CAT524

Configured Digitally Programmable Potentiometer (DPP™): Programmable Voltage Applications

FEATURES

- **Four 8-bit DPPs configured as programmable voltage sources in DAC-like applications**
- **Common reference inputs**
- **Buffered wiper outputs**
- **Non-volatile NVRAM memory wiper storage**
- **Output voltage range includes both supply rails**
- **4 independently addressable buffered output wipers**
- **1 LSB accuracy, high resolution**
- **Serial µP interface**
- **Single supply operation: 2.7V-5.5V**
- **Setting read-back without effecting outputs**

APPLICATIONS

- **Automated product calibration**
- **Remote control adjustment of equipment**
- **Offset, gain and zero adjustments in self-calibrating and adaptive control systems**
- **Tamper-proof calibrations**
- **DAC (with memory) substitute**

DESCRIPTION

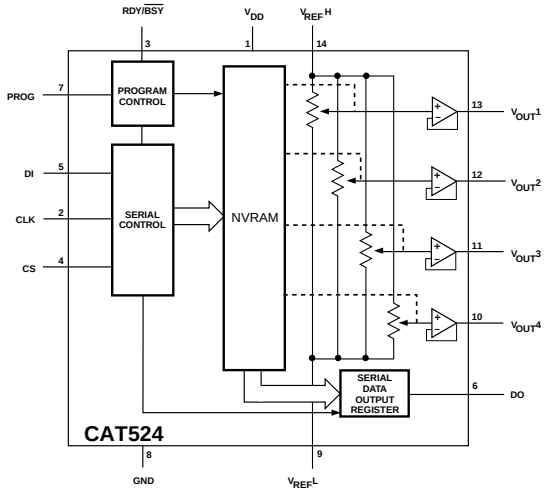
The CAT524 is a quad, 8-bit digitally-programmable potentiometer (DPP™) configured for programmable voltage and DAC-like applications. Intended for final calibration of products such as camcorders, fax machines and cellular telephones on automated high volume production lines, it is also well suited for self-calibrating systems and for applications where equipment which requires periodic adjustment is either difficult to access or in a hazardous environment.

The four independently programmable DPPs have an output range which includes both supply rails. The wipers are buffered by rail to rail op amps. Wiper settings, stored in non-volatile NVRAM memory, are not lost when the device is powered down and are automatically reinstated when power is returned. Each wiper can be dithered to test new output values without effecting the stored settings, and stored settings can be read back without disturbing the DPP's output.

The CAT524 is controlled with a simple 3 wire serial interface. A Chip Select pin allows several devices to share a common serial interface. Communication back to the host controller is via a single serial data line thanks to the Tri-Stated CAT524 Data Output pin. A RDY/$\overline{\text{BSY}}$ output working in concert with an internal low voltage detector signals proper operation of the non-volatile NVRAM memory Erase/Write cycle.

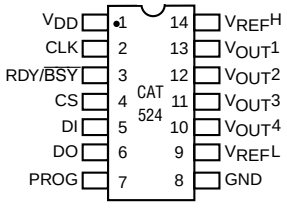
The CAT524 is available in the 0 to 70° C commercial and –40° C to 85° C industrial operating temperature ranges. Both 14-pin plastic DIP and SOIC packages are offered.

FUNCTIONAL DIAGRAM

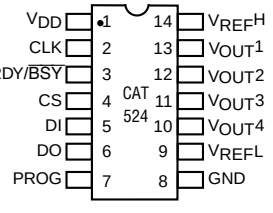


PIN CONFIGURATION

DIP Package (P)



SOIC Package (J)



Doc. No. 25076-00 4/01 M-1

ABSOLUTE MAXIMUM RATINGS*

Supply Voltage
- V_{DD} to GND ..... –0.5V to +7V

Inputs
- CLK to GND ..... –0.5V to V_{DD} +0.5V
- CS to GND ..... –0.5V to V_{DD} +0.5V
- DI to GND ..... –0.5V to V_{DD} +0.5V
- PROG to GND ..... –0.5V to V_{DD} +0.5V
- $V_{REF}H$ to GND ..... –0.5V to V_{DD} +0.5V
- $V_{REF}L$ to GND ..... –0.5V to V_{DD} +0.5V

