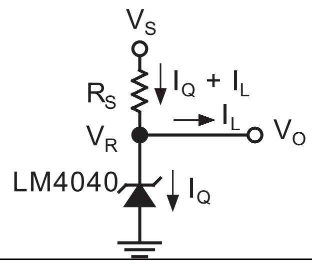
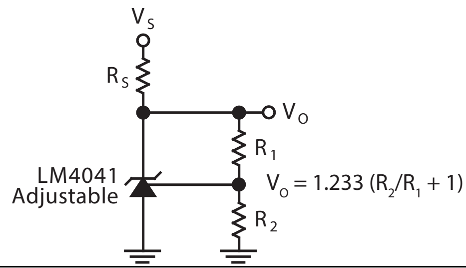
Typical Application Diagrams

LM4040/LM4041 Fixed Shunt Regulator Application

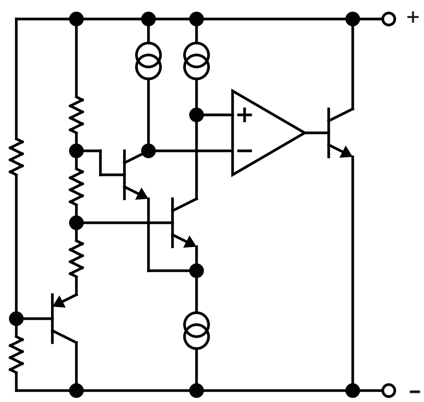


LM4041 Adjustable Shunt Regulator Application

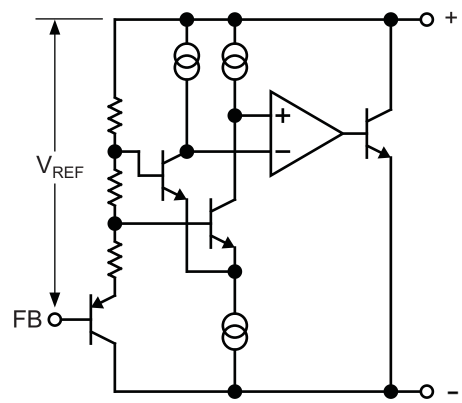


Functional Block Diagrams

LM4040/LM4041 Fixed



LM4041 Adjustable



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Reverse Current .... 20 mA
Forward Current .... 10 mA
Maximum Output Voltage (LM4041-ADJ) 15V
Power Dissipation (T_A = +25°C; Note 1) .... 306 mW
ESD Susceptibility (HBM; Note 2) .... 2 kV
ESD Susceptibility (MM; Note 2) 200V

Operating Ratings ‡

Reverse Current (LM4040-2.5) .... 60 µA to 15 mA
Reverse Current (LM4040-4.1) .... 68 µA to 15 mA
Reverse Current (LM4040-5.0) .... 74 µA to 15 mA
Reverse Current (LM4041-1.2) .... 60 µA to 12 mA
Reverse Current (LM4041-ADJ) .... 60 µA to 12 mA
Output Voltage Range (LM4041-ADJ) .... 1.24V to 10V

† **Notice:** Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

‡ **Notice:** The device is not guaranteed to function outside its operating ratings.

Note 1: The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{JMAX} (maximum junction temperature), Θ_{JA} (junction-to-ambient thermal resistance), and T_A (ambient temperature). The maximum allowable power dissipation at any temperature is $P_{DMAX} = (T_{JMAX} – T_A)/ \Theta_{JA}$ or the number given in the Absolute Maximum Ratings, whichever is lower. For the LM4040 and LM4041, T_{JMAX} = +125°C and the typical thermal resistance, when board-mounted, is +326°C/W for the SOT-23 package.

2: Devices are ESD sensitive. Handling precautions are recommended. Human body model, 1.5 kΩ in series with 100 pF. The machine model is a 200 pF capacitor discharged directly into each pin.

LM4040-2.5 ELECTRICAL CHARACTERISTICS (Note 1)

T_A = Operating Temperature Range, $T_A = T_J$ = –40°C to +85°C, unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
LM4040C						
Reverse-Breakdown Voltage	V_R	—	2.500	—	V	I_R = 100 µA, T_A = +25°C
Reverse-Breakdown Voltage Tolerance (Note 2)		—	—	±12	mV	I_R = 100 µA, T_A = +25°C
		—	—	±29	mV	I_R = 100 µA
Minimum Operating Current	I_{RMIN}	—	45	60	µA	T_A = +25°C
		—	—	65		—
Average Reverse-Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta_T$	—	±20	—	ppm/°C	I_R = 10 mA, T_A = +25°C
		—	±15	±100		I_R = 1 mA
		—	±15	—		I_R = 100 µA, T_A = +25°C
Reverse-Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	—	0.3	0.8	mV	$I_{RMIN} \le I_R \le$ 1 mA, T_A = +25°C
		—	—	1.0		$I_{RMIN} \le I_R \le$ 1 mA
		—	2.5	6.0		1 mA $\le I_R \le$ 15 mA, T_A = +25°C
		—	—	8.0		1 mA $\le I_R \le$ 15 mA
Reverse Dynamic Impedance	Z_R	—	0.3	0.9	Ω	I_R = 1 mA, f = 120 Hz, I_{AC} = 0.1 I_R, T_A = +25°C
Wideband Noise	e_N	—	35	—	μV_{RMS}	I_R = 100 µA, T_A = +25°C, 10 Hz ≤ f ≤ 10 kHz
Reverse-Breakdown Voltage Long-Term Stability	ΔV_R	—	120	—	ppm	t = 1000 hrs., T_A = +25°C ±0.1°C, I_R = 100 µA
LM4040D						
Reverse-Breakdown Voltage	V_R	—	2.500	—	V	I_R = 100 µA, T_A = +25°C
Reverse-Breakdown Voltage Tolerance (Note 2)		—	—	±25	mV	I_R = 100 µA, T_A = +25°C
		—	—	±49	mV	I_R = 100 µA
Minimum Operating Current	I_{RMIN}	—	45	65	µA	T_A = +25°C
		—	—	70		—
Average Reverse-Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta_T$	—	±20	—	ppm/°C	I_R = 10 mA, T_A = +25°C
		—	±15	±150		I_R = 1 mA
		—	±15	—		I_R = 100 µA, T_A = +25°C

Note 1: Specification for packaged product only.

2: The boldface (overtemperature) limit for Reverse-Breakdown Voltage Tolerance is defined as the room temperature Reverse-Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ is the V_R temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V_R is the reverse-breakdown voltage. The total overtemperature tolerance for the different grades follows:

a. C-grade: ±1.15% = ±0.5% ±100 ppm/°C × 65°C

b. D-grade: ±1.98% = ±1.0% ±150 ppm/°C × 65°C

Example: The C-grade LM4040-2.5 has an overtemperature Reverse-Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29 mV.

LM4040-2.5 ELECTRICAL CHARACTERISTICS (Note 1) (CONTINUED)

T_A = Operating Temperature Range, $T_A = T_J$ = –40°C to +85°C, unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Reverse-Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	—	0.3	1.0	mV	$I_{RMIN} \le I_R \le 1$ mA, T_A = +25°C
		—	—	1.2		$I_{RMIN} \le I_R \le 1$ mA
		—	2.5	8.0		1 mA $\le I_R \le$ 15 mA, T_A = +25°C
		—	—	10.0		1 mA $\le I_R \le$ 15 mA
Reverse Dynamic Impedance	Z_R	—	0.3	1.1	Ω	I_R = 1 mA, f = 120 Hz, I_{AC} = 0.1 I_R, T_A = +25°C
Wideband Noise	e_N	—	35	—	μV_{RMS}	I_R = 100 µA, 10 Hz ≤ f ≤ 10 kHz
Reverse-Breakdown Voltage Long-Term Stability	ΔV_R	—	120	—	ppm	t = 1000 hrs., T_A = +25°C ±0.1°C, I_R = 100 µA

Note 1: Specification for packaged product only.

2: The boldface (overtemperature) limit for Reverse-Breakdown Voltage Tolerance is defined as the room temperature Reverse-Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ is the V_R temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V_R is the reverse-breakdown voltage. The total overtemperature tolerance for the different grades follows:
a. C-grade: ±1.15% = ±0.5% ±100 ppm/°C × 65°C
b. D-grade: ±1.98% = ±1.0% ±150 ppm/°C × 65°C
Example: The C-grade LM4040-2.5 has an overtemperature Reverse-Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29 mV.

