Digital Potentiometers
Design Guide

Digital Potentiometer Solutions

Microchip's Family of Digital Potentiometers

- End-to-end resistance (Rab) values
    - 2.1 kΩ to 100 kΩ (typical)
- Resolution
    - 6-bit (64 steps)
    - 7-bit (128/129 steps)
    - 8-bit (256/257 steps)
    - 10-bit (1024 steps)
- Serial interfaces
    - Up/down
    - SPI
    - I^{2}C
- Memory types
    - Volatile
    - Non-volatile (EEPROM)
- Resistor network configurations
    - Potentiometer (voltage divider)
    - Rheostat (variable resistor)
- Single, dual and quad potentiometer options
- Different package options
- Special features
    - Shutdown mode
    - WiperLock™ technology
- Low-power options
- Low-voltage options (1.8V)
- High-voltage options (36V or ±18V)

Microchip's digital potentiometer portfolio offers a range of devices with end-to-end resistances between 2.1 and 100 kΩ, available in 6, 7, 8, or 10-bit resolutions. These devices are designed for easy integration using a mix of interface options. For straightforward applications, a simple up/down interface may suffice. Higher resolution devices often require direct read/write access to the wiper register, which is supported by SPI or I2C interfaces. While SPI is simpler to implement when only one Digipot is needed, I2C requires only two signals (pins) and better supports multiple devices on the same serial bus without additional pins.

Microchip provides both volatile and non-volatile (EEPROM) digital potentiometers, giving you the flexibility to optimize your system design. The integrated EEPROM option allows you to save potentiometer settings at power-down and restore them upon power-up.

A common Digipot use case is as a variable resistor (rheostat). In such cases, users only need access to one side of the resistor chain. Microchip offers dedicated rheostat products within the Digipot portfolio to support client needs in the most efficient manner.

Alternatively, there are products such as the MCP42U83 which support a mix of configurations and interface options. This flexibility allows our clients to streamline inventory management while still meeting diverse application requirements.

Packaging options have been chosen to meet your system requirements, balancing device cost, board area, and manufacturing considerations (surface mount vs. through-hole).

Low-Power Applications

Low power consumption is increasingly important, especially in battery-powered applications. Microchip's digital potentiometers are designed with low power in mind, featuring maximum Idd as low as 1 µA. The lowest current consumption is achieved when both the serial interface and non-volatile memory write cycle are inactive. Note that this current excludes any current through the resistor network (the A, B, and W pins). Review the Max Idd column in the Comprehensive portfolio table to identify the right product for your appllcation.

Many devices also offer the capability to either shut down the resistor network or disconnect it from the circuit. This significantly reduces the current through the resistor network(s). This shutdown mode can be activated either through a hardware pin (SHDN) or via software using the Terminal Control (TCON) register(s).

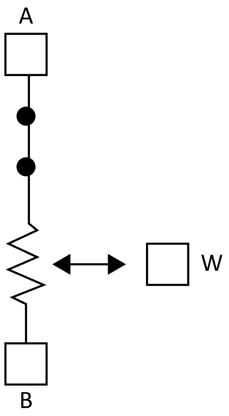
When hardware shutdown is engaged, the resistor network is forced into a defined condition where it is disconnected from the Terminal A pin, and the wiper value is set to 00h (wiper connected to Terminal B). The wiper register retains its value, thus when the shutdown mode is exited, the wiper returns to its previous position. This feature is particularly useful in low-power applications where the potentiometer settings do not change during power down cycles.

Normal vs. Shutdown Mode

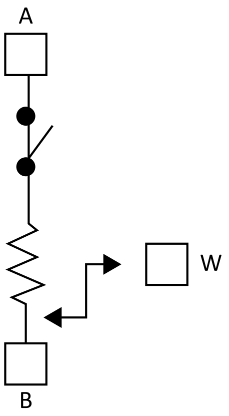
The software shutdown mode provides granular control over each of the resistor network terminal pins. Each resistor network is managed by a 4-bit TCON register, with one bit assigned to each terminal pin (A, B, and W) while the fourth bit replicates the hardware shutdown state. In this state, the resistor network is disconnected from the Terminal A pin, and the wiper value is set to 00h.

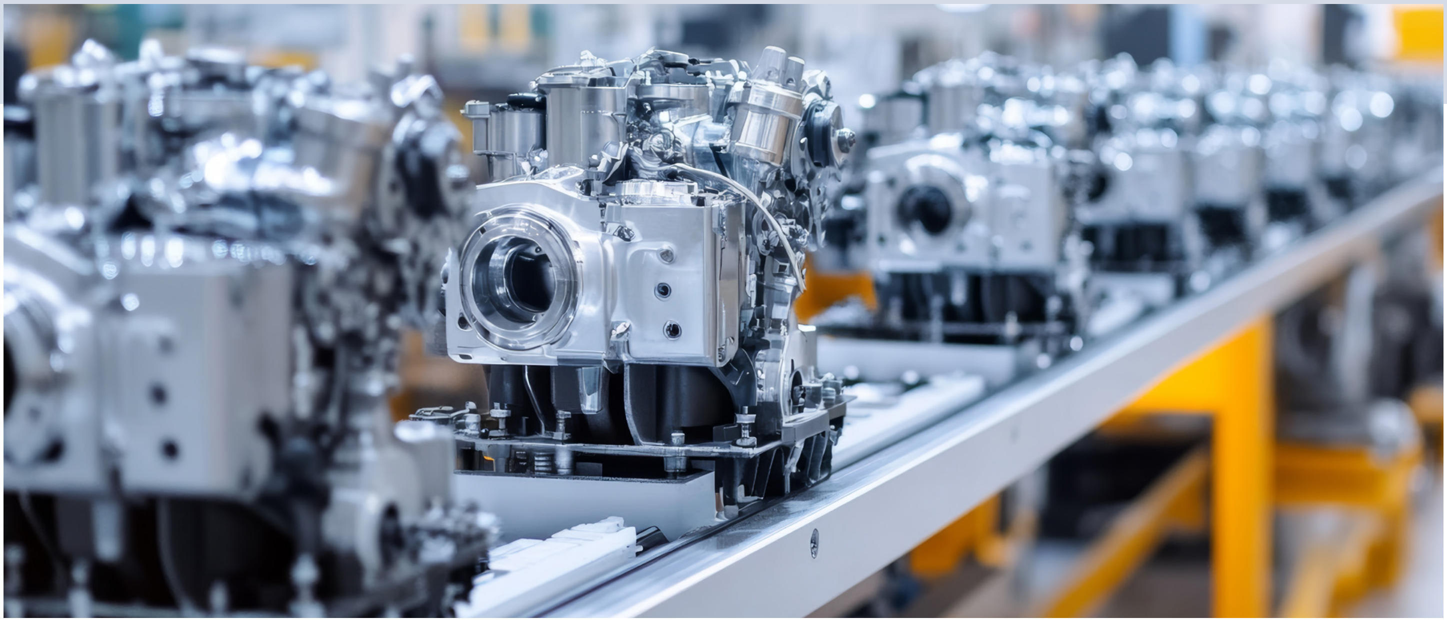
The software shutdown mode offers greater flexibility than the hardware shutdown pin. It allows devices to retain shutdown capabilities even when packaged in the smallest form factors where a hardware shutdown pin (SHDN) is not implemented. This flexibility ensures that you can achieve power savings and maintain control over the resistor network configuration, regardless of the package size.

