TB3073

Implementing a 10-Bit Digital Potentiometer using a Quad 8-Bit Digital Potentiometer Technical Brief

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INTRODUCTION

This technical brief will discuss how using the Terminal Control feature of Microchip's digital potentiometers allows a higher resolution digital potentiometer to be implemented.

Using a quad 8-bit digital potentiometer allows a 10-bit digital potentiometer to be implemented, while a dual 8-bit digital potentiometer allows a 9-bit digital potentiometer to be implemented.

Limitations of this implementation will be covered so that application issues may be understood. These limitations may be an acceptable trade-off to the possible cost savings.

OVERVIEW

The Terminal Control feature allows any of the three digital potentiometer terminals (A, W, or B) of the resistor network to be disconnected from the device's pins. The default state of the TCON register is terminals connected. The number of TCON registers is determined by the number of resistor networks on the device. For this discussion we will use a quad resistor network digital potentiometer, which is either the MCP43x1 or MCP44x1 device. The TCON registers bits are shown in Register 1.

The Terminal Control operation is shown in Figure 1 for all terminals connected (RxA, RxW, and RxB bits = `1`, default state after a POR/BOR event), while Figure 2 shows the Terminal Control operation for all terminals disconnected (the RxA, RxW, and RxB bits = `0`), where the "x" refers to the resistor network selected (0, 1, 2, or 3).

Implementing a higher resolution digital potentiometer requires that all the A and B terminals are connected (RxA and RxB bits = `1`) and all W pins are externally shorted together. With this configuration, only one of the W pins can be connected to the resistor network at any one time. If two or more W pins are connected to the resistor networks, then the higher resolution digital potentiometer R_{AB} resistance will be affected.