LM4040-4.1 ELECTRICAL CHARACTERISTICS (Note 1)

T_A = Operating Temperature Range, $T_A = T_J$ = –40°C to +85°C, unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
LM4040C						
Reverse-Breakdown Voltage	V_R	—	4.096	—	V	I_R = 100 µA, T_A = +25°C
Reverse-Breakdown Voltage Tolerance (Note 2)		—	—	±20	mV	I_R = 100 µA, T_A = +25°C
		—	—	±47	mV	I_R = 100 µA
Minimum Operating Current	I_{RMIN}	—	50	68	µA	T_A = +25°C
		—	—	73		—
Average Reverse-Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta_T$	—	±30	—	ppm/°C	I_R = 10 mA, T_A = +25°C
		—	±20	±100		I_R = 1 mA
		—	±20	—		I_R = 100 µA, T_A = +25°C
Reverse-Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	—	0.5	0.9	mV	$I_{RMIN} \le I_R \le$ 1 mA, T_A = +25°C
		—	—	1.2		$I_{RMIN} \le I_R \le$ 1 mA
		—	3.0	7.0		1 mA $\le I_R \le$ 15 mA, T_A = +25°C
		—	—	10.0		1 mA $\le I_R \le$ 15 mA
Reverse Dynamic Impedance	Z_R	—	0.5	1.0	Ω	I_R = 1 mA, f = 120 Hz, I_{AC} = 0.1 I_R, T_A = +25°C
Wideband Noise	e_N	—	80	—	μV_{RMS}	I_R = 100 µA, T_A = +25°C, 10 Hz ≤ f ≤ 10 kHz
Reverse-Breakdown Voltage Long-Term Stability	ΔV_R	—	120	—	ppm	t = 1000 hrs., T_A = +25°C ±0.1°C, I_R = 100 µA
LM4040D						
Reverse-Breakdown Voltage	V_R	—	4.096	—	V	I_R = 100 µA, T_A = +25°C
Reverse-Breakdown Voltage Tolerance (Note 2)		—	—	±41	mV	I_R = 100 µA, T_A = +25°C
		—	—	±81	mV	I_R = 100 µA
Minimum Operating Current	I_{RMIN}	—	50	73	µA	T_A = +25°C
		—	—	78		—
Average Reverse-Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta_T$	—	±30	—	ppm/°C	I_R = 10 mA, T_A = +25°C
		—	±20	±150		I_R = 1 mA
		—	±20	—		I_R = 100 µA, T_A = +25°C

Note 1: Specification for packaged product only.

2: The boldface (overtemperature) limit for Reverse-Breakdown Voltage Tolerance is defined as the room temperature Reverse-Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ is the V_R temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V_R is the reverse-breakdown voltage. The total overtemperature tolerance for the different grades follows:

a. C-grade: ±1.15% = ±0.5% ±100 ppm/°C × 65°C

b. D-grade: ±1.98% = ±1.0% ±150 ppm/°C × 65°C

Example: The C-grade LM4040-2.5 has an overtemperature Reverse-Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29 mV.

LM4040-4.1 ELECTRICAL CHARACTERISTICS (Note 1) (CONTINUED)

T_A = Operating Temperature Range, $T_A = T_J$ = –40°C to +85°C, unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Reverse-Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	—	0.5	1.2	mV	$I_{RMIN} \le I_R \le 1$ mA, T_A = +25°C
		—	—	1.5		$I_{RMIN} \le I_R \le 1$ mA
		—	3.0	9.0		1 mA $\le I_R \le$ 15 mA, T_A = +25°C
		—	—	13.0		1 mA $\le I_R \le$ 15 mA
Reverse Dynamic Impedance	Z_R	—	0.5	1.3	Ω	I_R = 1 mA, f = 120 Hz, I_{AC} = 0.1 I_R, T_A = +25°C
Wideband Noise	e_N	—	80	—	μV_{RMS}	I_R = 100 µA, T_A = +25°C 10 Hz ≤ f ≤ 10 kHz
Reverse-Breakdown Voltage Long-Term Stability	ΔV_R	—	120	—	ppm	t = 1000 hrs., T_A = +25°C ±0.1°C, I_R = 100 µA

Note 1: Specification for packaged product only.

2: The boldface (overtemperature) limit for Reverse-Breakdown Voltage Tolerance is defined as the room temperature Reverse-Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ is the V_R temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V_R is the reverse-breakdown voltage. The total overtemperature tolerance for the different grades follows:

a. C-grade: ±1.15% = ±0.5% ±100 ppm/°C × 65°C

b. D-grade: ±1.98% = ±1.0% ±150 ppm/°C × 65°C

Example: The C-grade LM4040-2.5 has an overtemperature Reverse-Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29 mV.

LM4040-5.0 ELECTRICAL CHARACTERISTICS (Note 1)

T_A = Operating Temperature Range, $T_A = T_J$ = –40°C to +85°C, unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
LM4040C						
Reverse-Breakdown Voltage	V_R	—	5.000	—	V	I_R = 100 µA, T_A = +25°C
Reverse-Breakdown Voltage Tolerance (Note 2)		—	—	±25	mV	I_R = 100 µA, T_A = +25°C
		—	—	±58	mV	I_R = 100 µA
Minimum Operating Current	I_{RMIN}	—	54	74	µA	T_A = +25°C
		—	—	80		—
Average Reverse-Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta_T$	—	±30	—	ppm/°C	I_R = 10 mA, T_A = +25°C
		—	±20	±100		I_R = 1 mA
		—	±20	—		I_R = 100 µA, T_A = +25°C
Reverse-Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	—	0.5	1.0	mV	$I_{RMIN} \le I_R \le$ 1 mA, T_A = +25°C
		—	—	1.4		$I_{RMIN} \le I_R \le$ 1 mA
		—	3.5	8.0		1 mA ≤ I_R ≤ 15 mA, T_A = +25°C
		—	—	12.0		1 mA ≤ I_R ≤ 15 mA
Reverse Dynamic Impedance	Z_R	—	0.5	1.1	Ω	I_R = 1 mA, f = 120 Hz, I_{AC} = 0.1 I_R, T_A = +25°C
Wideband Noise	e_N	—	80	—	$µV_{RMS}$	I_R = 100 µA, T_A = +25°C, 10 Hz ≤ f ≤ 10 kHz
Reverse-Breakdown Voltage Long-Term Stability	ΔV_R	—	120	—	ppm	t = 1000 hrs., T_A = +25°C ±0.1°C, I_R = 100 µA
LM4040D						
Reverse-Breakdown Voltage	V_R	—	5.000	—	V	I_R = 100 µA, T_A = +25°C
Reverse-Breakdown Voltage Tolerance (Note 2)		—	—	±50	mV	I_R = 100 µA, T_A = +25°C
		—	—	±99	mV	I_R = 100 µA
Minimum Operating Current	I_{RMIN}	—	54	79	µA	T_A = +25°C
		—	—	85		—
Average Reverse-Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta_T$	—	±30	—	ppm/°C	I_R = 10 mA, T_A = +25°C
		—	±20	±150		I_R = 1 mA
		—	±20	—		I_R = 100 µA, T_A = +25°C

Note 1: Specification for packaged product only.

2: The boldface (overtemperature) limit for Reverse-Breakdown Voltage Tolerance is defined as the room temperature Reverse-Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ is the V_R temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V_R is the reverse-breakdown voltage. The total overtemperature tolerance for the different grades follows:

a. C-grade: ±1.15% = ±0.5% ±100 ppm/°C × 65°C

b. D-grade: ±1.98% = ±1.0% ±150 ppm/°C × 65°C

Example: The C-grade LM4040-2.5 has an overtemperature Reverse-Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29 mV.

LM4040-5.0 ELECTRICAL CHARACTERISTICS (Note 1) (CONTINUED)

T_A = Operating Temperature Range, $T_A = T_J$ = –40°C to +85°C, unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Reverse-Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	—	0.5	1.3	mV	$I_{RMIN} \le I_R \le 1$ mA, T_A = +25°C
		—	—	1.8		$I_{RMIN} \le I_R \le 1$ mA
		—	3.5	10.0		1 mA $\le I_R \le$ 15 mA, T_A = +25°C
		—	—	15.0		1 mA $\le I_R \le$ 15 mA
Reverse Dynamic Impedance	Z_R	—	0.5	1.5	Ω	I_R = 1 mA, f = 120 Hz, I_{AC} = 0.1 I_R, T_A = +25°C
Wideband Noise	e_N	—	80	—	μV_{RMS}	I_R = 100 µA, T_A = +25°C, 10 Hz ≤ f ≤ 10 kHz
Reverse-Breakdown Voltage Long-Term Stability	ΔV_R	—	120	—	ppm	t = 1000 hrs., T_A = +25°C ±0.1°C, I_R = 100 µA

Note 1: Specification for packaged product only.

2: The boldface (overtemperature) limit for Reverse-Breakdown Voltage Tolerance is defined as the room temperature Reverse-Breakdown Voltage Tolerance ±[($\Delta V_R/\Delta T$)(65°C)(V_R)]. $\Delta V_R/\Delta T$ is the V_R temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V_R is the reverse-breakdown voltage. The total overtemperature tolerance for the different grades follows:
  a. C-grade: ±1.15% = ±0.5% ±100 ppm/°C × 65°C
  b. D-grade: ±1.98% = ±1.0% ±150 ppm/°C × 65°C

Example: The C-grade LM4040-2.5 has an overtemperature Reverse-Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29 mV.