Normal Mode



ShutdownMode





Low-Voltage Applications

Some applications require a low operating voltage. To meet these needs, Microchip offers a range of devices featuring digital circuitry supporting operation at 1.8V. Analog performance between 1.8V and 2.7V is not explicitly specified, but it has been characterized and reflected in datasheet graphs. These graphs provide the information needed to make informed design decisions for low-voltage applications.

The devices supporting Low Voltage applications can be found by looking for the entry 2/5 in the Comprehensive Portfolio table.

High-Voltage Applications

In some applications (industrial, audio, e.g.) operation at >5.5V is necessary. Microchip's offers a family of digital potentiometers which address this need, supporting up to 36V operation. These devices feature dual power rails, with the analog voltage range determined by the voltage applied to the V and V− pins. Meanwhile, the digital power rail (VL and DGND) supports operation from 1.8V to 5.5V, ensuring proper communication with microcontrollers.

Dual rail can be configured as either symmetric (±18V, e.g.) or asymmetric (6V/−30V, e.g.), relative to the digital logic ground (DGND). The devices supporting High Voltage applications can be found by looking for the entry <36V in the Comprehensive Portfolio table

Non-Volatile Applications

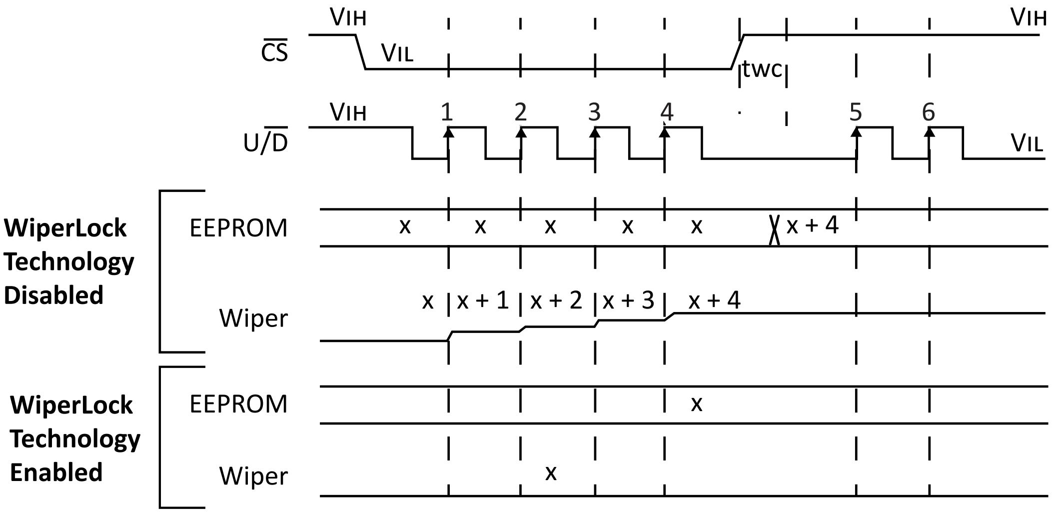
Non-volatile digital potentiometers offer the advantage of saving the desired wiper position during device power-down or brownout conditions. When power is restored, the wiper value automatically loads from the non-volatile register, so the device powers on with the desired wiper settings intact.

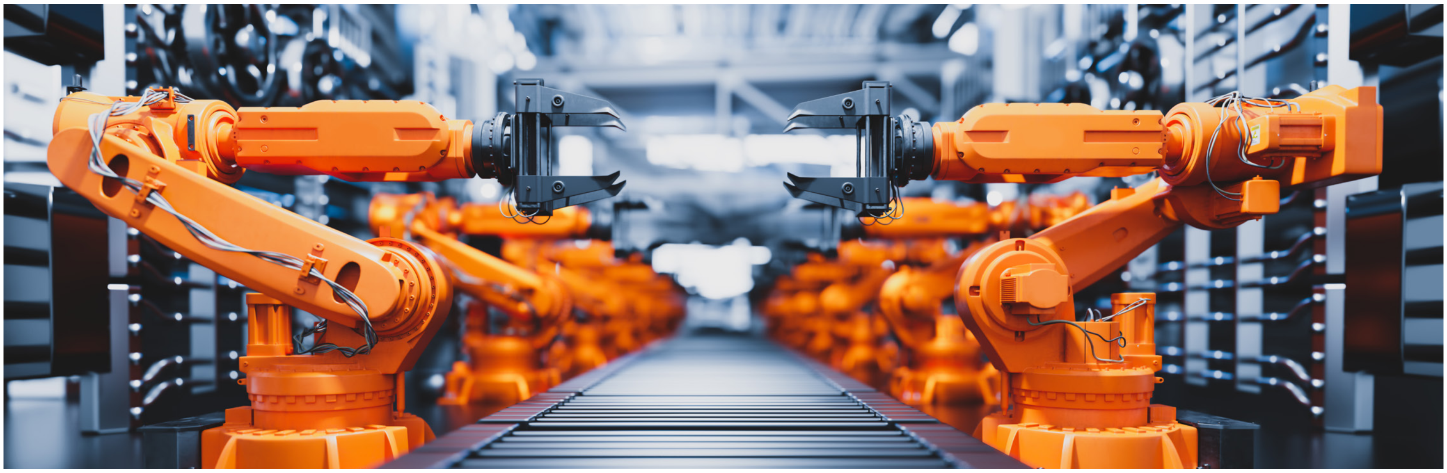
This feature is particularly useful in applications where the wiper value is programmed once and remains unchanged (such as system calibration) as well as in applications where the last user setting needs to be saved upon system power-down (such as a volume setting).

