voltage (V_{IN}), V_{OUT} , load current, and temperature in real time, respectively. The values are visualized in the “Monitoring” section in Box 4 (see Figure 7).

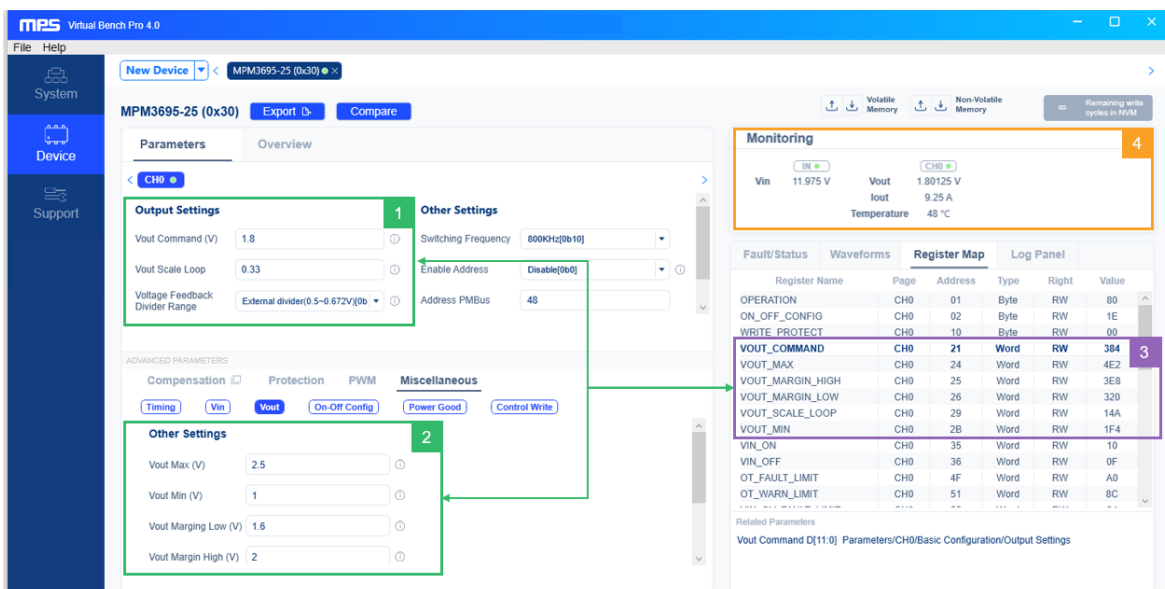


Figure 7: MPM3695-25 GUI

VOUT_COMMAND (21h) sets the nominal voltage source. Figure 8 shows whether the values monitored in real time (indicated in the yellow box) match the target values from the application. To set VOUT_MARGIN_HIGH (25h) as the nominal V_{OUT} source and turn on the device with a high margin, set OPERATION (01h), bits[5:4] = 10b. Based on Table 6, the target margin high value is set to 2V.

Figure 8 shows whether V_{OUT} as monitored in real time (indicated in the green box) matches the value configured via VOUT_MARGIN_HIGH (25h).

