# Application Report Implementing Output Voltage Offset in the TPS40322

TEXAS INSTRUMENTS

## ABSTRACT

Changing output voltage on the fly may be needed in some particular applications such as running turbo mode or low-power mode. Some systems may require different supply voltages for each operation mode to achieve best performance. This application report describes how to adjust the TPS40322 regulated output voltage ( $V_{OUT}$ ) on-the-fly by implementing the TPL0102-100 (100-k $\Omega$  end-to-end resistance, 256-taps digital potentiometers).

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# 1 Introduction

This application note introduces a method to implement the TPS40322 device, changing the output voltage onthe-fly by sending an I2C command to set the TPL0102-100 digital potentiometer.

# **2 Circuit Description**

This section provides the system block diagram, FB network circuit, and calculations for VOUT settings.

TPS40322 Buck Converter

?

FB

VIN

Figure 2-1 illustrates the system block diagram.

 $V_{IN}$ 

MCU I<sup>2</sup>C TPL0102-100 Digital Potentiometer Figure 2-1. System Block Diagram

## 2.1 Calculation for VOUT Settings

Figure 2-2 shows the FB network circuit.

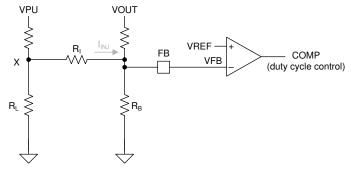


Figure 2-2. FB Network



VOUT



Converter DC regulation forces  $V_{FB} = V_{REF} = 0.6$  V. Therefore, the divider is injecting current  $i_{INJ}$  into the FB node to offset the output voltage.

1. Calculate VOUT as a function of  $i_{INJ}$ 

KCL at FB node:

$$\frac{V_{OUT} - V_{FB}}{R_T} + i_{INJ} = \frac{V_{FB}}{R_B}$$
(1)

Rearrange and simplify as Equation 2 shows:

$$V_{OUT} = V_{FB} \left( 1 + \frac{R_T}{R_B} \right) - i_{INJ} \times R_T$$
(2)

2. Solve for i<sub>INJ</sub>

$$i_{\rm INJ} = \frac{V_{\rm x} - V_{\rm FB}}{R_{\rm i}}$$
(3)

KCL @ X to solve for Vx:

$$\frac{\mathsf{V}_{\mathsf{P}\mathsf{U}} - \mathsf{V}_{\mathsf{x}}}{\mathsf{R}_{\mathsf{H}}} = \frac{\mathsf{V}_{\mathsf{x}}}{\mathsf{R}_{\mathsf{L}}} + \frac{\mathsf{V}_{\mathsf{x}} - \mathsf{V}_{\mathsf{F}\mathsf{B}}}{\mathsf{R}_{\mathsf{i}}}$$
(4)

Rearrange and simplify as Equation 5 shows:

$$V_{x} = \frac{V_{PU} \times R_{L} \times R_{i} + V_{FB} \times R_{L} \times R_{H}}{R_{H} \times R_{i} + R_{L} \times R_{H} + R_{L} \times R_{i}}$$
(5)

3. Substitute:

$$V_{OUT} = V_{FB} \left( 1 + \frac{R_T}{R_B} \right) - \left( \frac{V_x - V_{FB}}{R_i} \right) \times R_T$$
(6)

where  $V_x$  equals Equation 5.

These calculations are integrated in the TPS40322 Resistor Divider Vout Offset Calculator tool.



# 3 Setup TPL0102-100 EVM

 $R_H$  and  $R_L$  in Figure 2 are presenting the  $R_{HW}$ ,  $R_{WL}$  of the TPL0102 device. An I2C master connects to the TPL0102 and is required to get control the  $R_{HW}$ ,  $R_{WL}$  of the TPL0102. Figure 3-1 shows a connection example which uses the TI EV2400 tool as a I2C master to set the  $R_{HW}$ ,  $R_{WL}$  values via the bqStudio GUI.

## 3.1 Connection Block Diagram

This section details the hardware equipment and setup.

#### Hardware Equipment:

- PC or laptop
- EV2400
- TPL0102 EVM
- DC power supply

#### Hardware Setup:

- 1. Insert header caps in J1, J2, and J3 to set A2, A1, and A0, respectively. The board is shipped with the following settings: A2 = 0, A1 = 0, and A0 = 1.
- 2. Connect the I2C bus of the host(EV2400) to the board via connector J14 (pins marked SCL, SDA). Also connect the GND pin on J14 to GND of the host processor.
- 3. Apply the positive supply voltage 2.7 V–5.5 V(VDD) to center pin of J4. Apply GND to lowest pin of J4.
- 4. Apply the negative supply voltage (VSS) to J5. The board is shipped with a header cap that connects VSS to GND.
- 5. Write to the TPL0102 data registers per protocol in the *TPL0102 Two 256-Taps Digital Potentiometers With Non-Volatile Memory Data Sheet.*
- 6. Measure resistance between H, W, L terminals as appropriate on headers J8–J13.