Traditionally, mechanical trim pots have been used for device calibration to optimize system performance. Digital potentiometers with non-volatile memory are smaller in size with higher reliability. Microchip's non-volatile digital potentiometers utilize a methodology called WiperLock technology, which ensures that once the non-volatile wiper is "locked," the wiper setting can only be modified with "high-voltage" commands. This precludes unintentional changes to the wiper setting during normal operation.

Many of the non-volatile devices include bytes of general-purpose EEPROM memory. This memory can store system information such as calibration codes, manufacture dates, serial numbers, or user information.

WiperLock™ Technology Example (up/Down Interface)

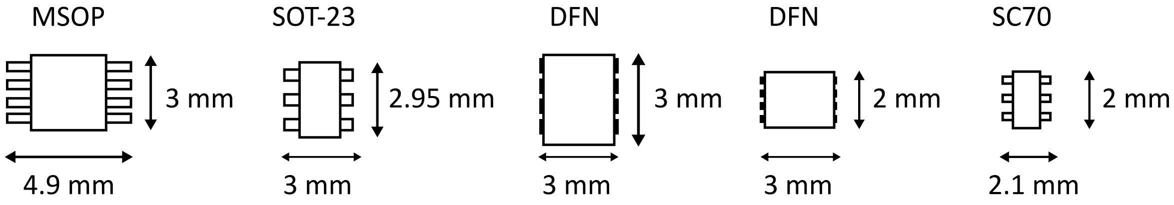




Small-Footprint Applications

For applications with package-size constraints or where board-space is limited, Microchip provides a variety of compact packages, enabling designers to optimize board space without compromising functionality.

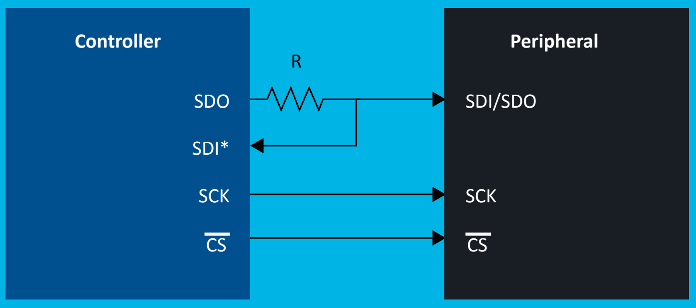
Package	Area (mm2)	Comment
MSOP	~14.7	
DFN (3 × 3)	~9	39% Smaller than MSOP
SOT-23	~8.3	44% Smaller than MSOP
DFN (2 × 3)	~6	59% Smaller than MSOP 33% Smaller than DFN 3 × 3
SC70	~4.2	71% Smaller than MSOP 55% Smaller than DFN 3 × 3 30% Smaller than DFN 2 × 3



SPI Interface

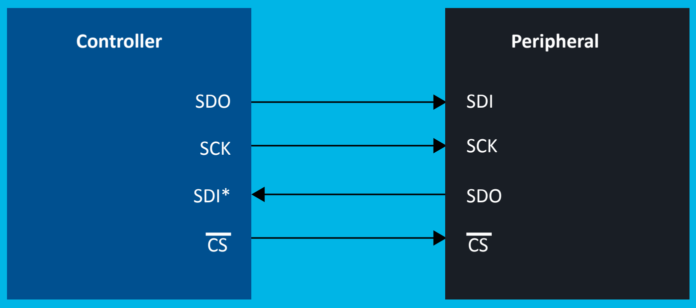
SPI requires three or four I/O pins. Use cases are depicted below. Many microcontrollers support SPI as a hardware module, simplifying code development.

Controller to Single Peripheral With Multiplexed SDI and SDO Pins



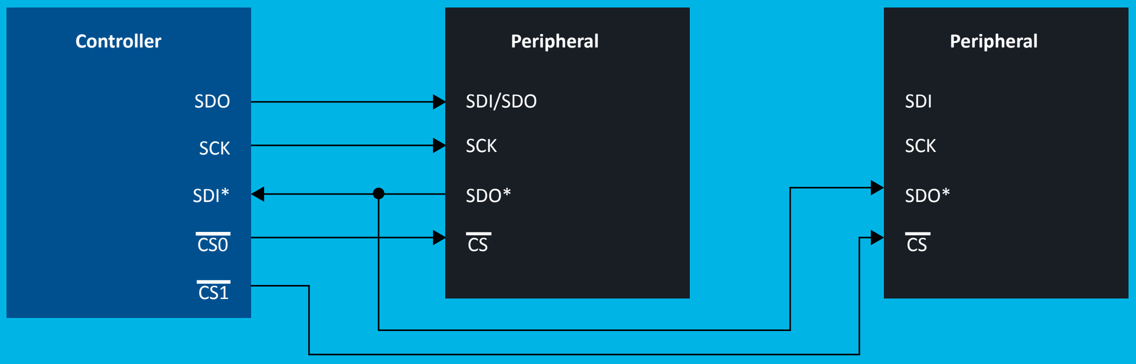
***This connection is optional and only required for read operations.**

Controller to Single Peripheral



***This connection is optional and only required for read operations.**

Controller to Multiple Peripheral (Multiple Chip Selects)

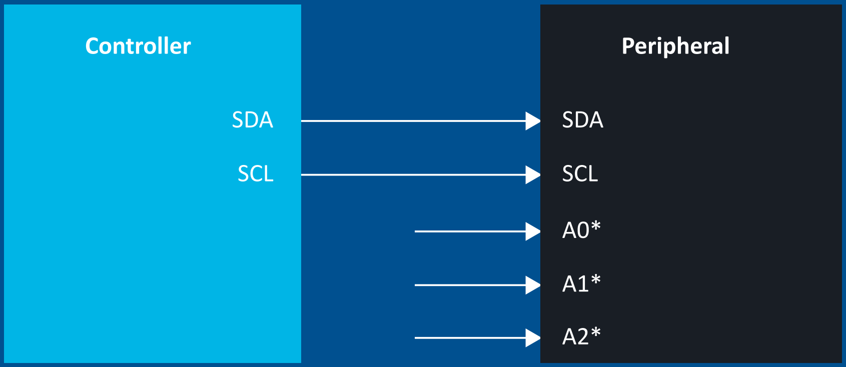


***This connection is optional and only required for read operations.**
Additional circuitry may be required for ORing of the peripheral SDO signals based on the device selected.