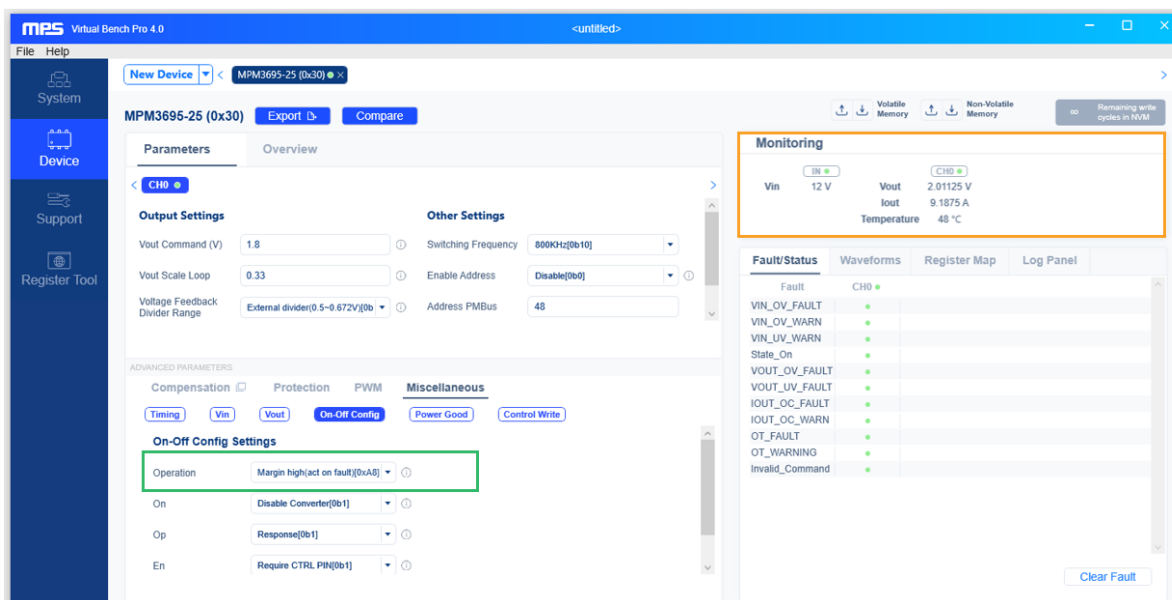


Figure 8: VOUT_MARGIN_HIGH (25h) Configuration Example

Figure 9 shows whether the result from VOUT_MARGIN_LOW (26h) matches the configured values used in this example.

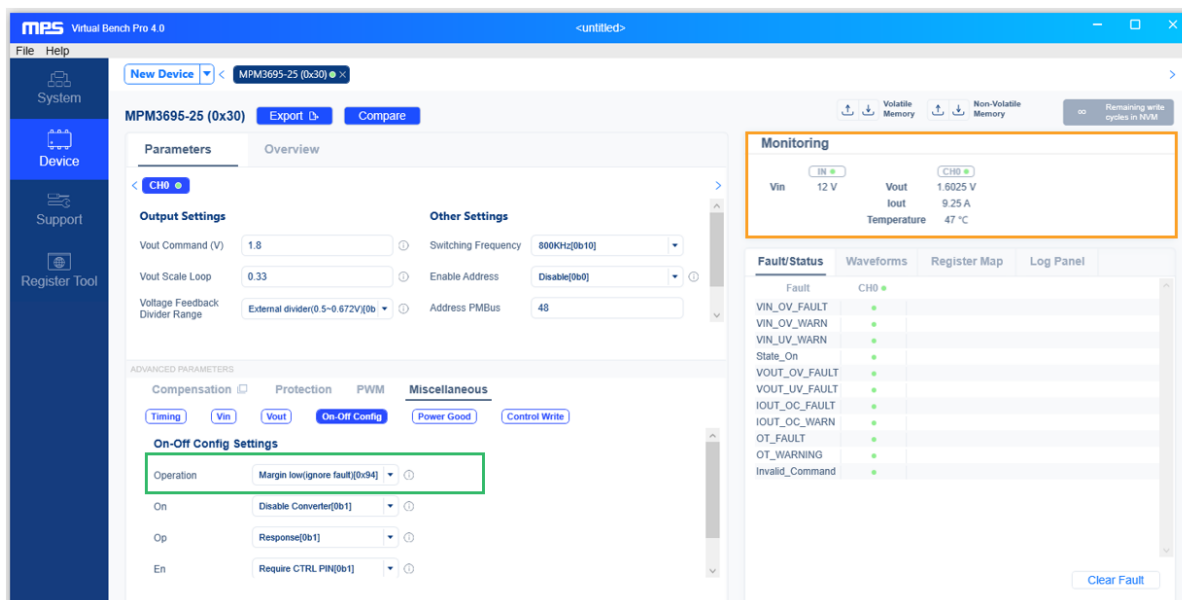


Figure 9: VOUT_MARGIN_LOW Command Configuration Example

Internal Voltage Divider

Consider the parameters in Table 6. This section describes how to configure V_{OUT} using the internal voltage divider.

Verify that the VOSNS+ and VOSNS- pins are connected directly to the V_{OUT} sense points (see Figure 4). In this scenario, R_3 is set to 0Ω , and R_4 was removed in Figure 6.

For safety considerations while switching between internal and external dividers, it is highly recommended to disable the part through the EN pin; otherwise, the device could sustain damage.

The V_{OUT} range was set via MFR_CTRL_VOUT (D1h), bits[1:0] (when set to 10b), and VOUT_SCALE_LOOP (29h) was set to 0x00FA (see Table 3). Table 8 shows the PMBus command sequence to set V_{OUT} to 1.8V using the internal resistor divider.