LM4041-1.2 ELECTRICAL CHARACTERISTICS (Note 1)

T_A = Operating Temperature Range, $T_A = T_J$ = –40°C to +85°C, unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
LM4041C						
Reverse-Breakdown Voltage	V_R	—	1.225	—	V	I_R = 100 µA, T_A = +25°C
Reverse-Breakdown Voltage Tolerance (Note 2)		—	—	±6	mV	I_R = 100 µA, T_A = +25°C
		—	—	±14	mV	I_R = 100 µA
Minimum Operating Current	I_{RMIN}	—	45	60	µA	T_A = +25°C
		—	—	65		—
Average Reverse-Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta_T$	—	±20	—	ppm/°C	I_R = 10 mA, T_A = +25°C
		—	±15	±100		I_R = 1 mA
		—	±15	—		I_R = 100 µA, T_A = +25°C
Reverse-Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	—	0.7	1.5	mV	$I_{RMIN} \leq I_R \leq$ 1 mA, T_A = +25°C
		—	—	2.0		$I_{RMIN} \leq I_R \leq$ 1 mA
		—	4.0	6.0		1 mA ≤ I_R ≤ 12 mA, T_A = +25°C
		—	—	8.0		1 mA ≤ I_R ≤ 12 mA
Reverse Dynamic Impedance	Z_R	—	0.5	1.5	Ω	I_R = 1 mA, f = 120 Hz, I_{AC} = 0.1 I_R, T_A = +25°C
Wideband Noise	e_N	—	20	—	μV_{RMS}	I_R = 100 µA, T_A = +25°C, 10 Hz ≤ f ≤ 10 kHz
Reverse-Breakdown Voltage Long-Term Stability	ΔV_R	—	120	—	ppm	t = 1000 hrs., T_A = +25°C ±0.1°C, I_R = 100 µA
LM4041D						
Reverse-Breakdown Voltage	V_R	—	1.225	—	V	I_R = 100 µA, T_A = +25°C
Reverse-Breakdown Voltage Tolerance (Note 2)		—	—	±12	mV	I_R = 100 µA, T_A = +25°C
		—	—	±24		I_R = 100 µA
Minimum Operating Current	I_{RMIN}	—	45	65	µA	T_A = +25°C
		—	—	70		—
Average Reverse-Breakdown Voltage Temperature Coefficient	$\Delta V_R/\Delta_T$	—	±20	—	ppm/°C	I_R = 10 mA, T_A = +25°C
		—	±15	±150		I_R = 1 mA
		—	±15	—		I_R = 100 µA, T_A = +25°C

Note 1: Specification for packaged product only.

2: The boldface (overtemperature) limit for Reverse-Breakdown Voltage Tolerance is defined as the room temperature Reverse-Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ is the V_R temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V_R is the reverse-breakdown voltage. The total overtemperature tolerance for the different grades follows:
   a. C-grade: ±1.15% = ±0.5% ±100 ppm/°C × 65°C
   b. D-grade: ±1.98% = ±1.0% ±150 ppm/°C × 65°C

Example: The C-grade LM4040-2.5 has an overtemperature Reverse-Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29 mV.

LM4041-1.2 ELECTRICAL CHARACTERISTICS (Note 1) (CONTINUED)

T_A = Operating Temperature Range, $T_A = T_J$ = –40°C to +85°C, unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Reverse-Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	—	0.7	2.0	mV	$I_{RMIN} \le I_R \le 1$ mA, T_A = +25°C
		—	—	2.5		$I_{RMIN} \le I_R \le 1$ mA
		—	2.5	8.0		1 mA $\le I_R \le$ 12 mA, T_A = +25°C
		—	—	10.0		1 mA $\le I_R \le$ 12 mA
Reverse Dynamic Impedance	Z_R	—	0.5	2.0	Ω	I_R = 1 mA, f = 120 Hz, I_{AC} = 0.1 I_R, T_A = +25°C
Wideband Noise	e_N	—	20	—	μV_{RMS}	I_R = 100 µA, T_A = +25°C, 10 Hz ≤ f ≤ 10 kHz
Reverse-Breakdown Voltage Long-Term Stability	ΔV_R	—	120	—	ppm	t = 1000 hrs., T_A = +25°C ±0.1°C, I_R = 100 µA

Note 1: Specification for packaged product only.

2: The boldface (overtemperature) limit for Reverse-Breakdown Voltage Tolerance is defined as the room temperature Reverse-Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ is the V_R temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V_R is the reverse-breakdown voltage. The total overtemperature tolerance for the different grades follows:
a. C-grade: ±1.15% = ±0.5% ±100 ppm/°C × 65°C
b. D-grade: ±1.98% = ±1.0% ±150 ppm/°C × 65°C
Example: The C-grade LM4040-2.5 has an overtemperature Reverse-Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29 mV.

LM4041-ADJ ELECTRICAL CHARACTERISTICS (Note 1)

T_A = Operating Temperature Range, $T_A = T_J$ = –40°C to +85°C, unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
LM4041C						
Reverse-Breakdown Voltage	V_R	—	1.233	—	V	I_R = 100 µA, V_{OUT} = 5V
Reverse-Breakdown Voltage Tolerance (Note 2)		—	—	±6.2	mV	I_R = 100 µA, T_A = +25°C
		—	—	±14	mV	I_R = 100 µA
Minimum Operating Current	I_{RMIN}	—	45	60	µA	T_A = +25°C
		—	—	65		—
Reference Voltage Change with Operating Current	$\Delta V_{REF}/\Delta I_R$	—	0.7	1.5	mV	$I_{RMIN} \le I_R \le$ 1 mA, $V_{OUT} \ge$ 1.6V (Note 3), T_A = +25°C
		—	—	2.0		$I_{RMIN} \le I_R \le$ 1 mA, $V_{OUT} \ge$ 1.6V (Note 3)
		—	2.0	4.0		1 mA $\le I_R \le$ 12 mA, $V_{OUT} \ge$ 1.6V (Note 3), T_A = +25°C
		—	—	6.0		1 mA $\le I_R \le$ 12 mA, $V_{OUT} \ge$ 1.6V (Note 3)
Reference Voltage Change with Output Voltage Change	$\Delta V_{REF}/\Delta V_O$	—	–1.55	–2.0	mV/V	I_R = 1 mA, T_A = +25°C
		—	—	–2.5		I_R = 1 mA
Feedback Current	I_{FB}	—	60	100	nA	T_A = +25°C
		—	—	120		—
Average Reference Voltage Temperature Coefficient	$\Delta V_{REF}/\Delta T$	—	±20	—	ppm/°C	V_{OUT} = 5V, I_R = 10 mA, T_A = +25°C
		—	±15	±100		V_{OUT} = 5V, I_R = 1 mA
		—	±15	—		V_{OUT} = 5V, I_R = 100 µA, T_A = +25°C
Dynamic Output Impedance	Z_{OUT}	—	0.3	—	Ω	I_R = 1 mA, f = 120 Hz, T_A = +25°C, I_{AC} = 0.1 I_R, V_{OUT} = V_{REF}
		—	—	2.0		V_{OUT} = 10V, T_A = +25°C
Wideband Noise	e_N	—	20	—	μV_{RMS}	I_R = 100 µA, T_A = +25°C, 10 Hz ≤ f ≤ 10 kHz

Note 1: Specification for packaged product only.

2: The boldface (overtemperature) limit for Reverse-Breakdown Voltage Tolerance is defined as the room temperature Reverse-Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ is the V_R temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V_R is the reverse-breakdown voltage. The total overtemperature tolerance for the different grades follows:

a. C-grade: ±1.15% = ±0.5% ±100 ppm/°C × 65°C

b. D-grade: ±1.98% = ±1.0% ±150 ppm/°C × 65°C

Example: The C-grade LM4040-2.5 has an overtemperature Reverse-Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29 mV.

3: When $V_{OUT} \le$ 1.6V, the LM4041-ADJ must operate at reduced I_R. This is caused by the series resistance of the die attach between the die (-) output and the package (-) output pin. See the Output Saturation curve in the Typical Performance Curves section.