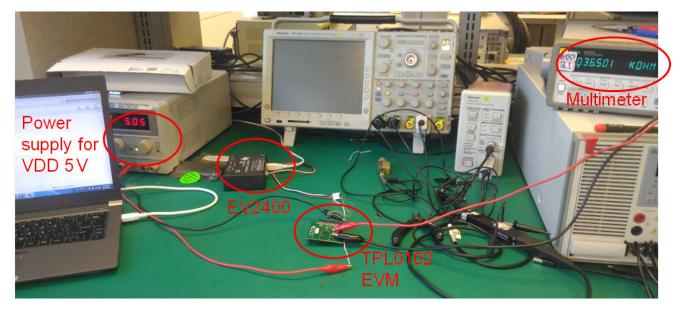


Figure 3-1. Hardware Setup



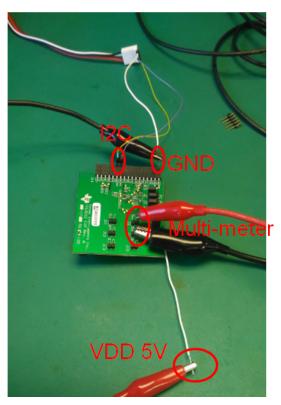


Figure 3-2. TPL0102 EVM Board Connection

## 3.2 Software GUI Setup

Utilize the bqStudio GUI for read/write the I2C commands to I2C slave device. Use the following procedure to set up the bqStudio GUI to control the TPL0102-100EVM and adjust as a variable resistor. Figure 3-5 second (fourth) Figure 3-6

1. Open BqStudio, select *Charger*, and click the *Next* button

a Target Selection Wizard									
Battery Management Studio (bqStudio) Supported Targets									
Please select a device type									
All									
Gauge									
Charger									
Wireless Charging Protector									
Reference Design									
Auto Detected Device : None									
If the type of device is not in the list above, you may download the latest version of bqStudio at <a href="http://www.ti.com/tool/bqstudio">http://www.ti.com/tool/bqstudio</a> . (new versions add support for newer devices)									
< Back Next > Finish	Cancel								
	Cuncer								

Figure 3-3. Charger Device Type



## 2. Select the *bq24773.bqz* target and click the *Finish* button

a Target Selection Wizard
Battery Management Studio (bqStudio) Supported Targets
Please select a target
Charger 1_00-bq24188.bqz Charger 1_00-bq24260.bqz Charger 1_00-bq24260.hqz Charger 1_00-bq24208.bqz Charger 1_00-bq24705.bqz Charger 1_00-bq24705.bqz Charger 1_00-bq257002C 1012015.bqz Charger 1_00-bq257002C 1012015.bqz Charger 1_00-bq257005MB 0212015.bqz Charger 1_00-bq257005MB 0212052016 CV.bqz Charger 1_00-bq257005MB 9620 07162016.bqz Charger 1_00-bq2570395MB 9620 07162016.bqz Charger 1_00-bq25805.bqz Charger 1_00-bq25805.bq
< Back Next > Finish Cancel

## Figure 3-4. bq24773.bqz Target

#### 3. Select the Advanced Comm tab

Battery Management Studio v1.3.52 (Device	- bq24773) Ch	arger_1_00-bq24	773.Ł	pqz							-	-		-	e 1.,	-	-		
ile View Window Help																			
Charger dvanced	Comm	Errors																	🛛 😰 🛛 📴 Battery Management Studio Persp
bq24773 Default View	C Pro View																		
Registers																			
Save Registers Load Registers Start Log	Write Register	Read Register	Auto	Read	d: OF	F 🗸	Up	date N	Node	Im	medi	ate	• T	gt A	ddres	s D	4(6A	) 🔻	
Register Name	Address	Current Value	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Charge Option 0
Charge Option 0	0x00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	EN LWPWR
Charge Option 1	0x02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Charge Option 2	0x10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	WDTMR_ADJ
Charge Current	0x0A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	IDPM AUTO DISABLE
Maximum Charge Voltage	0x0C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Minimum System Voltage	0x0E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SYSOVP
Input Current	0x0F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Audio Frequency Limit
Prochot Option 0	0x04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Switching Frequency
Prochot Option 1	0x06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Switching Frequency
Device ID Read Back	0x09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ACOC
																			LSFET OCP Threshold
																			EN LEARN
																			IADPT Gain
																			IDCHG Gain

Figure 3-5. Advanced Comm tab



#### 4. Read/Write I2C command to TPL0102-100 EVM

illustrates using the *Advanced Comm* tab to set the device address to 0xA0h and read/write 1 byte data from and to the register 0x00h for accessing the Wiper Resistance Register of Potentiometer A.

Battery Management Studi	o v1.3.52	(Device - bq	27500) Cha	arger_1_00	-bq25703I2C PG12 05202016 CV.bqz
File View Window Help					
Charger	Adv 🥸	anced Com	m 📕	Errors	
🗢 bq27500 Default View 餐	Advanced	Comm 🖾			
Advanced Comm I2C	:				
I2C Master Control Panel					
Byte Read/Write					
	ess (Hex)	a0			
Start Regis	ter (Hex)	00			
Bytes to Wr	rite (Hex)	80			Write
					<b>v</b>
Number of Bytes to Read (	Decimal	9			Read
Transaction Log					
TimeStamp	Rd/Wr	Address	Register	Length	Data
2017-08-14 10:40:11 530	Rd	a0	00	1	11
2017-08-14 10:41:48 971	Rd	a0	00	1	11
2017-08-14 10:42:09 039	Wr	a0	00	1	80

#### Figure 3-6. Byte Read/Write Settings

## 4 Conclusion

- 1. Typically the absolute value of a silicon resistor divider may not very accurate (approximately ±20%), but the ratio is very accurate. Use some parallel resistors with the TPL0102 to control the absolute values.
- 2. The TPL0102 device probably changes the resistance quickly. It would be better to have some capacitance in the circuit to slow down the Vref step change, so regulator does not overshoot.

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