I^{2}C Interface

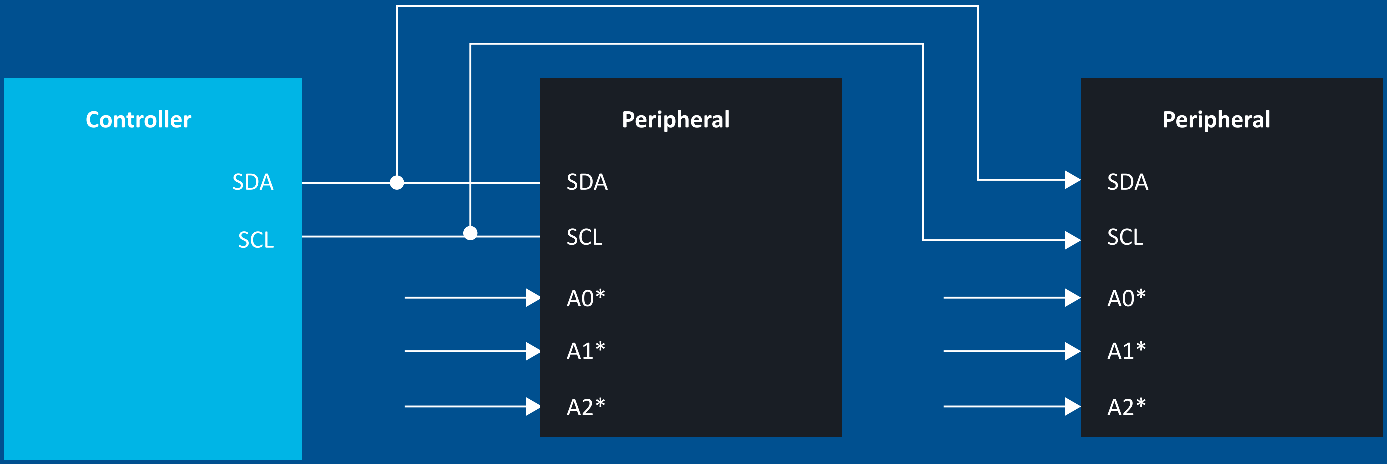
The I^{2}C interface is a two-wire protocol that supports read and write operations via two pins. Multiple devices can share the I^{2}C bus, if each has a unique address. While I^{2}C needs just two pins, it requires more firmware overhead than SPI. Many microcontrollers include a dedicated I^{2}C hardware module, simplifying code development.

Controller to Single Peripheral



***This connection is optional and only required for read operations.**

Controller to Multiple Peripheral (Multiple Chip Selects)



Comprehensive Digipot Portfolio

	Interface			Memory			RAB (in kΩ) [1]						Configuration		Packages (pin count) [5]									Max Idd	V Range
Device #	U/D	SPI	I^2C	type	bits	Ch	2.1	5	10	20	50	100	Pot	Rheo	SOT23	SC70	SOIC	MSOP	DFN	PDIP	TSSOP	QFN	VQFN	(µA) [2]	(V) [4]
MCP4011	Y	N	N	V	6	1	Y	Y	Y	N	Y	N	Y	N	N/A	N/A	8	8	8	N/A	N/A	N/A	N/A	1	2/5
MCP4012	Y	N	N	V	6	1	Y	Y	Y	N	Y	N	N	Y	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	2/5
MCP4013	Y	N	N	V	6	1	Y	Y	Y	N	Y	N	Y (4)	N	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	2/5
MCP4014	Y	N	N	V	6	1	Y	Y	Y	N	Y	N	N	Y (4)	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	2/5
MCP4017	N	N	Y	V	7	1	N	Y	Y	N	Y	Y	N	Y	N/A	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	2/5
MCP4018	N	N	Y	V	7	1	N	Y	Y	N	Y	Y	Y	N	N/A	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	2/5
MCP4019	N	N	Y	V	7	1	N	Y	Y	N	Y	Y	N	Y	N/A	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	2/5
MCP4021	Y	N	N	EE	6	1	Y	Y	Y	N	Y	N	Y	N	N/A	N/A	8	8	8	N/A	N/A	N/A	N/A	1	3/5
MCP4022	Y	N	N	EE	6	1	Y	Y	Y	N	Y	N	N	Y	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	3/5
MCP4023	Y	N	N	EE	6	1	Y	Y	Y	N	Y	N	Y (4)	N	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	3/5
MCP4024	Y	N	N	EE	6	1	Y	Y	Y	N	Y	N	N	Y (4)	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	3/5
MCP40D17	N	N	Y	V	7	1	N	Y	Y	N	Y	Y	N	Y	N/A	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	2/5
MCP40D18	N	N	Y	V	7	1	N	Y	Y	N	Y	Y	Y	N	N/A	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	2/5
MCP40D19	N	N	Y	V	7	1	N	Y	Y	N	Y	Y	N	Y	N/A	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	2/5
MCP41010	N	Y	N	V	8	1	N	N	Y	N	N	N	Y	N	N/A	N/A	8	N/A	N/A	8	N/A	N/A	N/A	1	3/5
MCP41050	N	Y	N	V	8	1	N	N	N	N	Y	N	Y	N	N/A	N/A	8	N/A	N/A	8	N/A	N/A	N/A	1	3/5
MCP41100	N	Y	N	V	8	1	N	N	N	N	N	Y	Y	N	N/A	N/A	8	N/A	N/A	8	N/A	N/A	N/A	1	3/5
MCP4131	N	Y	N	V	7	1	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	2/5
MCP4132	N	Y	N	V	7	1	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	2/5
MCP4141	N	Y	N	EE	7	1	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	3/5
MCP4142	N	Y	N	EE	7	1	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	3/5
MCP4151	N	Y	N	V	8	1	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	2/5
MCP4152	N	Y	N	V	8	1	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	2/5
MCP4161	N	Y	N	EE	8	1	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	3/5
MCP4162	N	Y	N	EE	8	1	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	3/5
MCP41HV31	N	Y	N	V	7	1	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	≤36
MCP41HV51	N	Y	N	V	8	1	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	≤36
MCP42010	N	Y	N	V	8	2	N	N	Y	N	N	N	Y	N	N/A	N/A	8	N/A	N/A	8	N/A	N/A	N/A	1	3/5
MCP42050	N	Y	N	V	8	2	N	N	N	N	Y	N	Y	N	N/A	N/A	8	N/A	N/A	8	N/A	N/A	N/A	1	3/5
MCP42100	N	Y	N	V	8	2	N	N	N	N	N	Y	Y	N	N/A	N/A	8	N/A	N/A	8	N/A	N/A	N/A	1	3/5
MCP4231	N	Y	N	V	7	2	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	2/5
MCP4232	N	Y	N	V	7	2	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	2/5
MCP4241	N	Y	N	EE	7	2	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	3/5
MCP4242	N	Y	N	EE	7	2	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	3/5
MCP4251	N	Y	N	V	8	2	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	2/5
MCP4252	N	Y	N	V	8	2	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	2/5
MCP4261	N	Y	N	EE	8	2	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	3/5
MCP4262	N	Y	N	EE	8	2	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	3/5