LM4041-ADJ ELECTRICAL CHARACTERISTICS (Note 1) (CONTINUED)

T_A = Operating Temperature Range, $T_A = T_J$ = –40°C to +85°C, unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Reverse-Breakdown Voltage Long-Term Stability	ΔV_R	—	120	—	ppm	t = 1000 hrs., T_A = +25°C ±0.1°C, I_R = 100 µA
LM4041D						
Reverse-Breakdown Voltage	V_R	—	1.233	—	V	I_R = 100 µA, V_{OUT} = 5V
Reverse-Breakdown Voltage Tolerance (Note 2)		—	—	±12	mV	I_R = 100 µA, T_A = +25°C
		—	—	±24	mV	I_R = 100 µA
Minimum Operating Current	I_{RMIN}	—	45	65	µA	T_A = +25°C
		—	—	70		—
Reference Voltage Change with Operating Current	$\Delta V_{REF}/\Delta I_R$	—	0.7	2.0	mV	$I_{RMIN} \le I_R \le$ 1 mA, $V_{OUT} \ge$ 1.6V (Note 3), T_A = +25°C
		—	—	2.5		$I_{RMIN} \le I_R \le$ 1 mA, $V_{OUT} \ge$ 1.6V (Note 3)
		—	2.0	6.0		1 mA $\le I_R \le$ 12 mA, $V_{OUT} \ge$ 1.6V (Note 3), T_A = +25°C
		—	—	8.0		1 mA $\le I_R \le$ 12 mA, $V_{OUT} \ge$ 1.6V (Note 3)
Reference Voltage Change with Output Voltage Change	$\Delta V_{REF}/\Delta V_O$	—	–1.55	–2.5	mV/V	I_R = 1 mA, T_A = +25°C
		—	—	–3.0		I_R = 1 mA
Feedback Current	I_{FB}	—	60	150	nA	T_A = +25°C
		—	—	200		—
Average Reference Voltage Temperature Coefficient	$\Delta V_{REF}/\Delta T$	—	±20	—	ppm/°C	V_{OUT} = 5V, I_R = 10 mA, T_A = +25°C
		—	±15	±150		V_{OUT} = 5V, I_R = 1 mA
		—	±15	—		V_{OUT} = 5V, I_R = 100 µA, T_A = +25°C
Dynamic Output Impedance	Z_{OUT}	—	0.3	—	Ω	I_R = 1 mA, f = 120 Hz, T_A = +25°C, I_{AC} = 0.1 I_R, V_{OUT} = V_{REF}
		—	—	2.0		V_{OUT} = 10V, T_A = +25°C

Note 1: Specification for packaged product only.

2: The boldface (overtemperature) limit for Reverse-Breakdown Voltage Tolerance is defined as the room temperature Reverse-Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ is the V_R temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V_R is the reverse-breakdown voltage. The total overtemperature tolerance for the different grades follows:

a. C-grade: ±1.15% = ±0.5% ±100 ppm/°C × 65°C

b. D-grade: ±1.98% = ±1.0% ±150 ppm/°C × 65°C

Example: The C-grade LM4040-2.5 has an overtemperature Reverse-Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29 mV.

3: When $V_{OUT} \le$ 1.6V, the LM4041-ADJ must operate at reduced I_R. This is caused by the series resistance of the die attach between the die (-) output and the package (-) output pin. See the Output Saturation curve in the Typical Performance Curves section.

LM4041-ADJ ELECTRICAL CHARACTERISTICS (Note 1) (CONTINUED)

T_A = Operating Temperature Range, $T_A = T_J$ = –40°C to +85°C, unless noted.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Wideband Noise	e_N	—	20	—	μV_{RMS}	I_R = 100 µA, T_A = +25°C, 10 Hz ≤ f ≤ 10 kHz
Reverse-Breakdown Voltage Long-Term Stability	ΔV_R	—	120	—	ppm	t = 1000 hrs., T_A = +25°C ±0.1°C, I_R = 100 µA

Note 1: Specification for packaged product only.

2: The boldface (overtemperature) limit for Reverse-Breakdown Voltage Tolerance is defined as the room temperature Reverse-Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ is the V_R temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V_R is the reverse-breakdown voltage. The total overtemperature tolerance for the different grades follows:
   a. C-grade: ±1.15% = ±0.5% ±100 ppm/°C × 65°C
   b. D-grade: ±1.98% = ±1.0% ±150 ppm/°C × 65°C

Example: The C-grade LM4040-2.5 has an overtemperature Reverse-Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29 mV.

3: When V_{OUT} ≤ 1.6V, the LM4041-ADJ must operate at reduced I_R. This is caused by the series resistance of the die attach between the die (-) output and the package (-) output pin. See the Output Saturation curve in the Typical Performance Curves section.

TEMPERATURE SPECIFICATIONS (Note 1)

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Operating Temperature Range	T_A	–40	—	+85	°C	—
Storage Temperature	T_S	–65	—	+150	°C	—
Lead Temperature	—	—	+215	—	°C	Vapor phase, 60s
Lead Temperature	—	—	+220	—	°C	Infrared, 15s
Package Thermal Resistance						
3-Pin SOT-23	Θ_{JA}	—	+326	—	°C/W	—

Note 1: The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e., T_A, T_J, θ_{JA}). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum +125°C rating. Sustained junction temperatures above +125°C can impact the device reliability.