FIGURE 1: *Terminal Connections After POR/BOR Event*

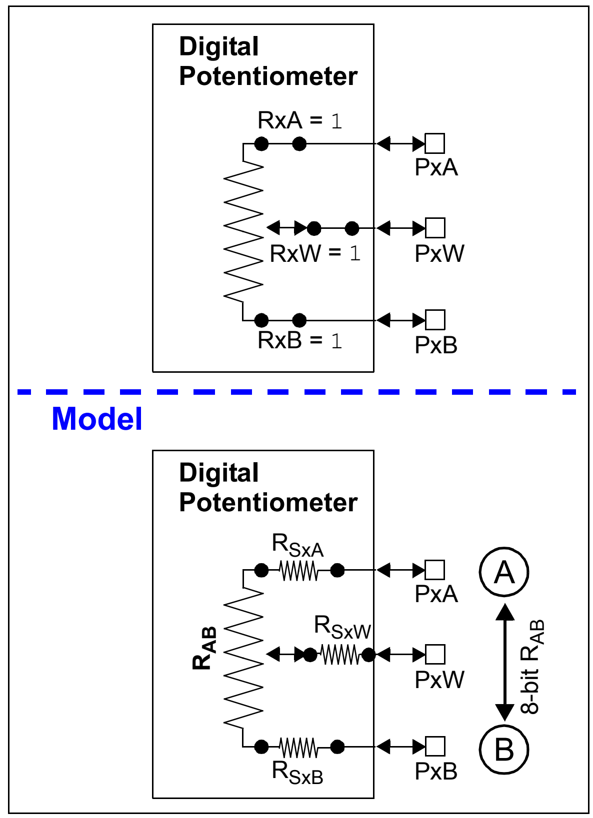


FIGURE 2: *Terminal Connections – All Terminals Open*

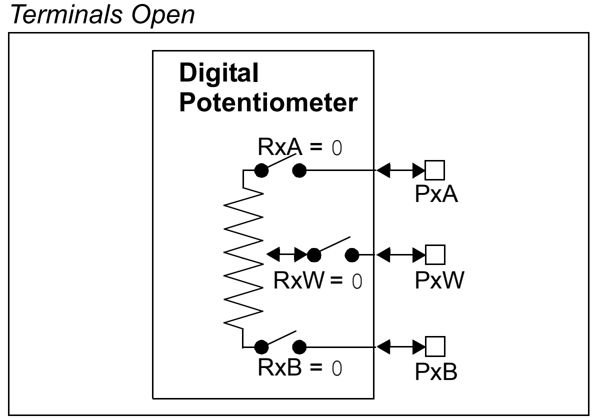
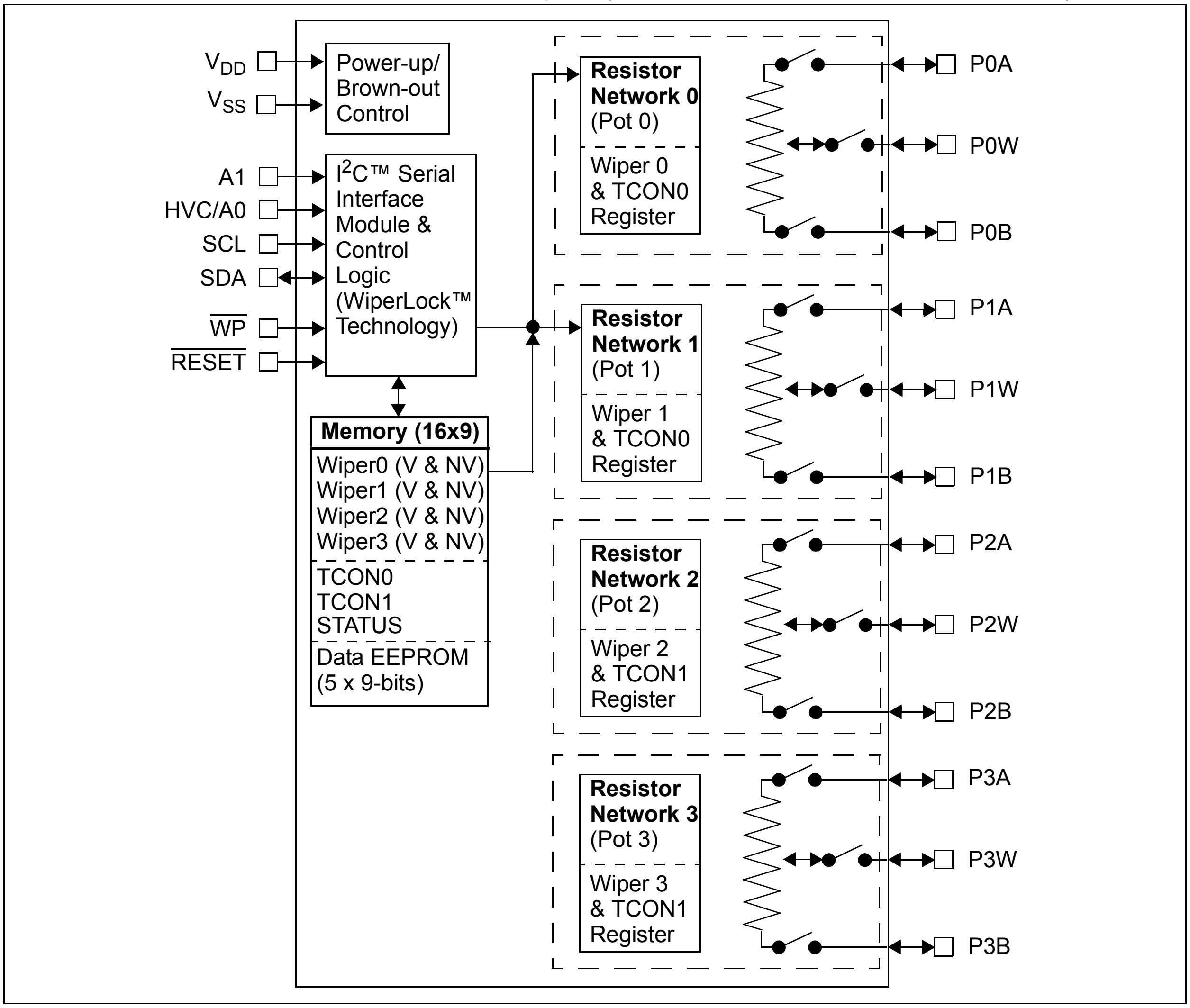


Figure 3 shows the block diagram for the MCP4461 device, which is a quad output 8-bit nonvolatile digital potentiometer with I^{2}C™ serial interface.

FIGURE 3: *MCP4461 Device Block Diagram (8-bit Nonvolatile with I^{2}C Serial Interface)*



REGISTER 1: TCON REGISTER BITS

Register	Control Bit with POR/BOR State								
	R-1	**R/W-1**	**R/W-1**	**R/W-1**	**R/W-1**	**R/W-1**	**R/W-1**	**R/W-1**	**R/W-1**
TCON0	D8	R1HW	R1A	R1W	R1B	R0HW	R0A	R0W	R0B
TCON1	D8	R3HW	R3A	R3W	R3B	R2HW	R2A	R2W	R2B
	bit 8								bit 0

Legend:

R = Readable bit	W = Writable bit	U = Unimplemented bit, read as ‘0’	
-n = Value at POR	‘1’ = Bit is set	‘0’ = Bit is cleared	x = Bit is unknown

bit 8 **D8:** Reserved. Forced to “1”

bit 7 **R1HW or R3HW:** Resistor Network 1 / 3 Hardware Configuration Control bit
This bit forces Resistor Network 1 / 3 into the “shutdown” configuration of the Hardware pin
1 = Resistor Network 1 / 3 is NOT forced to the hardware pin “shutdown” configuration
0 = Resistor Network 1 / 3 is forced to the hardware pin “shutdown” configuration

bit 6 **R1A or R3A:** Resistor Network 1 / 3 Terminal A (P1A/P3A pin) Connect Control bit
This bit connects/disconnects the Resistor Network 1 / 3 Terminal A to the Resistor 1 / 3 Terminal A Pin
1 = P1A/P3A pin is connected to the Resistor Network 1 / 3 Terminal A
0 = P1A/P3A pin is disconnected from the Resistor Network 1 / 3 Terminal A

bit 5 **R1W or R3W:** Resistor Network 1 / 3 Wiper (P1W/P3W pin) Connect Control bit
This bit connects/disconnects the Resistor Network 1 / 3 Wiper to the Resistor 1 / 3 Terminal W Pin
1 = P1W/P3W pin is connected to the Resistor Network 1 / 3 Terminal W
0 = P1W/P3W pin is disconnected from the Resistor Network 1 / 3 Terminal W