Comprehensive Digipot Portfolio

	Interface			Memory			RAB (in kΩ) [1]						Configuration		Packages (pin count) [5]									Max Idd	V Range
Device #	U/D	SPI	I^{2}C	type	bits	Ch	2.1	5	10	20	50	100	Pot	Rheo	SOT23	SC70	SOIC	MSOP	DFN	PDIP	TSSOP	QFN	VQFN	(µA) [2]	(V) [4]
MCP4331	N	Y	N	V	7	4	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	N/A	N/A	20	20	N/A	5	2/5
MCP4332	N	Y	N	V	7	4	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	N/A	N/A	14	N/A	N/A	5	2/5
MCP4341	N	Y	N	EE	7	4	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	N/A	N/A	20	20	N/A	5	3/5
MCP4342	N	Y	N	EE	7	4	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	N/A	N/A	14	N/A	N/A	5	3/5
MCP4351	N	Y	N	V	8	4	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	N/A	N/A	20	20	N/A	5	2/5
MCP4352	N	Y	N	V	8	4	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	N/A	N/A	14	N/A	N/A	5	2/5
MCP4361	N	Y	N	EE	8	4	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	N/A	N/A	20	20	N/A	5	3/5
MCP4362	N	Y	N	EE	8	4	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	N/A	N/A	14	N/A	N/A	5	3/5
MCP4431	N	N	Y	V	7	4	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	N/A	N/A	20	20	N/A	5	2/5
MCP4432	N	N	Y	V	7	4	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	N/A	N/A	14	N/A	N/A	5	2/5
MCP4441	N	N	Y	EE	7	4	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	N/A	N/A	20	20	N/A	5	3/5
MCP4442	N	N	Y	EE	7	4	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	N/A	N/A	14	N/A	N/A	5	3/5
MCP4451	N	N	Y	V	8	4	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	N/A	N/A	20	20	N/A	5	2/5
MCP4452	N	N	Y	V	8	4	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	N/A	N/A	14	N/A	N/A	5	2/5
MCP4461	N	N	Y	EE	8	4	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	N/A	N/A	20	20	N/A	5	3/5
MCP4462	N	N	Y	EE	8	4	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	N/A	N/A	14	N/A	N/A	5	3/5
MCP4531	N	N	Y	V	7	1	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	2/5
MCP4532	N	N	Y	V	7	1	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	2/5
MCP4541	N	N	Y	EE	7	1	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	3/5
MCP4542	N	N	Y	EE	7	1	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	3/5
MCP4551	N	N	Y	V	8	1	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	2/5
MCP4552	N	N	Y	V	8	1	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	2/5
MCP4561	N	N	Y	EE	8	1	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	3/5
MCP4562	N	N	Y	EE	8	1	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	3/5
MCP45HV31	N	N	Y	V	7	1	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	≤36
MCP45HV51	N	N	Y	V	8	1	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	N/A	N/A	8	N/A	N/A	N/A	N/A	5	≤36
MCP4631	N	N	Y	V	7	2	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	2/5
MCP4632	N	N	Y	V	7	2	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	2/5
MCP4641	N	N	Y	EE	7	2	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	3/5
MCP4642	N	N	Y	EE	7	2	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	3/5
MCP4651	N	N	Y	V	8	2	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	2/5
MCP4652	N	N	Y	V	8	2	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	2/5
MCP4661	N	N	Y	EE	8	2	N	Y	Y	N	Y	Y	Y	N	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	3/5
MCP4662	N	N	Y	EE	8	2	N	Y	Y	N	Y	Y	N	Y	N/A	N/A	14	N/A	N/A	14	14	16	N/A	5	3/5
MCP42U83	N	Y	Y	MTP	10	2	N	Y	Y	Y	Y	Y	Y	Y	N/A	N/A	N/A	N/A	N/A	N/A	14	N/A	16	2	3/5
MCP41U83	N	Y	Y	MTP	10	1	N	Y	Y	Y	Y	Y	Y	Y	N/A	N/A	N/A	N/A	N/A	N/A	14	N/A	16	2	3/5

1. When >1 Resistor option is available, the corresponding ordering part numbers are: −202 (2.1 kΩ), −502 (5.0 kΩ), −103 (10.0 kΩ), -203 (20.0 kΩ), −503 (50.0 kΩ) and −104 (100.0 kΩ).
2. This current is with the serial interface inactive, and not during an EEPROM write cycle (for non-volatile devices).
3. The serial interface has been tested to 1.8V, the device's analog characteristics (resistor) have been tested from 2.7V to 5.5V. Review the device's characterization graphs for information on analog performance between 1.8V and 2.7V.
4. One of the terminal pins (A or B) is internally connected to ground, due to the limitation of the number of pins on the package.
5. N/A indicates the device is not available in thie corresponding package style

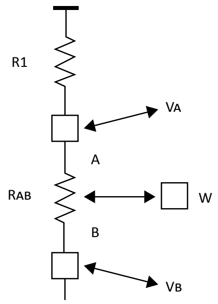
Step Resistance and Voltage Windowing

The Step Resistance (Rs)

Step resistance refers to the incremental resistance change between adjacent wiper positions. This critical parameter determines the resolution and precision of the device. Smaller step resistance allows for finer adjustments and higher precision.