Test Circuits

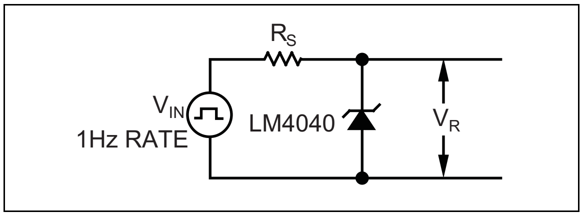


FIGURE 1-1: *LM4040.*

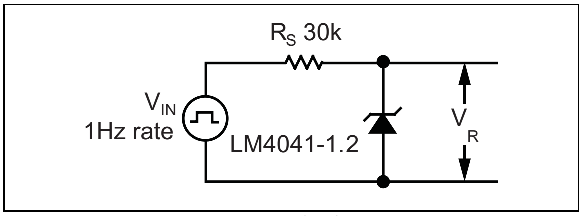


FIGURE 1-2: *LM4041.*

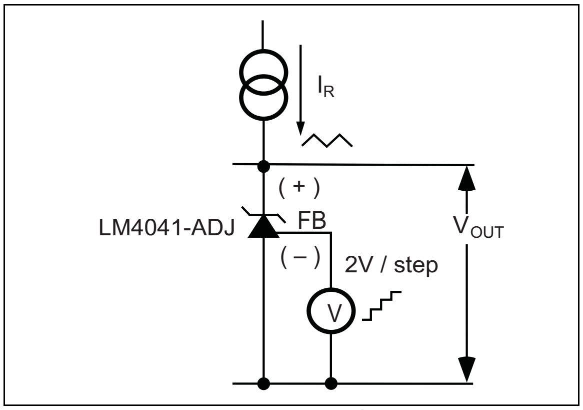


FIGURE 1-3: *Reverse Characteristics Test Circuit.*

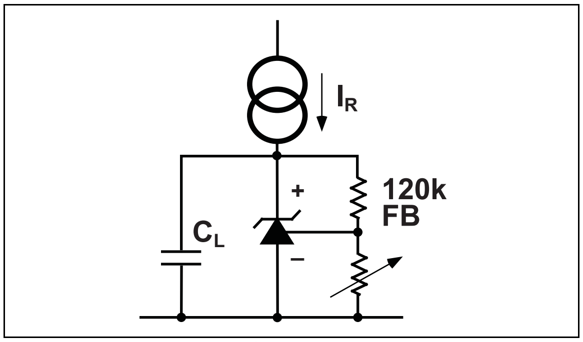


FIGURE 1-4: *Output Impedance vs. Frequency Test Circuit.*

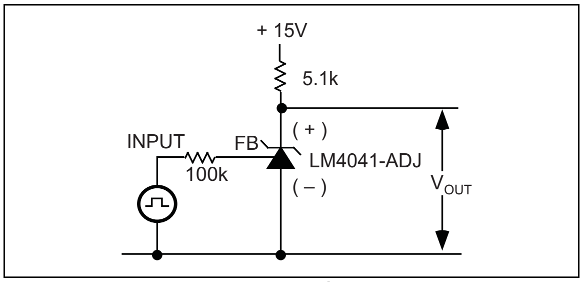


FIGURE 1-5: *Large Signal Response Test Circuit.*

2.0 TYPICAL PERFORMANCE CURVES

Note:	The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

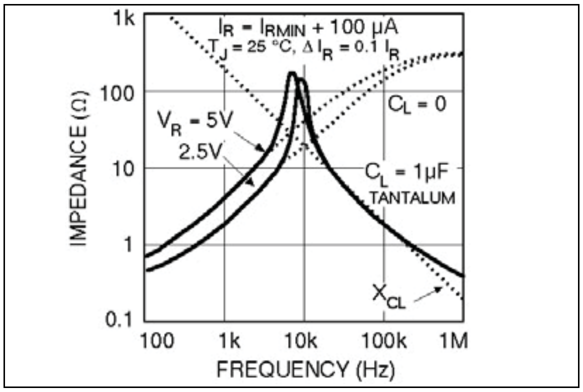


FIGURE 2-1: *LM4040 Output Impedance vs. Frequency.*

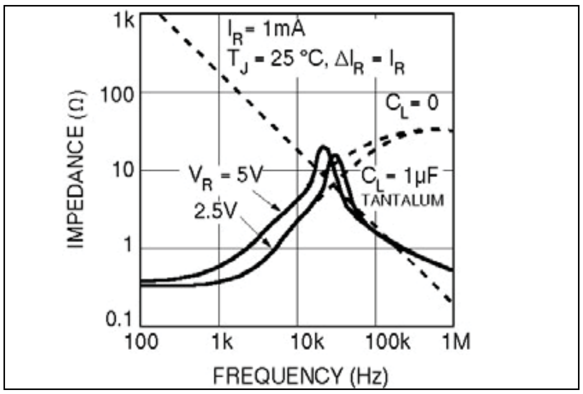


FIGURE 2-2: *LM4040 Output Impedance vs. Frequency.*

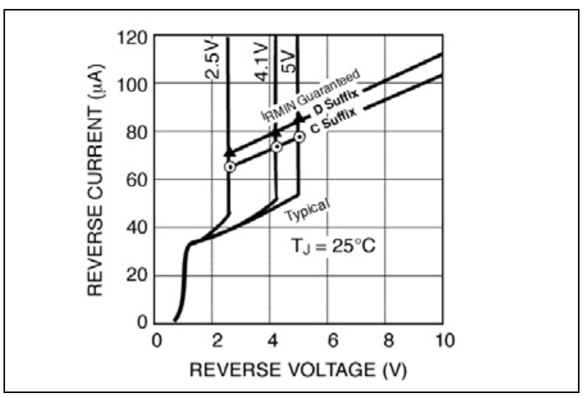


FIGURE 2-3: *LM4040 Reverse Characteristics and Minimum Operating Current.*

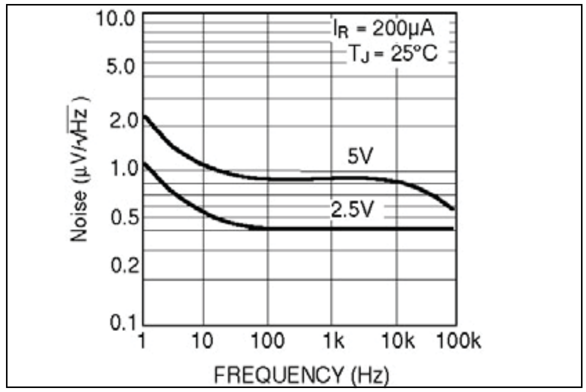


FIGURE 2-4: *LM4040 Noise Voltage vs. Frequency.*

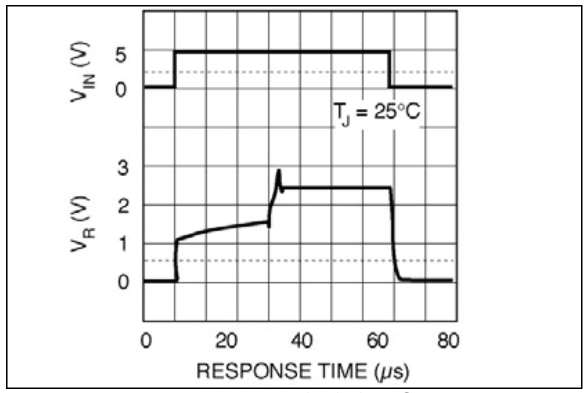


FIGURE 2-5: *LM4040-2.5 Start-Up Characteristics (R_S = 30 kΩ).*

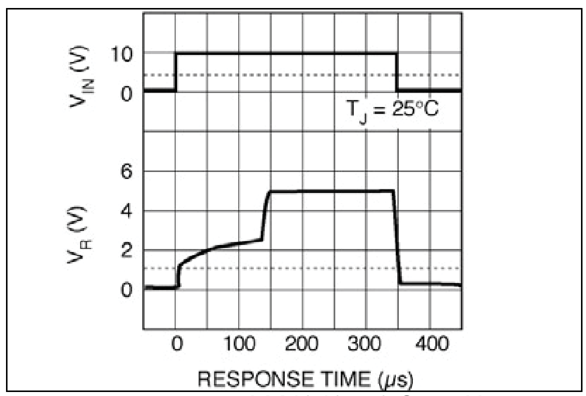


FIGURE 2-6: *LM4040-5.0 Start-Up Characteristics (R_S = 30 kΩ).*

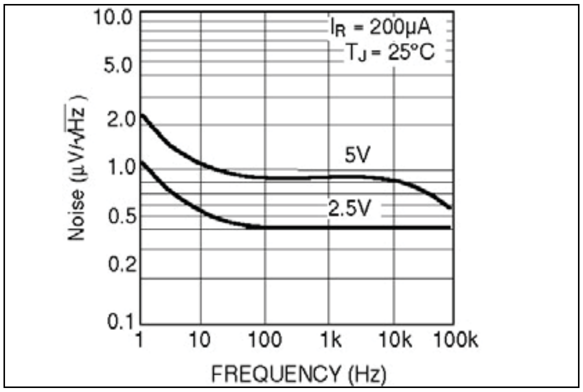


FIGURE 2-7: *LM4041 Noise Voltage vs. Frequency.*

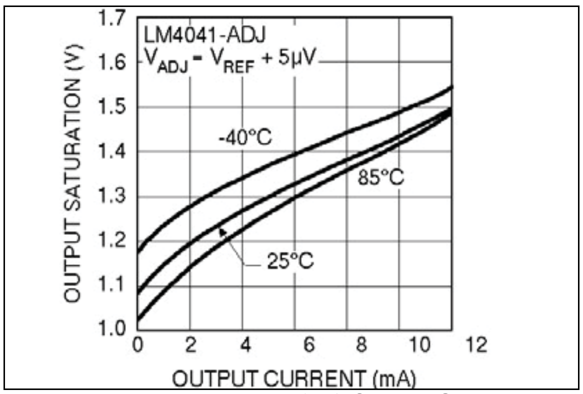


FIGURE 2-8: *LM4041 Output Saturation.*

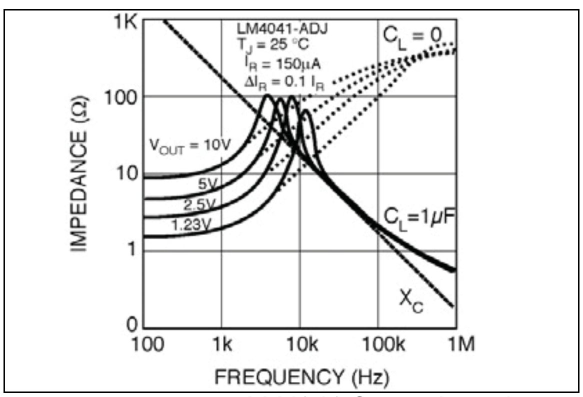


FIGURE 2-9: *LM4041 Output Impedance vs. Frequency.*

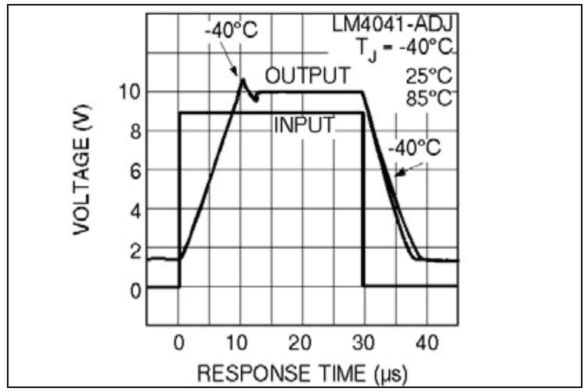


FIGURE 2-10: *LM4041 Large Signal Response.*

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin Number Fixed	Pin Number Adjustable	Pin Name	Description
1	2	+	Cathode. Connect to positive voltage.
—	1	FB	Feedback. Connect to a resistive divider network to set the output voltage.
2	3	–	Anode. Connect to negative voltage.
3	—	NC	Not internally connected. This pin must be left floating or connected to –.

4.0 APPLICATION INFORMATION

The stable operation of the LM4040 and LM4041 references require an external capacitor greater than 10 nF connected between the (+) and (–) pins. Bypass capacitors with values between 100 pF and 10 nF have been found to cause the devices to exhibit instabilities.

4.1 Schottky Diode

LM4040-x.x and LM4041-1.2 in the SOT-23 package have a parasitic Schottky diode between Pin 2 (–) and Pin 3 (die attach interface connect). Pin 3 of the SOT-23 package must float or be connected to Pin 2. The LM4041-ADJ use Pin 3 as the (–) output.

4.2 Conventional Shunt Regulator

In a conventional shunt regulator application (see Figure 5-1), an external series resistor (R_S) is connected between the supply voltage and the LM4040-x.x or LM4041-1.2 reference. R_S determines the current that flows through the load (I_L) and the reference (I_Q). Because load current and supply voltage may vary, R_S should be small enough to supply at least the minimum acceptable I_Q to the reference even when the supply voltage is at its minimum and the load current is at its maximum value. When the supply voltage is at its maximum and I_L is at its minimum, R_S should be large enough so that the current flowing through the LM4040-x.x is less than 15 mA, and the current flowing through the LM4041-1.2 or LM4041-ADJ is less than 12 mA.