bit 4 **R1B or R3B:** Resistor Network 1 / 3 Terminal B (P1B/P3B pin) Connect Control bit
This bit connects/disconnects the Resistor Network 1 / 3 Terminal B to the Resistor 1 / 3 Terminal B Pin
1 = P1B/P3B pin is connected to the Resistor Network 1 / 3 Terminal B
0 = P1B/P3B pin is disconnected from the Resistor Network 1 / 3 Terminal B

bit 3 **R0HW or R2HW:** Resistor Network 0 / 2 Hardware Configuration Control bit
This bit forces Resistor Network 0 / 2 into the “shutdown” configuration of the Hardware pin
1 = Resistor Network 0 / 2 is NOT forced to the hardware pin “shutdown” configuration
0 = Resistor Network 0 / 2 is forced to the hardware pin “shutdown” configuration

bit 2 **R0A or R2A:** Resistor Network 0 / 2 Terminal A (P0A/P2A pin) Connect Control bit
This bit connects/disconnects the Resistor Network 0 / 2 Terminal A to the Resistor 0 / 2 Terminal A Pin
1 = P0A/P2A pin is connected to the Resistor Network 0 / 2 Terminal A
0 = P0A/P2A pin is disconnected from the Resistor Network 0 / 2 Terminal A

bit 1 **R0W or R2W:** Resistor Network 0 / 2 Wiper (P0W/P2W pin) Connect Control bit
This bit connects/disconnects the Resistor Network 0 / 2 Wiper to the Resistor 0 / 2 Terminal W Pin
This bit connects/disconnects the Resistor 0 Wiper to the Resistor 0 Network
1 = P0W/P2W pin is connected to the Resistor Network 0 / 2 Terminal W
0 = P0W/P2W pin is disconnected from the Resistor Network 0 / 2 Terminal W

bit 0 **R0B or R2B:** Resistor Network 0 / 2 Terminal B (P0B/P2B pin) Connect Control bit
This bit connects/disconnects the Resistor Network 0 / 2 Terminal B to the Resistor 0 / 2 Terminal B Pin
1 = P0B/P2B pin is connected to the Resistor Network 0 / 2 Terminal B
0 = P0B/P2B pin is disconnected from the Resistor Network 0 / 2 Terminal B

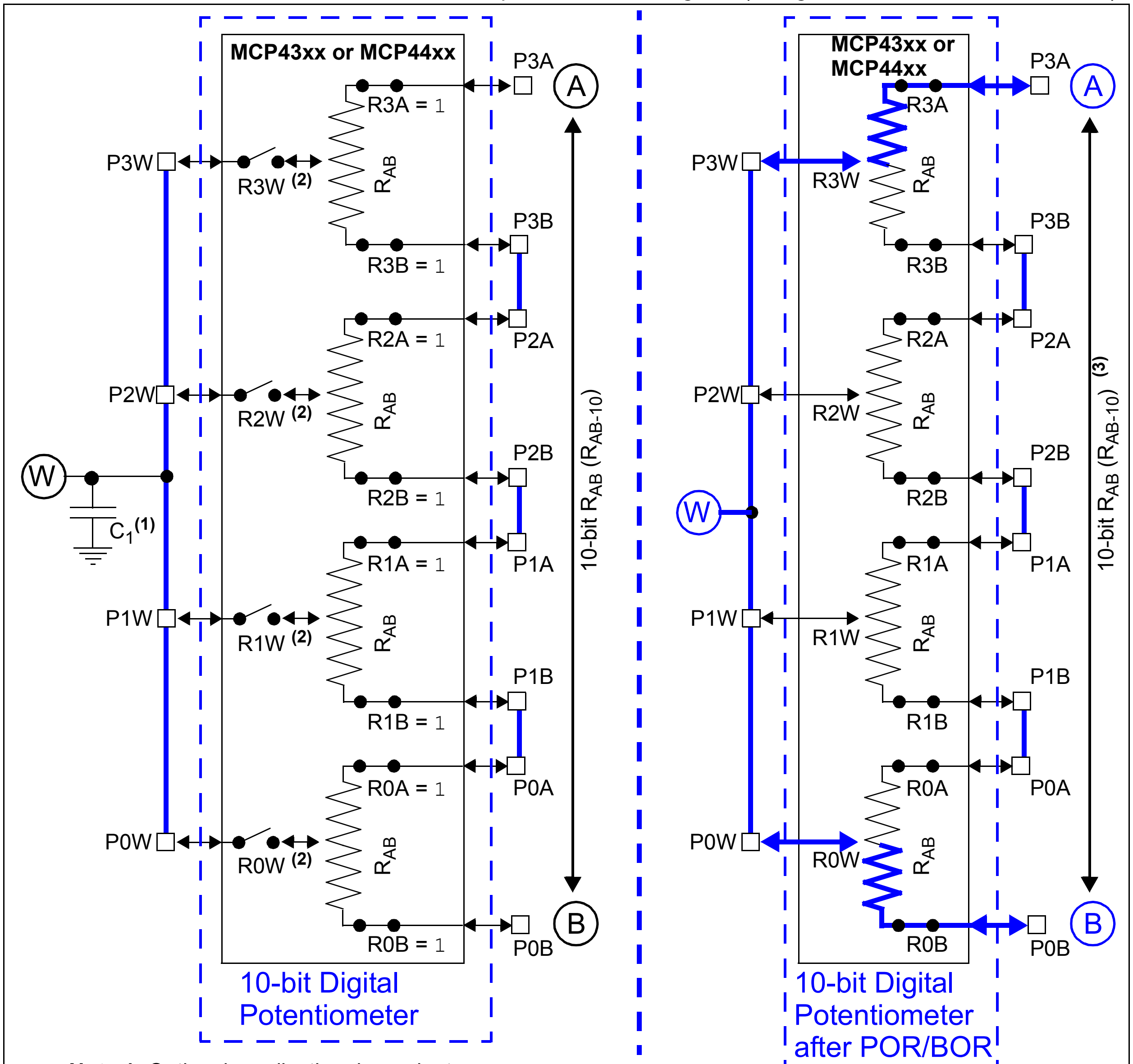
Note 1: These bits do not affect the wiper register values.