Step resistance is calculated by dividing the total resistance (Rab) by the number of steps minus one. For example, a 10kΩ digital potentiometer with 256 steps will have a step resistance of approximately 39.2Ω. Understanding step resistance is essential to choosing the right resolution.

Voltage Windowing



Voltage windowing is a technique where Terminal A and Terminal B of a Digipot can be set to any voltage within the device's specification limits, denoted as Va and Vb. The voltage across the resistor network, Vab, is the absolute difference |Va − Vb|. This voltage is influenced by the values of the resistors R1, R2, and Rab. As Vab becomes smaller relative to the overall voltage range, the effective resolution of the device increases.

This method allows a less precise digital potentiometer to achieve more precise circuit tuning over a narrower voltage range. This configuration is appropriate when replacing a mechanical potentiometer; R1 and R2 can be any resistance, including zero. Voltage windowing is a valuable technique for enhancing the precision of digital potentiometers in various applications.

Step Resistance

RAB (kΩ)	6-b Ω	7-b Ω	8-b Ω	10-b Ω
2.1	33.33	N/A	N/A	N/A
5	79.365	39.37	19.608	4.888
10	158.73	78.74	39.216	9.775
20	N/A	N/A	N/A	19.550
50	793.651	393.701	196.078	48.876
100	N/A	787.402	392.157	97.752

How the Vab Voltage Effects the Effective Resolution

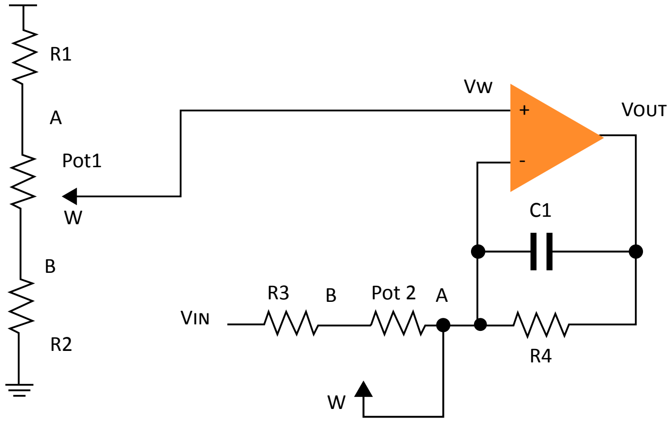
Vab	mV per step				Effective Resolution vs. 5V Vdd			
(in V)	6-bit	7-bit	8-bit	10-bit	6-bit	7-bit	8-bit	10-bit
5	79.4	39.1	19.5	5.0	6	7	8	10
2.5	39.7	19.5	9.8	2.5	7	8	9	11
1.25	19.8	9.8	4.9	1.3	8	9	10	12

Common Digital Potentiometer Applications

1. Volume Control in Audio Systems
2. Sensor and Instrument Calibration
3. Programmable Power Supplies and Oscillators
4. Adjustable Filters
5. LED Dimming and Photographic Light Intensity Control
6. Biasing in RF Circuits
7. Digital Gain Control in Instrumentation Amplifiers
8. BMS (Battery Management Systems)
9. Temperature Compensation
10. Automated Test Equipment (ATE)
11. Feedback Control Systems

Application Circuits and Techniques

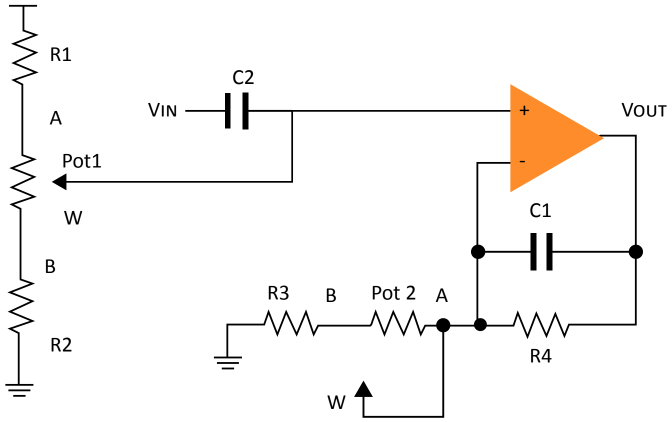
Inverting Amplifier with Offset and Gain Trimming



Digital potentiometers may be used to trim offset and gain in amplifier circuits. In the following example, a resistor ladder establishes a voltage window. Pot1 adjusts the desired offset for the inverting amplifier. Pot2, operating in rheostat mode, combined with resistor R3 controls the amplifier's gain. The step resistance of Pot2 relative to resistor R3 determines the granularity of the gain trimming. Capacitor C1 is included for op amp compensation, preventing output oscillation.

In this configuration, there is no interaction between the offset and gain trimming. That said, the input signal (Vin) is affected by the combined resistance of R2 and Pot2's Rbw value.

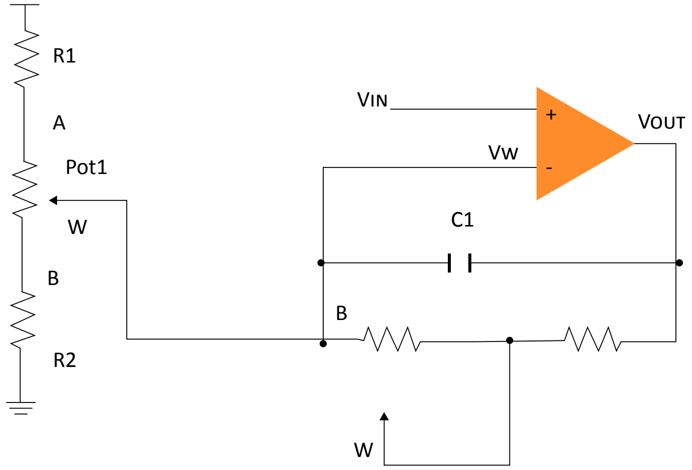
Band Pass Filter with Offset and Gain Trimming



In this example, a resistor ladder again establishes a voltage window. Here Pot1 is used to adjust the desired offset for a band pass filter. Pot2, operating in rheostat mode, combined with resistors R3 and R4 control the amplifier's gain. The step resistance of Pot2 relative to resistors R3 and R4 determines the granularity of the gain trimming. Capacitor C1, in conjunction with Pot2, R3, and R4, is used to set the low pass filter frequency.