Outputs
- D_0 to GND ..... –0.5V to V_{DD} +0.5V
- V_{OUT} 1– 4 to GND ..... –0.5V to V_{DD} +0.5V

Operating Ambient Temperature
- Commercial ('C' or Blank suffix) ..... 0°C to +70°C
- Industrial ('I' suffix) ..... – 40°C to +85°C

Junction Temperature ..... +150°C
Storage Temperature ..... –65°C to +150°C
Lead Soldering (10 sec max) ..... +300°C

* Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. Absolute Maximum Ratings are limited values applied individually while other parameters are within specified operating conditions, and functional operation at any of these conditions is NOT implied. Device performance and reliability may be impaired by exposure to absolute rating conditions for extended periods of time.

RELIABILITY CHARACTERISTICS

Symbol	Parameter	Min	Max	Units	Test Method
V_{ZAP}(1)	ESD Susceptibility	2000		Volts	MIL-STD-883, Test Method 3015
I_{LTH}(1)(2)	Latch-Up	100		mA	JEDEC Standard 17

NOTES: 1. This parameter is tested initially and after a design or process change that affects the parameter.
2. Latch-up protection is provided for stresses up to 100mA on address and data pins from –1V to V_{CC} + 1V.

DC ELECTRICAL CHARACTERISTICS:

V_{DD} = +2.7 to +5.5V, $V_{REF}H$ = V_{DD}, $V_{REF}L$ = 0V, unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
	Resolution		8	—	—	Bits
Accuracy						
INL	Integral Linearity Error	I_{LOAD} = 10 µA T_R = C	—	—	± 1	LSB
		I_{LOAD} = 10 µA T_R = I	—	—	± 1	LSB
		I_{LOAD} = 40 µA T_R = C	—	—	± 2	LSB
		I_{LOAD} = 40 µA T_R = I	—	—	± 2	LSB
DNL	Differential Linearity Error	I_{LOAD} = 10 µA T_R = C	—	—	± 0.5	LSB
		I_{LOAD} = 10 µA T_R = I	—	—	± 0.5	LSB
		I_{LOAD} = 40 µA T_R = C	—	—	± 1.5	LSB
		I_{LOAD} = 40 µA T_R = I	—	—	± 1.5	LSB
Logic Inputs						
I_{IH}	Input Leakage Current	V_{IN} = V_{DD}	—	—	10	µA
I_{IL}	Input Leakage Current	V_{IN} = 0V	—	—	–10	µA
V_{IH}	High Level Input Voltage		2	—	V_{DD}	V
V_{IL}	Low Level Input Voltage		0	—	0.8	V
V_{RH}	$V_{REF}H$ Input Voltage Range		2.7	—	V_{DD}	V
V_{RL}	$V_{REF}L$ Input Voltage Range		GND	—	V_{DD} -2.7	V
Z_{IN}	$V_{REF}H$–$V_{REF}L$ Resistance		—	7	—	kΩ
V_{OH}	High Level Output Voltage	I_{OH} = – 40 µA	V_{DD} –0.3	—	—	V
V_{OL}	Low Level Output Voltage	I_{OL} = 1 mA, V_{DD} = +5V	—	—	0.4	V
		I_{OL} = 0.4 mA, V_{DD} = +3V	—	—	0.4	V

DC ELECTRICAL CHARACTERISTICS (Cont.)**:**
V_{DD} = +2.7V to +5.5V , $V_{REF}H$ = +V_{DD}, $V_{REF}L$ = 0V, unless otherwise specified