IMPLEMENTATION

Figure 4 shows the connections of the four 8-bit resistor networks of a quad digital potentiometer device (MCP4351/61 or MCP4451/61) to implement a single 10-bit digital potentiometer. To achieve this, only one of the four wiper terminals may be connected at a time (the other three are disconnected, which is floating). Also, the A terminal of resistor network 0 is connected to the B terminal of resistor network 1, the A terminal of resistor network 1 is connected to the B terminal of resistor network 2, and the A terminal of resistor network 2 is connected to the B terminal of resistor network 3. This means that the implemented 10-bit R_{AB} (R_{AB-10}) resistance is four times the 8-bit R_{AB} (R_{AB-08}) resistance. So, if the 8-bit resistor network resistances are 5kΩ, then the 10-bit R_{AB} resistance (R_{AB-10}) is 20 kΩ.

Note:	After POR, and before writing to the TCON registers, the R_{AB-10} resistance will be ~ the R_{AB-08} resistance since all wiper terminals are connected and the wiper will be at mid-scale (volatile devices or NV devices where NV Wiper 0 and NV Wiper 3 = mid-scale). So, after POR and until the device is configured, the R_{AB-10} resistance approximately equals the R_{AB-08} resistance.

FIGURE 4: *10-bit Resistor Network Implementation Diagram (using four 8-bit Resistor Networks).*



Note 1: Optional, application dependant.

2: Typically only one of these wiper switches will be closed at a time.

3: After POR/BOR event, the effective resistance is shown as blue path.

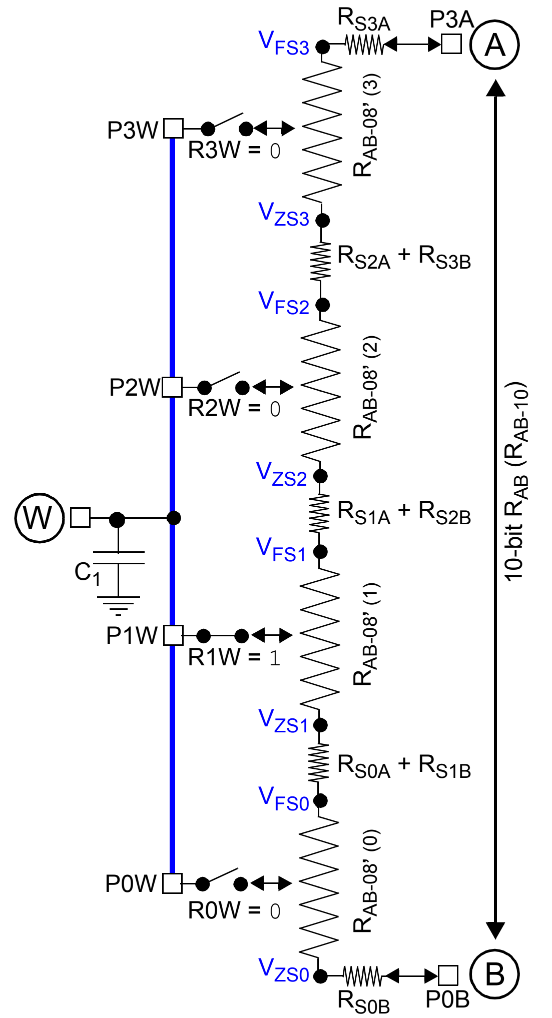
The Implementation shown in Figure 4 can be modeled as shown in Figure 5. The analog switches for each Terminal A and Terminal B connections will add resistance to the resistor ladder. The use of a larger R_{AB} resistance device, such as 100 kΩ, is one method to minimize the errors due to the analog switch resistance (see Table 2).

So, using typical switch resistance values (75Ω), the switch resistance between each 8-bit digital potentiometer (R_{S0A} + R_{S1B}, R_{S1A} + R_{S2B}, and R_{S2A} + R_{S3B}) is 150Ω. This will affect the V_W output voltage for the output code of $R_{AB(n)}$ at Full Scale and $R_{AB(n+1)}$ at Zero Scale.