Capacitor C1 also serves to compensate the op amp and prevent output oscillation. If capacitor C1 is not present, the circuit functions as a high-pass filter, whereas if capacitor C2 is not present, the circuit functions as a low-pass filter.

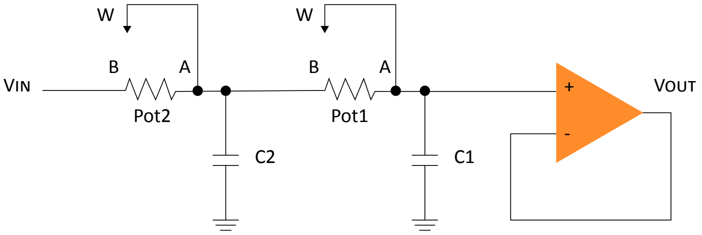
Non-Inverting Amplifier with Offset and Gain Trimming



In this example, a resistor ladder establishes a voltage window. Again, Pot1 adjusts the desired offset for the inverting amplifier. Here Pot2, operating in rheostat mode, independently control the amplifier's gain. The step resistance of Pot2 relative to resistor R3 also determines the granularity of the gain trimming. Capacitor C1 is included for op amp compensation, preventing output oscillation

In this configuration, there is an interaction between the offset and gain trimming. To minimize this interaction, Pot2 should be small compared to resistor R3, and Pot1 should be small relative to the sum of R1 and R2. The input signal (Vin) is not loaded.

Programmable Filter



In this example, a resistor ladder again establishes a voltage window. Here Pot1 is used to adjust the desired offset for a band pass filter. Pot2, operating in rheostat mode, combined with resistors R3 and R4 control the amplifier's gain. The step resistance of Pot2 relative to resistors R3 and R4 determines the granularity of the gain trimming. Capacitor C1, in conjunction with Pot2, R3, and R4, is used to set the low pass filter frequency.

Capacitor C1 also serves to compensate the op amp and prevent output oscillation. If capacitor C1 is not present, the circuit functions as a high-pass filter, whereas if capacitor C2 is not present, the circuit functions as a low-pass filter.

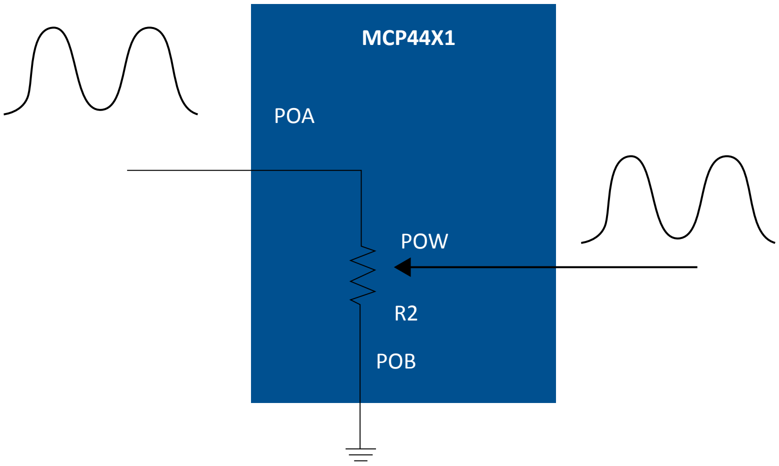
Application Circuits and Techniques

Logarithmic Steps

For audio applications, logarithmic steps are desirable because that is how the human ear perceives sound. A linear potentiometer can approximate a logarithmic potentiometer but with fewer steps. An 8-bit potentiometer can achieve fourteen 3 dB log steps, plus a 100% (0 dB) and a mute setting.

The figure below shows a block diagram of an MCP44X1 resistor network used to attenuate an input signal, with attenuation referenced to ground. Terminal B can be connected to a common mode voltage, but the voltages on terminals A, B, and the wiper must not exceed the MCP44X1 device's Vdd/Vss voltage limits.

Signal Attenuation Block Diagram: Ground Referenced



More detail on this can be found in Section 8.5 of the MCP444X/446X Data Sheet (DS22265).

dB	VOUT/VIN Ratio
–3	0.70795
–2	0.79433
–1	0.89125

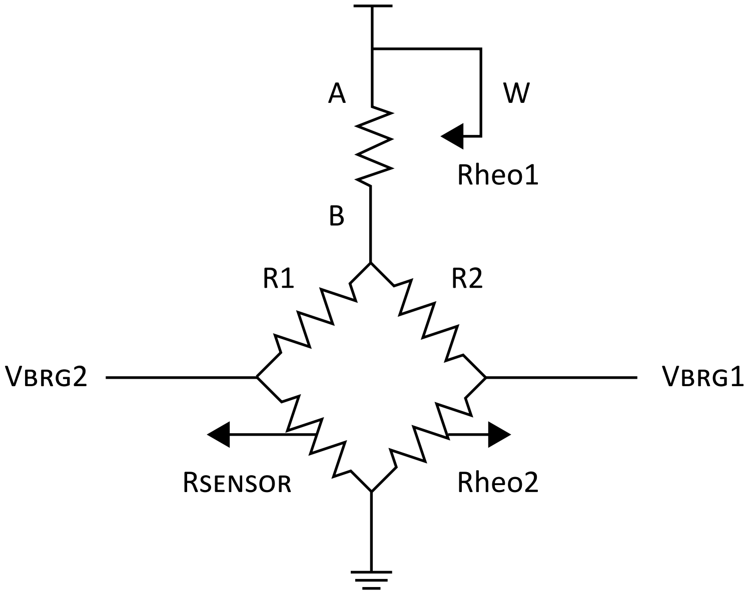
Wheatstone Bridge Trimming

A Wheatstone Bridge has four resistive elements. In this example, two are fixed values (R1 and R2), one is a resistive sensor (Rsensor), and the fourth is a digital potentiometer configured as a rheostat. The potentiometer is used to calibrate the circuit compensating for variations in the resistive sensor. This sensor could be used for temperature or weight measurement.