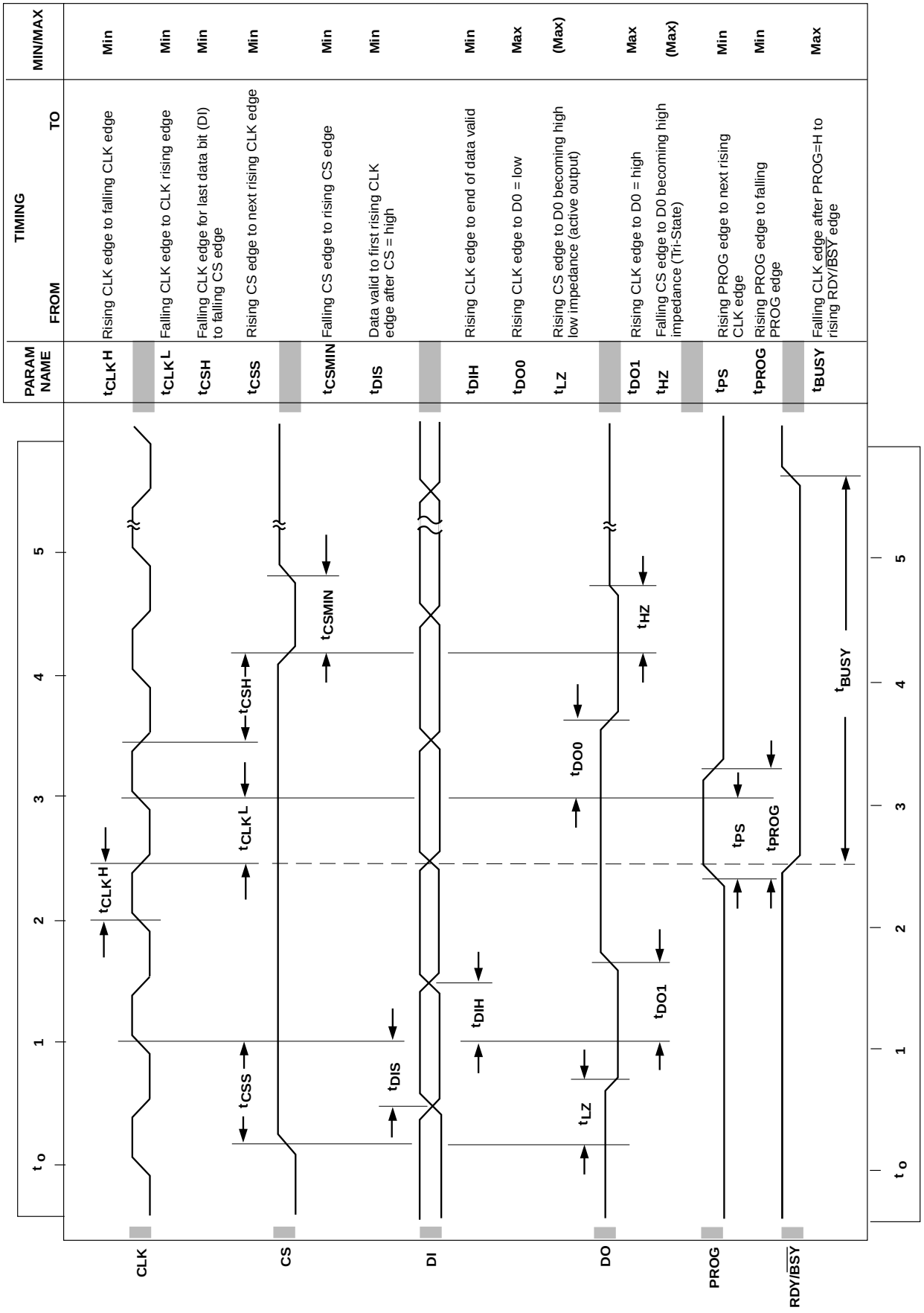
Symbol	Parameter	Conditions	Min	Typ	Max	Units
Analog Output						
FSO	Full-Scale Output Voltage	$V_R = V_{REF}H–V_{REF}L$	0.99 V_R	0.995 V_R	—	V
ZSO	Zero-Scale Output Voltage	$V_R = V_{REF}H–V_{REF}L$	—	0.005 V_R	0.01 V_R	V
I_L	DAC Output Load Current		—	—	1	µA
R_{OUT}	DAC Output Impedance	V_{DD} = +5V	—	—	100	kΩ
		V_{DD} = +3V	—	—	150	kΩ
PSSR	Power Supply Rejection	I_{LOAD} = 250 nA	—	—	1	LSB / V
Temperature						
TC_O	V_{OUT} Temperature Coefficient	$V_{REF}H$ = +5V, $V_{REF}L$ = 0V	—	—	200	µV/ °C
		V_{DD} = +5V, I_{LOAD} = 250nA				
TC_{REF}	Temperature Coefficient of	$V_{REF}H$ to $V_{REF}L$	—	700	—	ppm / °C
	V_{REF} Resistance					
Power Supply						
I_{DD1}	Supply Current (Read)	Normal Operating	—	400	600	µA
I_{DD2}	Supply Current (Write)	V_{DD}=5V	—	1600	2500	µA
		V_{DD}=3V	—	1000	1600	µA
V_{DD}	Operating Voltage Range		2.7	—	5.5	V