The value of these switch resistances are determined by factors such as device V_{DD} voltage, applied terminal voltages (R_{S3A}, R_{S0B}, and the Wiper), and device temperature. Therefore, as the R_{AB-10} resistance increases, as a result of having multiple R_{AB-08} resistances in series, the Zero-Scale and Full-Scale errors decrease approximately proportionally. That is to say, doubling the R_{AB-10} resistance will reduce the Zero-Scale and Full-Scale errors by half.

Due to the terminal switches being analog switches (NMOS and PMOS transistors in parallel), the R_{ON} resistance of the analog switch will depend on several factors which include the device V_{DD} voltage, the voltages at P3A, P0B, and W. W is the 10-bit wiper, which is the P0W, P1W, P2W, and P3W pins shorted together. This variation of the analog switch resistance will effect the step voltages between the 8-bit resistor networks, which can be seen when setting the wiper connections to V_{FS1} and V_{ZS2}. These voltages will determine the voltages at P3B/P2A, P2B/P1A, and P1B/P0A, as well as currents through the resistor network elements, and the device temperature.

FIGURE 5: *10-bit Implementation Model (for Wiper Value between 100h and 1FFh)*

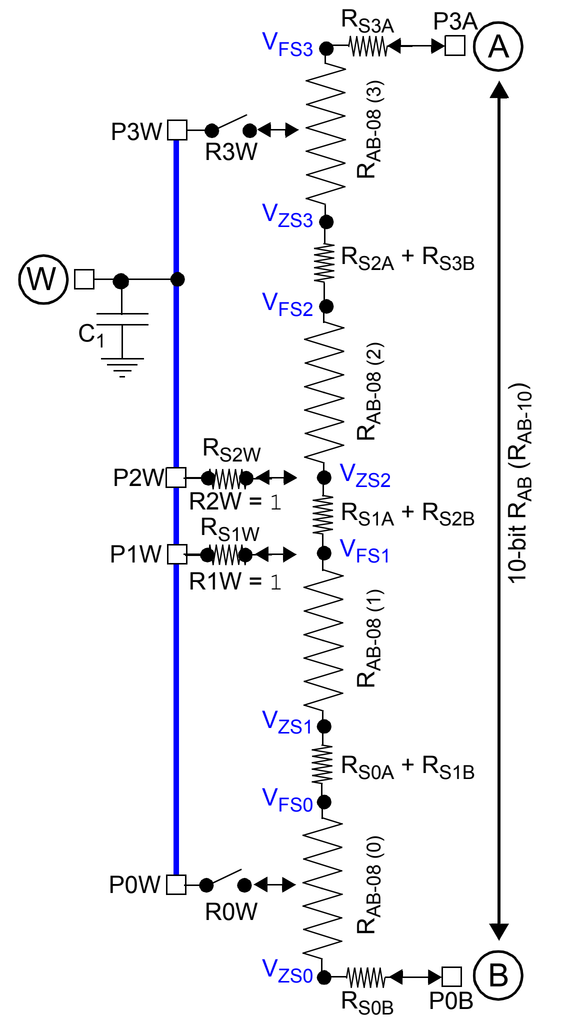


Note: R_{SxA} and R_{SxB} are the resistances associated with the analog switches connecting the A terminal to the A pin and the B terminal to the B pin.

TRANSITIONS BETWEEN 8-BIT RESISTOR NETWORKS IN 10-BIT RESISTOR LADDER

To reduce the transition error that occurs between $R_{AB-08\ (x)}$ and $R_{AB-08\ (x+1)}$ both wiper switches can be connected to the resistor network (see example in Figure 6). This will cause the Wiper voltage (V_W) to be at approximately the mid-point of $R_{AB-08\ (x)@FS}$ and $R_{AB-08\ (x+1)@ZS}$. Doing this will have a minimal effect on the R_{AB-10} resistance. This is due to the two wiper resistances (R_{S1W} and R_{S2W}) being in parallel with the Terminal A and Terminal B switch resistances (R_{S1A} and R_{S2B}). In Figure 6, the R_{AB-10} resistance is decreased where the (R_{S2B} + R_{S1A}) resistance is changed from (R_{S2B} + R_{S1A}) to ((R_{S2W} + R_{S1W}) || (R_{S2B} + R_{S1A})).

FIGURE 6: *10-bit Implementation Model for Value at Full-Scale/Zero-Scale Transition*



Note: R_{SxA} and R_{SxB} are the resistances associated with the analog switches connecting the A terminal to the A pin and the B terminal to the B pin.

FOUR SINGLE POTENTIOMETERS OR A SINGLE QUAD POTENTIOMETER?

It is recommended to use a single quad potentiometer since each of the potentiometers on that single die will have similar characteristics including the tempco.

Four resistor networks on the same die will have very similar R_{AB} resistances, as specified by the "Nominal Resistance Match" electrical specification. The typical variation for the MCP4461 is 0.2%. When the four R_{AB} resistors are on different die, the variation is +/- 20% from the typical value. So, with a 5 kΩ typical device the resistance could range from 4 kΩ to 6 kΩ. Table 2 calculates 10-bit R_{AB} (RAB-10) for a quad digital potentiometer with the typical R_{AB-08} value, while Table 3 shows an example of the potential variation using four single digital potentiometers.