R_S is determined by the supply voltage (V_S), the load and operating current, (I_L and I_Q), and the reference's reverse breakdown voltage (V_R):

EQUATION 4-1:

$$R_S = \frac{(V_S - V_R)}{(I_L + I_Q)}$$

4.3 Adjustable Regulator

The LM4041-ADJ's output voltage can be adjusted to any value between 1.24V and 10V. It is a function of the internal reference voltage (V_{REF}) and the ratio of the external feedback resistors as shown in Figure 5-2. The output is found using the following equation:

EQUATION 4-2:

$$V_O = V_{REF}[(R2/R1) + 1]$$

Where:

V_O Desired Output Voltage

The actual value of the internal V_{REF} is a function of V_O. The corrected V_{REF} is determined by:

EQUATION 4-3:

$$V_{REF} = V_O \times \left(\frac{\Delta V_{REF}}{\Delta V_O}\right) + V_Y$$

Where:

V_O Desired Output Voltage

$\Delta V_{REF}/\Delta V_O$ is found in the Electrical Characteristics section and is typically –1.3 mV/V and V_Y is equal to 1.233V. Replace the value of V_{REF} in Equation 4-2 with the value V_{REF} found using Equation 4-3.

Note that actual output voltage can deviate from that predicted using the typical $\Delta V_{REF}/\Delta V_O$ in Equation 4-3; for C-grade parts, the worst case $\Delta V_{REF}/\Delta V_O$ is –2.5 mV/V and V_Y = 1.248V.

The following example shows the difference in output voltage resulting from the typical and worst case values of $\Delta V_{REF}/\Delta V_O$.

Let V_O = +9V. Using the typical values of $\Delta V_{REF}/\Delta V_O$, V_{REF} is 1.223V. Choosing a value of R1 = 10 kΩ, R2 = 63.272 kΩ. Using the worst case $\Delta V_{REF}/\Delta V_O$ for the C-grade and D-grade parts, the output voltage is actually 8.965V and 8.946V respectively. This results in possible errors as large as 0.39% for the C-grade parts and 0.59% for the D-grade parts. Once again, resistor values found using the typical value of $\Delta V_{REF}/\Delta V_O$ will work in most cases, requiring no further adjustment.