Table 8: PMBus Command Sequence to Configure the Internal Voltage Divider

Step	Command Name	Code	Hexadecimal Value	Decimal Value
1	MFR_CTRL_VOUT	0xD1	0x02	2
2	VOUT_SCALE_LOOP	0x29	0x14F	335
3	VOUT_COMMAND	0x21	0x384	1.8V
-	VOUT_MARGIN_HIGH	0x25	0x3E8	2V
-	VOUT_MARGIN_LOW	0x26	0x320	1.6V
-	VOUT_MIN	0x2B	0x1F4	1V
-	VOUT_MAX	0x24	0x4E2	2.5V

Adjusting V_{OUT} on-the-fly via the PMBus interface is particularly useful when changing the I/O voltage, such as when reconfiguring the functionality of new FPGAs like the [Achronix Speedster7t](#) solution. Additionally, this on-the-fly feature can also be utilized to adjust the FPGA's core voltage during operation to minimize power consumption.

Figure 10 shows the GUI when configuring V_{OUT} with the internal resistor divider, where the green box shows the commanded values for $V_{OUT_COMMAND}$ (21h) and MFR_CTRL_VOUT (D1h), bits[1:0]. The V_{OUT} current measurement, load current, and device's temperature can be monitored in the “Monitoring” section (indicated in the yellow box) (see Figure 10).

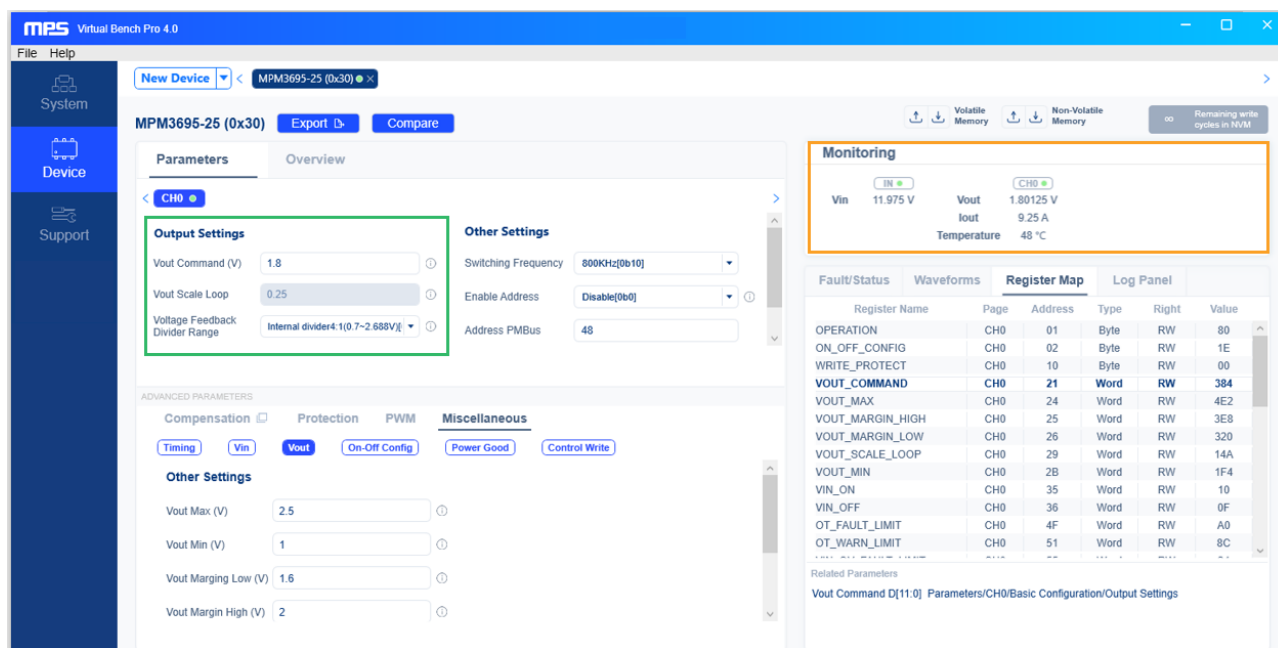


Figure 10: V_{OUT} Configured Using the Internal Voltage Divider

Conclusion

Choosing between an internal or external voltage divider to configure V_{OUT} depends on the specific requirements of the application, including design flexibility, space constraints, precision needs, and susceptibility to environmental factors.

The MPM3695 family ([MPM3695-10](#), [MPM3695-20](#), [MPM3695-25](#), and [MPM3695-100](#)) offers excellent flexibility to configure V_{OUT} by using either an external or internal voltage divider. Based on the results presented, both methods provide high accuracy for real-time V_{OUT} measurements. Furthermore, by including the margin levels and PMBus commands, the MPM3695 family is well-suited for applications where precise V_{OUT} control is needed.

For more power module solutions for your application, explore MPS's wide array of [power modules](#).