Table 1 shows that for the four devices whose resistor networks are shown in Table 3, the step voltage (V_S) will vary based on which of the four 8-bit resistor networks is currently controlling the wiper voltage (V_W). The variation can range from a step voltage of approximately 3.9 mV to approximately 5.9 mV for the different devices used to form the R_{AB-10} resistor network.

TABLE 1: EXAMPLE VARIATION OF VS WHEN USING FOUR SINGLE POTENTIOMETERS (1)

	R_{AB3} (2)	R_{AB2} (2)	R_{AB1} (2)	R_{AB0} (2)
	5,000	4,000	6,000	4,200
V_{FSx} (3) (V)	4.9805	3.6784	2.6367	1.0742
V_{ZSx} (4) (V)	3.7174	2.6758	1.1133	0.0195
V_S (5) (mV)	4.934	3.916	5.951	4.120

Note 1: Potentiometer R_{AB3} is at the top of the ladder, Terminal A is connected to 5V, and Potentiometer R_{AB0} is at the bottom of the ladder, Terminal B is connected to V_{SS}.

2: Includes the Terminal A and Terminal B Switch Resistance. For this example, R_{SxA} and R_{SxB} are 75Ω.

3: The Full-Scale voltage is determined by the R_{ABx} resistance and the Terminal A Switch Resistance (75Ω for this example).

4: The Zero-Scale voltage is determined by the R_{ABx} resistance and the Terminal B Switch Resistance (75Ω for this example).

5: The Step voltage (V_S):

$$V_S = (V_{FS} - V_{ZS}) / (\#\ of\ R_S)$$

TABLE 2: CALCULATING 10-BIT R_{AB} (WITH QUAD 8-BIT DEVICE)

8-bit (Typ.)					10-bit		8-bit Transition Error (Typ.) (1)		Comments
					R_{AB-10} (Typ.) (1)				
R_{AB-08}	R_{SxA} (1,2)	R_{SxB} (1,2)	R_{AB}' (R_{AB} - R_{SxA} - R_{SxB})	R_S (3)	4*R_{AB-08}	R_{S0A} + R_{S1B}, R_{S1A} + R_{S2B}, R_{S2A} + R_{S3B}	Relative to R_S	in LSb (R_S = 1 LSb)	
5,000	75	75	4,850	18.95	20,000	150	150 / 18.95	7.92	
10,000	75	75	9,850	38.48	40,000	150	150 / 38.48	3.90	
50,000	75	75	49,850	194.73	200,000	150	150 / 194.73	0.77	
100,000	75	75	99,850	390.04	400,000	150	150 / 390.04	0.38	Allows best performance

Note 1: Switch Resistance is dependant on many issues including device V_{DD} voltage, voltages on the analog switches source and drain, temperature, current through switch.

2: The effects of the analog switch resistance (R_{SxA}, R_{SxB}) decreases as the 8-bit R_{AB} values increases.

3: The Step Resistance (R_S) equals the $R_{AB'}$ divided by the number of Step Resistors (R_S = $R_{AB'}$ /(# of R_S)).

TABLE 3: EXAMPLE DEVICE TO DEVICE VARIATION IF USING 4 SINGLE 8-BIT DEVICES

8-bit												10-bit	
Device 0 (typical case)			Device 1 (min. case)			Device 2 (max. case)			Device 3			R_{AB-10} (Typ.) (1, 2)	
R_{AB0}	R_{AB0}' (3)	R_{S0} (4)	R_{AB1}	R_{AB1}' (3)	R_{S1} (4)	R_{AB2}	R_{AB2}' (3)	R_{S2} (4)	R_{AB3}	R_{AB3}' (3)	R_{S3} (4)	R_{AB0} + R_{AB1} + R_{AB2} + R_{AB3}	R_{S0A} + R_{S1B}, R_{S1A} + R_{S2B}, R_{S2A} + R_{S3B}
5,000	4,850	18.95	4,000	3,850	15.04	6,000	5,850	22.86	4,200	4,050	15.83	19,200	150
10,000	9,850	38.48	8,000	7,850	30.67	12,000	11,850	46.29	8,400	8,250	32.23	38,400	150
50,000	49,850	194.73	40,000	39,850	155.67	60,000	59,850	233.79	42,000	41,850	163.48	192,000	150
100,000	99,850	390.04	80,000	79,850	311.92	120,000	119,850	468.17	84,000	83,850	327.54	384,000	150

Note 1: Switch Resistance is dependant on many issues including device V_{DD} voltage, voltages on the analog switches source and drain, temperature, current through switch.

2: The effects of the analog switch resistance (R_{SxA}, R_{SxB}) decreases as the 8-bit R_{AB} values increases.

3: The R_{SxA} and R_{SxB} resistance is a typical 75Ω.

4: The Step Resistance (R_S) equals the $R_{AB'}$ divided by the number of Step Resistors (R_S = $R_{AB'}$ /(# of R_S)).