5.0 TYPICAL APPLICATION CIRCUITS

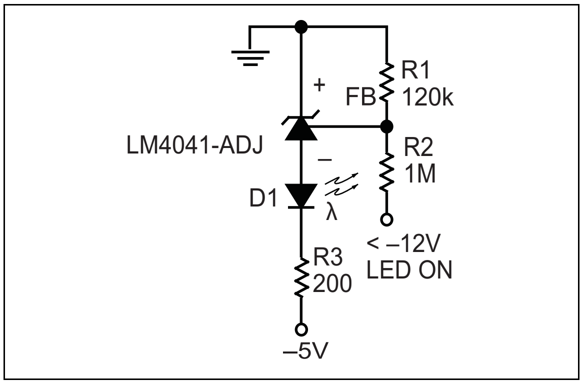


FIGURE 5-1: *Voltage Level Detector.*

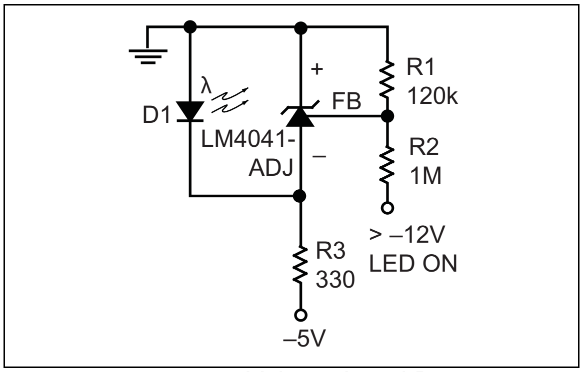


FIGURE 5-2: *Voltage Level Detector.*

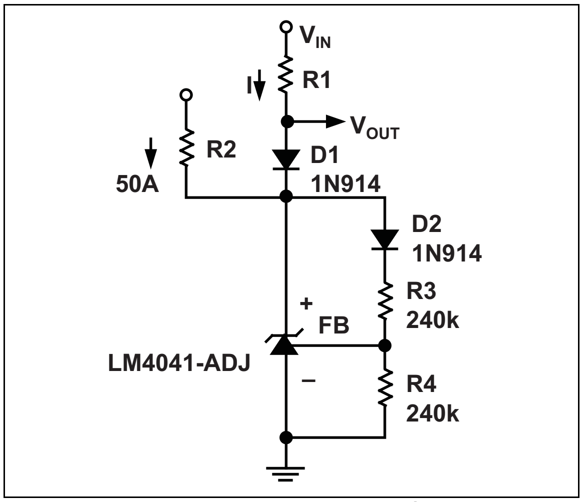


FIGURE 5-3: *Fast Positive Clamp, 2.4V + ΔV_{D1}.*

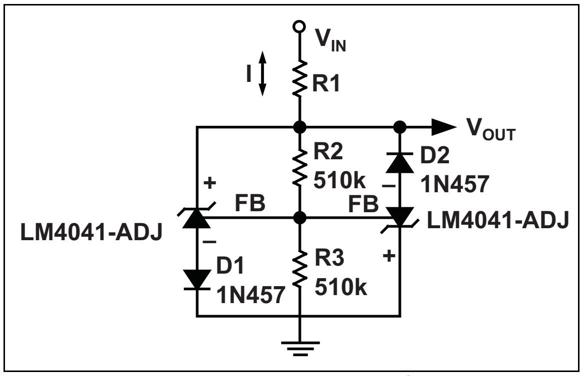


FIGURE 5-4: *Bidirectional Clamp ±2.4V.*

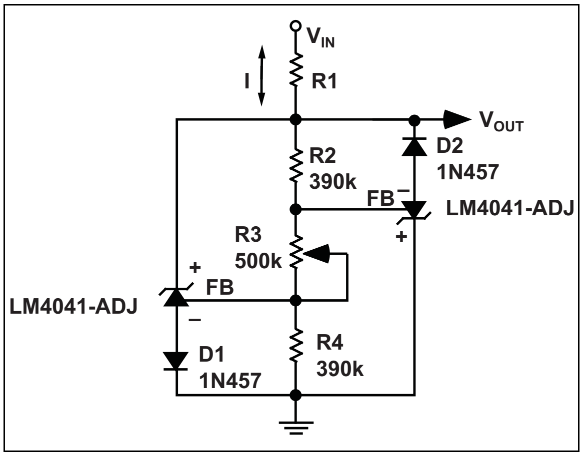


FIGURE 5-5: *Bidirectional Adjustable Clamp ±1.8V to ±2.4V.*

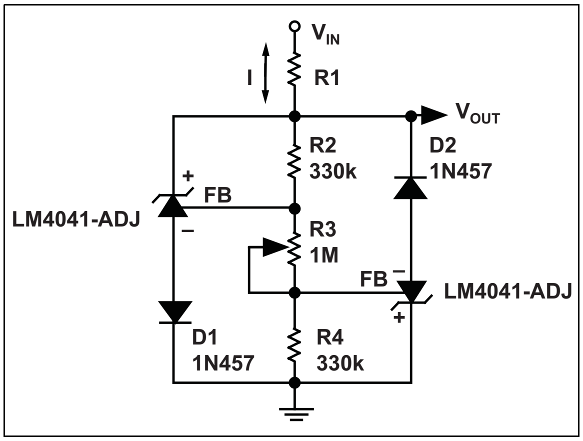


FIGURE 5-6: *Bidirectional Adjustable Clamp ±2.4V to ±6V.*

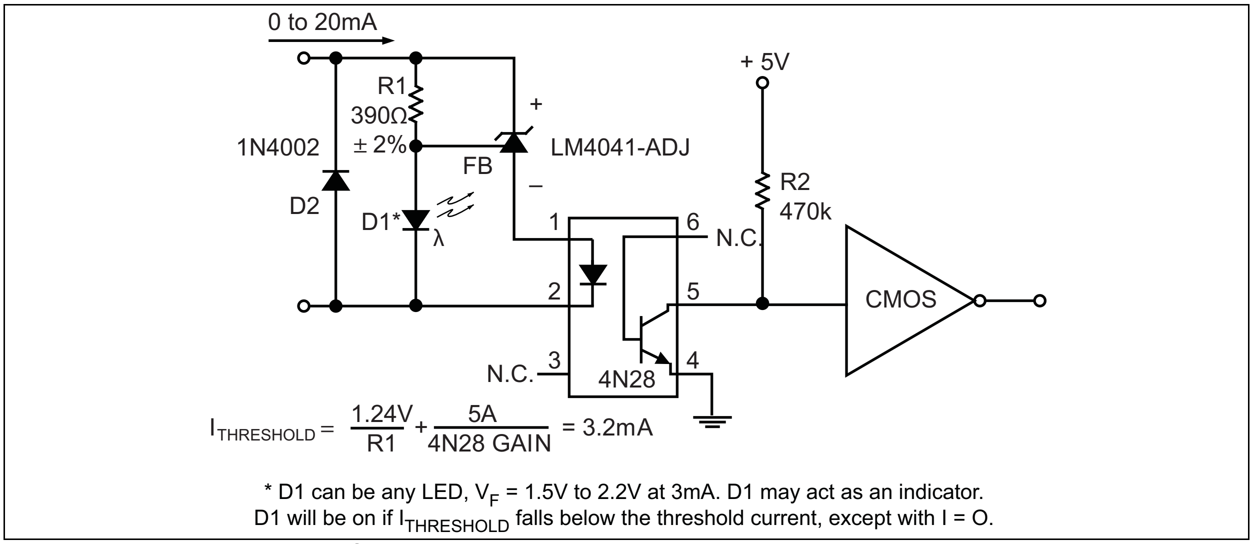


FIGURE 5-7: *Floating Current Detector.*

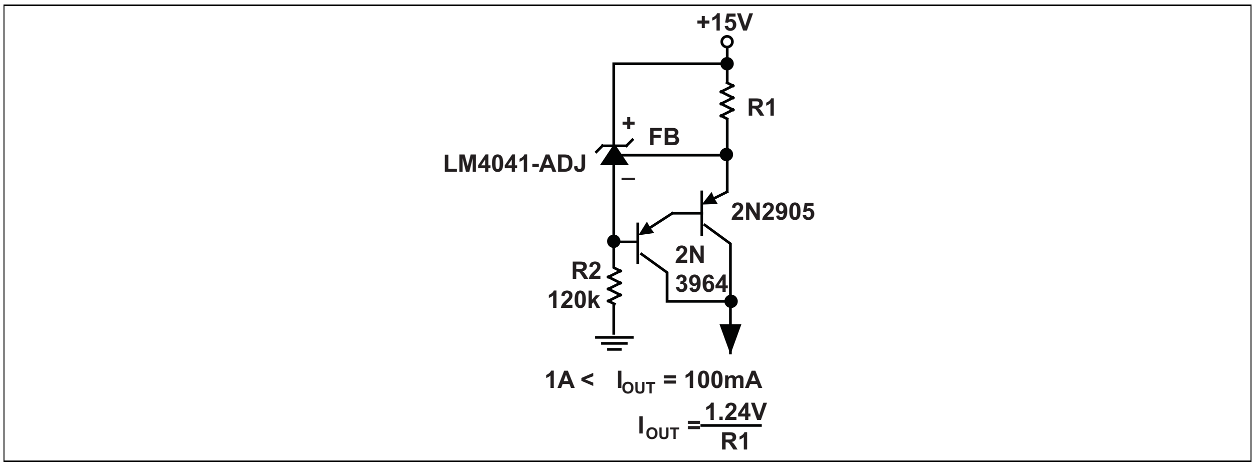


FIGURE 5-8: *Current Source.*

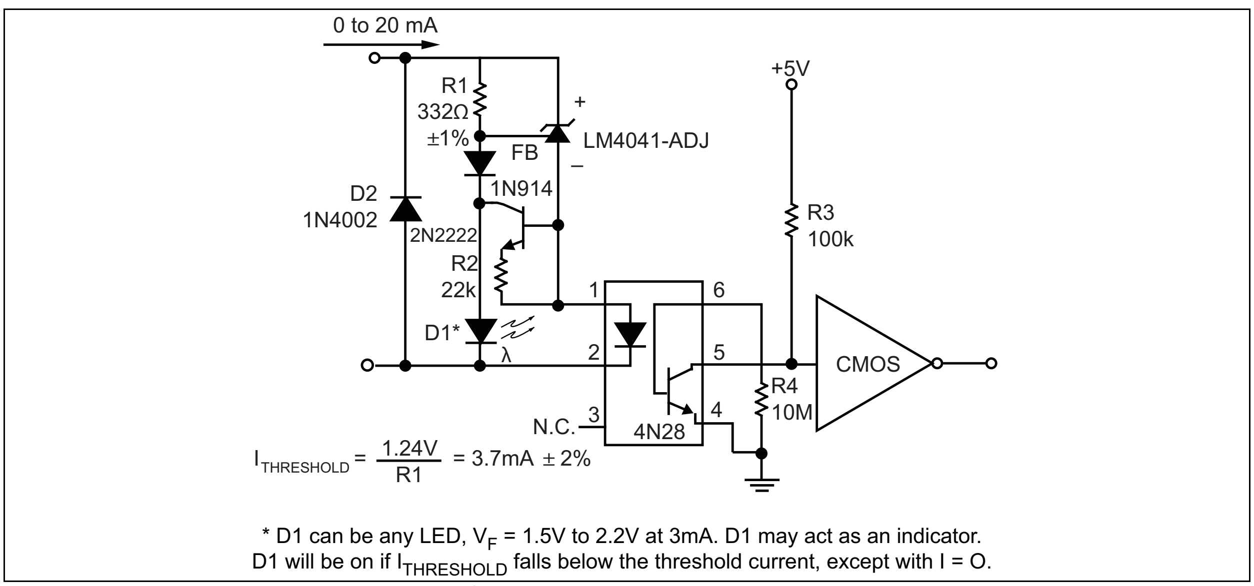
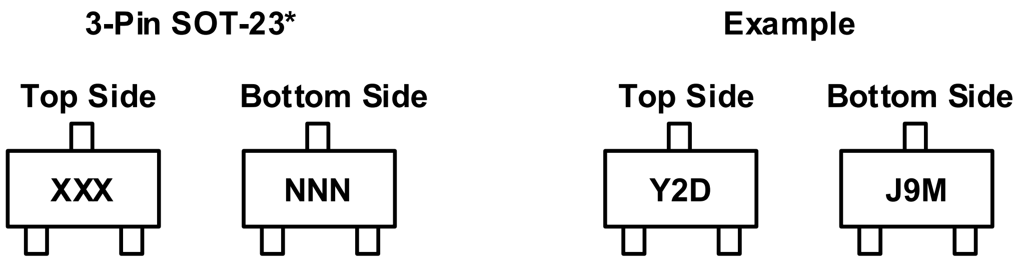


FIGURE 5-9: *Precision Floating Current Detector.*

6.0 PACKAGING INFORMATION

6.1 Package Marking Information



Device	Top Side Marking
LM4040CYM3-2.5-TR	Y2C
LM4040CYM3-4.1-TR	Y4C
LM4040CYM3-5.0-TR	Y5C
LM4040DYM3-2.5-TR	Y2D
LM4040DYM3-4.1-TR	Y4D
LM4040DYM3-5.0-TR	Y5D
LM4041CYM3-ADJ-TR	YAC
LM4041CYM3-1.2-TR	Y1C
LM4041DYM3-ADJ-TR	YAD
LM4041DYM3-1.2-TR	Y1D

Legend:	XX...X	Product code or customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	e3	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.
	●, ▲, ▼	Pin one index is identified by a dot, delta up, or delta down (triangle mark).

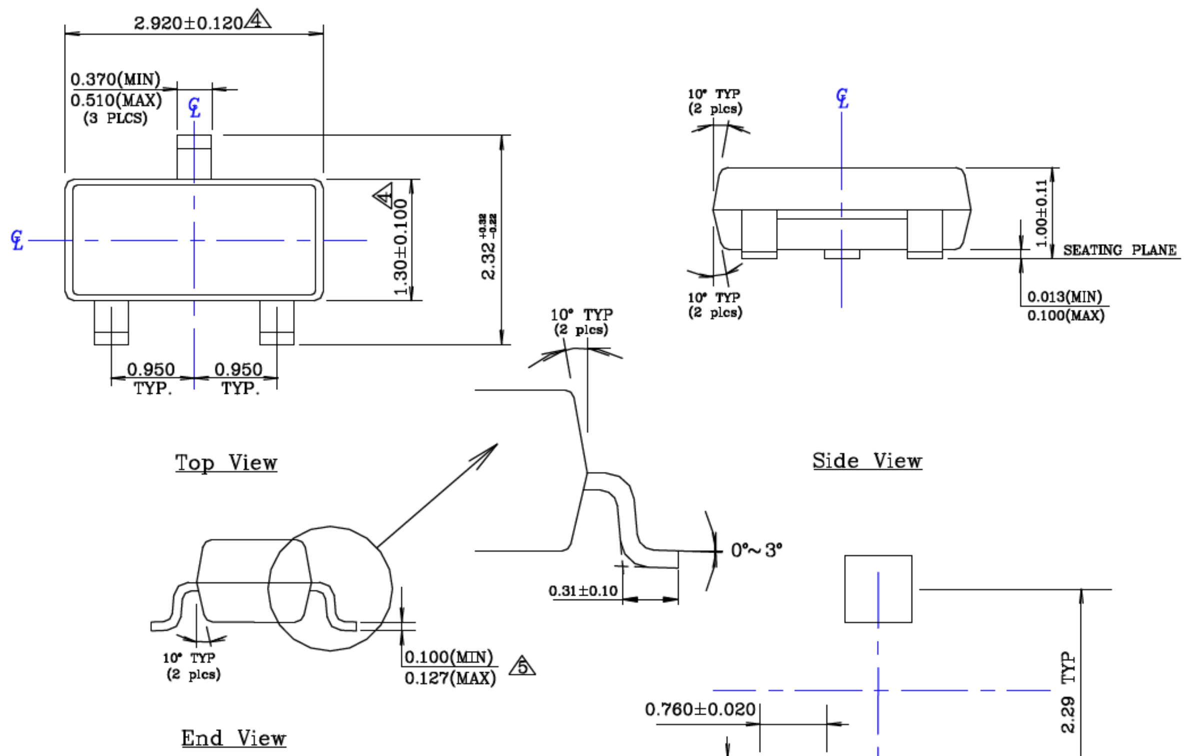
Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.