Under default conditions, the sensor will have a typical value, but this value likely varies from device to device. To compensate for the resistive changes in the R1 plus Rsensor leg of the bridge, the digital potentiometer (Rheo2) is adjusted in the other leg of the bridge. This adjustment ensures that the voltages at Vbrg1 and Vbrg2 are at their desired levels (often Vbrg1 = Vbrg2).

As the conditions affecting the sensor change, the resistance of the sensor will also change, causing the voltage at Vbrg2 to vary. The difference in voltage between Vbrg1 and Vbrg2 can then be used to determine the state of the system (e.g., temperature, weight, etc.).

Rheo1 limits or trims the current through the Wheatstone Bridge.



Implementing a More Precise Rheostat

The RAB value of a typical digital potentiometer can vary by ±20%, meaning a 10 kΩ device could range from 8 kΩ to 12 kΩ. If this variation is undesirable resolution may be sacrificed in favor of calibration.

By designing the circuit to operate the rheostat from 0Ω to 8 kΩ, all digital potentiometer devices will meet this requirement. Via calibration the max wiper value can be set to achieve the closest resistance to the target 8 kΩ. For a max RAB of 12 kΩ, a wiper value of 171 results in a resistance of 8016Ω. The resultant worst case effective resolution calculates to 7.4 bits, or 0.58%.

Note - In potentiometer mode, RAB variation has less impact since the device functions as a voltage divider.

Microchip Technology offers several boards that support the demonstration and evaluation of the digital potentiometer devices. These boards fall into two categories:

- Populated boards to demonstrate/evaluate the specific device(s)
- Blank printed circuit boards (PCBs)

Blank PCBs allow customers to populate the device and supporting circuit to best evaluate the performance and characteristics of the desired device configuration.

Links to the latest eval kits will be found on the product pages at Microchip.com.

Application Notes

The following literature is available on the Microchip web site. Any application notes newer than the latest revision of this brochure will be linked to individual Digipot product pages.

AN219: Comparing Digital Potentiometers to Mechanical Potentiometers

This application note compares two types of potentiometers, the mechanical potentiometer (also called a trimmer potentiometer) and the digital potentiometer.

Resistor potentiometers can be found in electronic circuits across a wide spectrum of applications. Most typically, they function in a voltage divider configuration in order to execute various types of tasks, such as offset or gain adjust.

AN691: Optimizing Digital Potentiometer Circuits to Reduce Absolute Temperature Variations

Circuit ideas are presented that use the necessary design techniques to mitigate errors, consequently optimizing the performance of the digital potentiometer.

AN692: Using Digital Potentiometers to Optimize a Precision Single-Supply Photo Detect Circuit

This application note shows how the adjustability of the digital potentiometer can be used to an advantage in photosensing circuits.

AN737: Using Digital Potentiometers to Design Low-Pass Adjustable Filters

A programmable, second-order, low-pass filter is presented in four different scenarios. The first three scenarios will illustrate how a dual digital potentiometer and a single amplifier can be configured for low-pass second-order Butterworth, Bessel and Chebyshev responses with a programmable corner frequency range of 1:100. An example of the digital potentiometer setting for these designs is summarized. The fourth scenario will show the same circuit design, where all three approximation methods (Butterworth, Bessel and Chebyshev) can coexist with a programmable corner frequency range of 1:10.

AN746: Interfacing Microchip's MCP41XXX/ MCP4XXX Digital Potentiometer to a PIC® Microcontroller Communications between the MCP41XXX and MCP42XXX

family of digital potentiometers and a PIC16F876 microcontroller is discussed. These devices communicate using a standard 3-wire SPI compatible interface. The code supplied with this application note will include both absolute and relocatable assembly code, written for both hardware SPI and firmware SPI implementations.

Application Notes

AN747: Communicating with Daisy Chained MCP42XXX Digital Potentiometers

The MCP41XXX and MCP42XXX family of digital potentiometers allow for daisy chaining of multiple devices on a single SPI bus. It is possible to communicate to multiple devices using one 3-wire data bus (CS, CLK and DATA), by connecting the SO pin on one device to the SI pin of the next device in the chain. This application note details one example of source code that is used to communicate with eight daisy chained devices.

AN757: Interfacing Microchip's MCP41XXX/ MCP4XXX Digital Potentiometer to the Motorola 68HC12 Microcontroller

Communication between the MCP41XXX and MCP42XXX family of digital potentiometers and the Motorola 68HC12 family of microcontrollers is discussed. These devices communicate using a standard 3-wire SPI compatible interface. Specifically, the MC68HC912B32 evaluation board was used.

AN1080: Understanding Digital Potentiometer Resistance Variations

This application note discusses how process, voltage and temperature effect the resistor network's characteristics, specifications and techniques to improve system performance.

AN1316: Using Digital Potentiometers for Programmable Amplifier Gain

This application note will discuss implementations of programmable gain circuits using an op amp and a digital potentiometer. This discussion will include implementation details for the digital potentiometer's resistor network. It is important to understand these details to understand the effects on the application.

Microchip’s Stand-Alone Analog and Interface Portfolio

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- Comparators

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- HV Interface
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- Wireless
- Real-Time Clock/Calendar

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- PWM Controllers
- Battery Chargers
- Power Modules
- Power MOSFET Drivers
- Power MOSFET
- Motor Drivers
- System Supervisors Voltage Detectors
- Power Switches
- Hot Swap Power Controllers
- DDR and SCSI Terminators
- Display/LED Drivers

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- Temperature Sensors
- Fan Control and Management

Safety and Security
- Smoke Detector ICs
- Piezoelectric Horn Drivers

Mixed Signal
- A/D Converters
- Current/DC Power Measurement ICs
- Power Monitoring and Metering
- DACs and Digital Potentiometers
- Voltage References

Timing
- Timers

Ultrasound
- Ultrasound Products