EXAMPLE STEPS FOR CONTROLLING THE FOUR 8-BIT RESISTOR NETWORKS FOR 10-BIT OPERATION

Example 1 shows a possible sequence of events and operations to control the operation of the 10-bit digital potentiometer.

After Power-on Reset (POR) all wiper terminals are connected to the external pins. With P0W and P3W shorted together the effective R_{AB-10} resistance will be approximately the R_{AB-08} resistance. This is due to the Resistor Network 0 wiper is at mid-scale and the Resistor Network 3 wiper is at mid-scale. With both wipers connected to their respective resistor network and externally shorted together, the effective resistance becomes approximately R_{AB-08}.

With two wiper control bits in each TCON register, the initialization sequence may require up to three serial commands to update the R_{AB-10} wiper position (V_W).

Table 4 shows how to use the upper two bits (D9:D8) of the 10-bit wiper code to select the correct Resistor Network to have the wiper connected to.

TABLE 4: DECODING 10-BIT CODES TO FOUR 8-BIT CODES

D9:D8	D7:D0	Resistor Network	Wiper TCON Bit States			
			R3W	R2W	R1W	R0W
00	xxxx xxxx	0	0	0	0	**1**
01	xxxx xxxx	1	0	0	**1**	0
10	xxxx xxxx	2	0	**1**	0	0
11	xxxx xxxx	3	**1**	0	0	0

EXAMPLE 1: EXAMPLE 10-BIT STATES AND SEQUENCES

Step	Event/Operation	Action	10-Bit Wiper	R_{AB-10}	V_W (1)	Comment
1	Power-Up (POR)	—	Mid-Scale	5 kΩ	$(V_A-V_B) / 2$	This is due to P0W and P3W being shorted together, V_W = Mid-Scale
2	—	Write TCON1 = DDh	—	15 kΩ	$(V_A-V_B) / 3$	P3W and P2W are disconnected
3	—	Write TCON0 = DDh	Floating	20 kΩ	$(V_A-V_B) / 3$	P1W and P0W are disconnected
4	—	Write Wiper 2 = 0	—	20 kΩ	$(V_A-V_B) / 3$	10-bit POR value will be Mid-Scale
5	—	TCON1 = DFh	200h	20 kΩ	$(V_A-V_B) / 2$	Wiper is at Mid-Scale
6	Change 10-bit Wiper to 37Fh	Write Wiper 3 = 7Fh	200h	20 kΩ	$(V_A-V_B) / 2$	
7	—	Write TCON1 = FDh	37Fh	20 kΩ	37Fh / 3FFh (2)	Resistor Network 3 Wiper = 7Fh.
8	Change 10-bit Wiper to 05Ah	Write Wiper 0 = 5Ah	37Fh	20 kΩ	37Fh / 3FFh (2)	
9	—	Write TCON1 = DDh	Floating	20 kΩ	37Fh / 3FFh (2)	External Capacitor holds V_W at ~ 37Fh voltage
10	—	Write TCON0 = DFh	05Ah	20 kΩ	05Ah / 3FFh (2)	
11	Change 10-bit Wiper to 0A5h	Write Wiper 0 = A5h	0A5h	20 kΩ	0A5h / 3FFh (2)	
12	Change 10-bit Wiper to 1A5h	Write Wiper 1 = 5Ah	0A5h	20 kΩ	0A5h / 3FFh (2)	
13	—	Write TCON0 = FDh	1A5h	20 kΩ	1A5h / 3FFh (2)	
14	Brown-Out (BOR)	—	—	Unknown	1A5h / 3FFh (2,3)	
15	Power-Up (POR)	—	Mid-Scale	5 kΩ	$(V_A - V_B) / 2$	Go back to Step 2

Note 1: For this example, voltage on terminal A (V_A) higher than voltage on terminal B (V_B).

2: This is the ratio for the voltage between the V_A and V_B voltages.

3: Volatile register values may become corrupted. This means that the Wiper register value may change and or the Terminal Control bits may change.

PSEUDO CODE FOR AN 8-BIT MICROCONTROLLER

Example 2 shows example pseudo code to update the 10-bit digital potentiometer which is implemented as four 8-bit potentiometers in series.

The 10-bit wiper code value requires two 8-bit registers. We will name the registers:

- WIPER_H
- WIPER_L

The WIPER_L register contains the lower 8-bits of the 10-bit wiper code, while the The WIPER_H register contains the upper 2-bits of the 10-bit wiper code. A variable OLD_TCON_PTR will indicate if last write used TCON0 or TCON1.

This pseudo code is written as a routine that is called when the 10-bit wiper value is to be updated. So once the operation is complete, this routine "returns" to the calling function.