Underbar (_) and/or Overbar (‾) symbol may not be to scale.

3-Lead SOT-23 Package Outline and Recommended Land Pattern

TITLE
3 LEAD SOT23 PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	SOT23-3LD-PL-1	UNIT	MM



NOTE:

1. All dimensions are in millimeters.
2. Package surface to be matte finish VDI 11~13. Y14.5M, 1982.
3. Die is facing up for mold & trim/form.

4. Dimension are exclusive mold flash and gate burr.

5. Dimension are exclusive solder plating.

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging.

NOTES:

APPENDIX A: REVISION HISTORY

Revision A (April 2017)

- Converted Micrel data sheet LM4040/LM4041 to Microchip DS20005757A.
- Minor text changes throughout.
- Updated temperature information in all Electrical Characteristics tables to better reflect which values are valid for T_A = +25°C.

Revision B (July 2018)

- Corrected part number for Reverse Current in Operating Ratings ‡ to LM4041-ADJ.
- Updated **Section 6.1 "Package Marking Information"** drawing and information.
- Updated information in Product Identification System.
- Updated "Reverse-Breakdown Voltage Change with Operating Current Change" conditions for LM4041-1.2 Electrical Characteristics (Note 1) and LM4041-ADJ Electrical Characteristics (Note 1).

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

PART NO.	X	X	XX	-X.X	-XX
Device	Accuracy, Temperature Coefficient	Temperature Range	Package	Voltage	Media Type

Device:	LM4040:		Precision Micropower Shunt Voltage Reference
	LM4041:		Precision Micropower Shunt Voltage Reference
Accuracy, Temp. Coefficient:	C	=	±0.5%, 100 ppm/°C
	D	=	±1.0%, 150 ppm/°C
Temperature Range:	Y	=	–40°C to +85°C (Industrial)
Package:	M3	=	3-Lead SOT-23
Voltage:	-2.5	=	2.500V
	-4.1	=	4.096V
	-5.0	=	5.000V
	-1.2	=	1.225V (LM4041 Only)
	ADJ	=	1.24V to 10V (LM4041 Only)
Media Type	TR	=	3,000/Reel

Examples:

a) LM4040CYM3-2.5-TR: LM4040, ±0.5%, 100 ppm/°C, –40°C to +85°C Temp. Range, 3-Lead SOT-23, 2.500V, 3,000/Reel

b) LM4040CYM3-4.1-TR: LM4040, ±0.5%, 100 ppm/°C, –40°C to +85°C Temp. Range, 3-Lead SOT-23, 4.096V, 3,000/Reel

c) LM4040CYM3-5.0-TR: LM4040, ±0.5%, 100 ppm/°C, –40°C to +85°C Temp. Range, 3-Lead SOT-23, 5.000V, 3,000/Reel

d) LM4040DYM3-2.5-TR: LM4040, ±1.0%, 150 ppm/°C, –40°C to +85°C Temp. Range, 3-Lead SOT-23, 2.500V, 3,000/Reel

e) LM4040DYM3-4.1-TR: LM4040, ±1.0%, 150 ppm/°C, –40°C to +85°C Temp. Range, 3-Lead SOT-23, 4.096V, 3,000/Reel

f) LM4040DYM3-5.0-TR: LM4040, ±1.0%, 150 ppm/°C, –40°C to +85°C Temp. Range, 3-Lead SOT-23, 5.000V, 3,000/Reel

g) LM4041CYM3-ADJ-TR: LM4041, ±0.5%, 100 ppm/°C, –40°C to +85°C Temp. Range, 3-Lead SOT-23, 1.24V to 10V, 3,000/Reel

h) LM4041CYM3-1.2-TR: LM4041, ±0.5%, 100 ppm/°C, –40°C to +85°C Temp. Range, 3-Lead SOT-23, 1.225V, 3,000/Reel

i) LM4041DYM3-ADJ-TR: LM4041, ±1.0%, 150 ppm/°C, –40°C to +85°C Temp. Range, 3-Lead SOT-23, 1.24V to 10V, 3,000/Reel

j) LM4041DYM3-1.2-TR: LM4041, ±1.0%, 150 ppm/°C, –40°C to +85°C Temp. Range, 3-Lead SOT-23, 1.225V, 3,000/Reel

Note 1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

NOTES:

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE**.** Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

QUALITY MANAGEMENT SYSTEM CERTIFIED BY DNV

== ISO/TS 16949 ==

Trademarks

The Microchip name and logo, the Microchip logo, AnyRate, AVR, AVR logo, AVR Freaks, BitCloud, chipKIT, chipKIT logo, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, Heldo, JukeBlox, KeeLoq, Kleer, LANCheck, LINK MD, maXStylus, maXTouch, MediaLB, megaAVR, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, Prochip Designer, QTouch, SAM-BA, SpyNIC, SST, SST Logo, SuperFlash, tinyAVR, UNI/O, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

ClockWorks, The Embedded Control Solutions Company, EtherSynch, Hyper Speed Control, HyperLight Load, IntelliMOS, mTouch, Precision Edge, and Quiet-Wire are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, BodyCom, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, EtherGREEN, In-Circuit Serial Programming, ICSP, INICnet, Inter-Chip Connectivity, JitterBlocker, KleerNet, KleerNet logo, memBrain, Mindi, MiWi, motorBench, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, PowerSmart, PureSilicon, QMatrix, REAL ICE, Ripple Blocker, SAM-ICE, Serial Quad I/O, SMART-I.S., SQI, SuperSwitcher, SuperSwitcher II, Total Endurance, TSHARC, USBCheck, VariSense, ViewSpan, WiperLock, Wireless DNA, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

ISBN: 978-1-5224-3309-5

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http://www.microchip.com/support
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453
Tel: 317-536-2380

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608
Tel: 951-273-7800

Raleigh, NC
Tel: 919-844-7510

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110
Tel: 408-436-4270

Canada - Toronto
Tel: 905-695-1980
Fax: 905-695-2078

ASIA/PACIFIC

Australia - Sydney
Tel: 61-2-9868-6733

China - Beijing
Tel: 86-10-8569-7000

China - Chengdu
Tel: 86-28-8665-5511

China - Chongqing
Tel: 86-23-8980-9588

China - Dongguan
Tel: 86-769-8702-9880

China - Guangzhou
Tel: 86-20-8755-8029

China - Hangzhou
Tel: 86-571-8792-8115

China - Hong Kong SAR
Tel: 852-2943-5100

China - Nanjing
Tel: 86-25-8473-2460

China - Qingdao
Tel: 86-532-8502-7355

China - Shanghai
Tel: 86-21-3326-8000

China - Shenyang
Tel: 86-24-2334-2829

China - Shenzhen
Tel: 86-755-8864-2200

China - Suzhou
Tel: 86-186-6233-1526

China - Wuhan
Tel: 86-27-5980-5300

China - Xian
Tel: 86-29-8833-7252

China - Xiamen
Tel: 86-592-2388138

China - Zhuhai
Tel: 86-756-3210040

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-3090-4444

India - New Delhi
Tel: 91-11-4160-8631

India - Pune
Tel: 91-20-4121-0141

Japan - Osaka
Tel: 81-6-6152-7160

Japan - Tokyo
Tel: 81-3-6880- 3770

Korea - Daegu
Tel: 82-53-744-4301

Korea - Seoul
Tel: 82-2-554-7200

Malaysia - Kuala Lumpur
Tel: 60-3-7651-7906

Malaysia - Penang
Tel: 60-4-227-8870

Philippines - Manila
Tel: 63-2-634-9065

Singapore
Tel: 65-6334-8870

Taiwan - Hsin Chu
Tel: 886-3-577-8366

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600

Thailand - Bangkok
Tel: 66-2-694-1351

Vietnam - Ho Chi Minh
Tel: 84-28-5448-2100

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

Finland - Espoo
Tel: 358-9-4520-820

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Garching
Tel: 49-8931-9700

Germany - Haan
Tel: 49-2129-3766400

Germany - Heilbronn
Tel: 49-7131-67-3636

Germany - Karlsruhe
Tel: 49-721-625370

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Germany - Rosenheim
Tel: 49-8031-354-560

Israel - Ra'anana
Tel: 972-9-744-7705

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Padova
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Norway - Trondheim
Tel: 47-7289-7561

Poland - Warsaw
Tel: 48-22-3325737

Romania - Bucharest
Tel: 40-21-407-87-50

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Gothenberg
Tel: 46-31-704-60-40

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820

10/25/17