AC ELECTRICAL CHARACTERISTICS:
V_{DD} = +2.7V to +5.5V, $V_{REF}H$ = +V_{DD}, $V_{REF}L$ = 0V, unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Digital						
t_{CSMIN}	Minimum CS Low Time		150	—	—	ns
t_{CSS}	CS Setup Time		100	—	—	ns
t_{CSH}	CS Hold Time	C_L = 100 pF, see note 1	0	—	—	ns
t_{DIS}	DI Setup Time		50	—	—	ns
t_{DIH}	DI Hold Time		50	—	—	ns
t_{DO1}	Output Delay to 1		—	—	150	ns
t_{DO0}	Output Delay to 0		—	—	150	ns
t_{HZ}	Output Delay to High-Z		—	400	—	ns
t_{Busy}	Erase/Write Cycle Time		—	4	5	ms
t_{LZ}	Output Delay to Low-Z		—	400	—	ns
t_{PROG}	Erase/Write Pulse Width		700	—	—	ns
t_{PS}	PROG Setup Time		150	—	—	ns
$t_{CLK}H$	Minimum CLK High Time		500	—	—	ns
$t_{CLK}L$	Minimum CLK Low Time		300	—	—	ns
f_C	Clock Frequency		DC	—	1	MHz
Analog						
t_{DS}	DAC Settling Time to 1/2 LSB	C_{LOAD} = 10 pF, V_{DD} = +5V	—	3	10	µs
		C_{LOAD} = 10 pF, V_{DD} = +3V	—	6	10	µs
Pin Capacitance						
C_{IN}	Input Capacitance	V_{IN} = 0V, f = 1 MHz(2)	—	8	—	pF
C_{OUT}	Output Capacitance	V_{OUT} = 0V, f = 1 MHz(2)	—	6	—	pF

NOTES: 1. All timing measurements are defined at the point of signal crossing V_{DD} / 2.
2. These parameters are periodically sampled and are not 100% tested.

A. C. TIMING DIAGRAM



PIN DESCRIPTION

Pin	Name	Function
1	V_{DD}	Power supply positive.
2	CLK	Clock input pin.Clock input pin.
3	RDY/$\overline{BSY}$	Ready/Busy Output
4	CS	Chip Select
5	DI	Serial data input pin.
6	DO	Serial data output pin.
7	PROG	EEPROM Programming Enable Input
8	GND	Power supply ground.
9	$V_{REF}L$	Minimum DAC output voltage.
10	$V_{OUT}4$	DAC output channel 4.
11	$V_{OUT}3$	DAC output channel 3.
12	$V_{OUT}2$	DAC output channel 2.
13	$V_{OUT}1$	DAC output channel 1.
14	$V_{REF}H$	Maximum DAC output voltage.

DAC addressing is as follows:

DAC OUTPUT	A0	A1
$V_{OUT}1$	0	0
$V_{OUT}2$	1	0
$V_{OUT}3$	0	1
$V_{OUT}4$	1	1

DEVICE OPERATION

The CAT524 is a quad 8-bit Digital to Analog Converter (DAC) whose outputs can be programmed to any one of 256 individual voltage steps. Once programmed, these output settings are retained in non-volatile EEPROM memory and will not be lost when power is removed from the chip. Upon power up the DACs return to the settings stored in EEPROM memory. Each DAC can be written to and read from independently without effecting the output voltage during the read or write cycle. Each output can also be temporarily adjusted without changing the stored output setting, which is useful for testing new output settings before storing them in memory.