EXAMPLE 2: EXAMPLE PSEUDO CODE TO UPDATE THE R_{AB-10} POTENTIOMETER

Label	Operation	Comment
UPDATE_DP	`WIPER_H AND 03h`	; Ensure that only bits `1` and `0` can be non-zero
	`IF WIPER_H == 0h, Goto RAB0`	; Check if Wiper code is in 1st 25% range
	`IF WIPER_H == 1h, Goto RAB1`	; Check if Wiper code is in 2nd 25% range
	`IF WIPER_H == 2h, Goto RAB2`	; Check if Wiper code is in 3rd 25% range
	`IF WIPER_H == 3h, Goto RAB3`	; Check if Wiper code is in 4th 25% range
RAB0	`IF OLD_TCON_PTR == 0, Write TCON0 = DDh`	; Both Wiper0 and Wiper1 are disconnected
	`IF OLD_TCON_PTR == 1, Write TCON1 = DDh`	; Both Wiper2 and Wiper3 are disconnected
	`Wiper0 = WIPER_L`	; Wiper0 Register is loaded with 8-bit value
	`TCON0 = DFh`	; Wiper0 is now connected
	`OLD_TCON_PTR = 0`	; Pointer indicates TCON0
	`RETURN`	; Return to calling routine
RAB1	`IF OLD_TCON_PTR == 0, Write TCON0 = DDh`	; Both Wiper0 and Wiper1 are disconnected
	`IF OLD_TCON_PTR == 1, Write TCON1 = DDh`	; Both Wiper2 and Wiper3 are disconnected
	`Wiper1 = WIPER_L`	; Wiper1 Register is loaded with 8-bit value
	`TCON0 = FDh`	; Wiper1 is now connected
	`OLD_TCON_PTR = 0`	; Pointer indicates TCON0
	`RETURN`	; Return to calling routine
RAB2	`IF OLD_TCON_PTR == 0, Write TCON0 = DDh`	; Both Wiper0 and Wiper1 are disconnected
	`IF OLD_TCON_PTR == 1, Write TCON1 = DDh`	; Both Wiper2 and Wiper3 are disconnected
	`Wiper2 = WIPER_L`	; Wiper2 Register is loaded with 8-bit value
	`TCON1 = DFh`	; Wiper2 is now connected
	`OLD_TCON_PTR = 1`	; Pointer indicates TCON1
	`RETURN`	; Return to calling routine
RAB3	`IF OLD_TCON_PTR == 0, Write TCON0 = DDh`	; Both Wiper0 and Wiper1 are disconnected
	`IF OLD_TCON_PTR == 1, Write TCON1 = DDh`	; Both Wiper2 and Wiper3 are disconnected
	`Wiper0 = WIPER_L`	; Wiper3 Register is loaded with 8-bit value
	`TCON1 = FDh`	; Wiper3 is now connected
	`OLD_TCON_PTR = 1`	; Pointer indicates TCON1
	`RETURN`	; Return to calling routine

CONSIDERATIONS

Potential applications considerations that need to be evaluated. These considerations may not be an issue based on the requirements of the end application.

These considerations include, but may not be limited to:

POR/BOR

When the device has a POR or BOR event, all terminals are connected. With all the wipers connected, the effective R_{AB-10} resistance is 25% of the resistance when only one wiper terminal is connected. This resistance is equivalent to the R_{AB-08} resistance. This POR/BOR resistance will remain until the TCON registers are configured. Due to the two TCON registers, the R_{AB-10} resistance will have intermediate values depending on the sequence of disconnecting the wiper terminals. This lower R_{AB-10} resistance may be a system issue due to the higher current possible changes to the V_A and V_B voltages until the digital potentiometer has been initialized.

8-Bit Code Transitions

Due to the Terminal A and Terminal B switch resistances as each R_{AB-08} is placed in series, the transition of the 10-bit codes at each 8-bit boundary (0FFh to 100h or 1FFh to 200h or 2FFh to 300h) will have a larger step voltage than code steps between x00h and xFFh. For the lower R_{AB-08} resistances, this transition can be in the multiple LSbs compared to a standard step. This characteristic is greatly diminished when the R_{AB-08} resistance is 100 kΩ (see Table 2).

Output Update

While the output is in each R_{AB-08} range, the output update rate is the same as for the R_{AB}, when the output code crosses the 8-bit boundary, then the update time needs to include changing the Wiper Terminal connections. This may require one or two additional serial commands.

Software Complexity

Due to the requirement to communicate with the multiple R_{AB-08} resistor networks and the TCON registers, the microcontroller's communication firmware is more complex than a dedicated 10-bit device. This is due to the requirement of determining which of the R_{AB-08} devices need to be written, as well as the update of the Wiper connect/disconnect bits of the TCON registers. This requires testing of the upper two bits of the 10-bit digital potentiometer code and comparing to the current setting to determine the changes required to transition from the old to the new code.

Board Area

The quad potentiometer can be used in either a 20-lead TSSOP or 20-lead QFN (4x4) package. The QFN is the smaller of the two options with a package size of about 16 mils^2. A single potentiometer may be available in an 8-lead DFN (3x3) package, which gives a package size of about 9 mils^2. This is about 56% of the board area.

SUMMARY

This technical brief has shown how the use on Microchip's Terminal Control feature allows the implementation of a higher resolution digital potentiometer. Although there are characteristics of this implementation that need to be understood during system operation, for many applications this is an acceptable solution to implement a higher resolution digital potentiometer device.

When possible, the use of higher resistance 8-bit digital potentiometers (100 kΩ) is preferred, as it will decrease errors due to the relationship between the switch resistances (R_{SxA}, R_{SxW}, and R_{SxB}) and the step resistance (R_S).

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