DIGITAL INTERFACE

The CAT524 employs a standard 3 wire serial control interface consisting of Clock (CLK), Chip Select (CS) and Data In (DI) inputs. For all operations, address and data are shifted in LSB first. In addition, all digital data must be preceded by a logic “1” as a start bit. The DAC address and data are clocked into the DI pin on the clock’s rising edge. When sending multiple blocks of information a minimum of two clock cycles is required between the last block sent and the next start bit.

Multiple devices may share a common input data line by selectively activating the CS control of the desired IC. Data Outputs (DO) can also share a common line because the DO pin is Tri-Stated and returns to a high impedance when not in use.

CHIP SELECT

Chip Select (CS) enables and disables the CAT524’s read and write operations. When CS is high data may be read to or from the chip, and the Data Output (DO) pin is active. Data loaded into the DAC control registers will remain in effect until CS goes low. Bringing CS to a logic low returns all DAC outputs to the settings stored in EEPROM memory and switches DO to its high impedance Tri-State mode.

Because CS functions like a reset the CS pin has been equipped with a 30 ns to 90 ns filter circuit to prevent noise spikes from causing unwanted resets and the loss of volatile data.

CLOCK

The CAT524’s clock controls both data flow in and out of the IC and EEPROM memory cell programming. Serial data is shifted into the DI pin and out of the DO pin on the clock’s rising edge. While it is not necessary for the clock to be running between data transfers, the clock must be operating in order to write to EEPROM memory, even though the data being saved may already be resident in the DAC control register.

No clock is necessary upon system power-up. The CAT524’s internal power-on reset circuitry loads data from EEPROM to the DACs without using the external clock.

As data transfers are edge triggered clean clock transitions are necessary to avoid falsely clocking data into the control registers. Standard CMOS and TTL logic families work well in this regard and it is recommended that any mechanical switches used for breadboarding or device evaluation purposes be debounced by a flip-flop or other suitable debouncing circuit.

V_{REF}

V_{REF}, the voltage applied between pins $V_{REF}H$ and $V_{REF}L$, sets the DAC's Zero to Full Scale output range where $V_{REF}L$ = Zero and $V_{REF}H$ = Full Scale. V_{REF} can span the full power supply range or just a fraction of it. In typical applications $V_{REF}H$ and $V_{REF}L$ are connected across the power supply rails. When using less than the full supply voltage $V_{REF}H$ is restricted to voltages between V_{DD} and $V_{DD}/2$ and $V_{REF}L$ to voltages between GND and $V_{DD}/2$.

READY/$\overline{BUSY}$

When saving data to non-volatile EEPROM memory, the Ready/Busy ouput (RDY/$\overline{BSY}$) signals the start and duration of the EEPROM erase/write cycle. Upon receiving a command to store data (PROG goes high) RDY/$\overline{BSY}$ goes low and remains low until the programming cycle is complete. During this time the CAT524 will ignore any data appearing at DI and no data will be output on DO.

RDY/$\overline{BSY}$ is internally ANDed with a low voltage detector circuit monitoring V_{DD}. If V_{DD} is below the minimum value required for EEPROM programming, RDY/$\overline{BSY}$ will remain high following the program command indicating a failure to record the desired data in non-volatile memory.

DATA OUTPUT

Data is output serially by the CAT524, LSB first, via the Data Out (DO) pin following the reception of a start bit and two address bits by the Data Input (DI). DO becomes active whenever CS goes high and resumes its high impedance Tri-State mode when CS returns low. Tri-Stating the DO pin allows several 524s to share a single serial data line and simplifies interfacing multiple 524s to a microprocessor.

WRITING TO MEMORY

Programming the CAT524's EEPROM memory is accomplished through the control signals: Chip Select (CS) and Program (PROG). With CS high, a start bit followed by a two bit DAC address and eight data bits are clocked into the DAC control register via the DI pin. Data enters on the clock's rising edge. The DAC output changes to its new setting on the clock cycle following D7, the last data bit.

Programming is achieved by bringing PROG high for a minimum of 3 ms. PROG must be brought high sometime after the start bit and at least 150 ns prior to the rising edge of the clock cycle immediately following the D7 bit. Two clock cycles after the D7 bit the DAC control register will be ready to receive the next set of address and data bits. The clock must be kept running throughout the programming cycle. Internal control circuitry takes care of ramping the programming voltage for data transfer to the EEPROM cells. The CAT524 EEPROM memory cells will endure over 100,000 write cycles and will retain data for a minimum of 20 years without being refreshed.

READING DATA

Each time data is transferred into a DAC control register currently held data is shifted out via the D0 pin, thus in every data transaction a read cycle occurs. Note, however, that the reading process is destructive. Data must be removed from the register in order to be read. Figure 2 depicts a Read Only cycle in which no change occurs in the DAC's output. This feature allows µPs to poll DACs for their current setting without disturbing the output voltage but it assumes that the setting being read is also stored in EEPROM so that it can be restored at the end of the read cycle. In Figure 2 CS returns low before the 13th clock cycle completes. In doing so the EEPROM's setting is reloaded into the DAC control register. Since

Figure 1. Writing to Memory

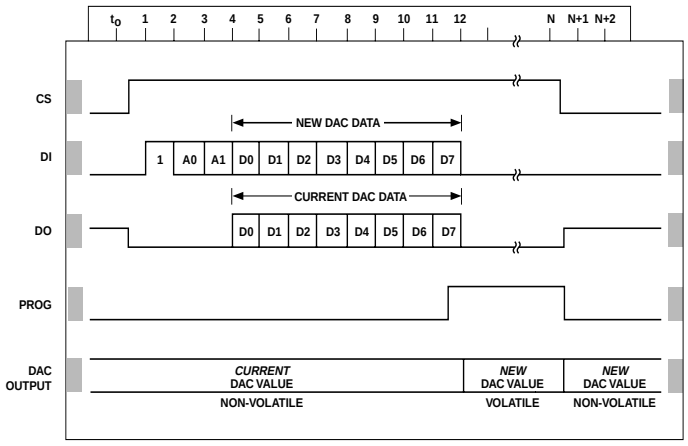
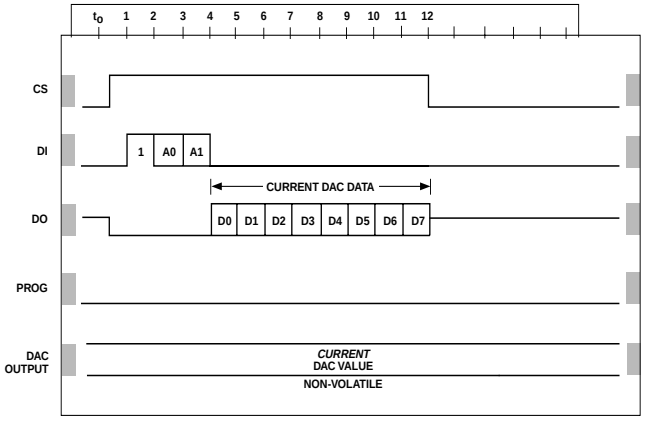


Figure 2. Reading from Memory



this value is the same as that which had been there previously no change in the DAC's output is noticed. Had the value held in the control register been different from that stored in EEPROM then *a change would occur* at the read cycle's conclusion.

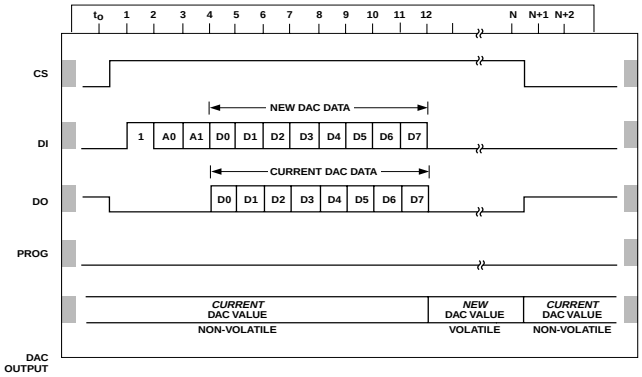
TEMPORARILY CHANGE OUTPUT

The CAT524 allows temporary changes in DAC's output to be made without disturbing the settings retained in EEPROM memory. This feature is particularly useful when testing for a new output setting and allows for user adjustment of preset or default values without losing the original factory settings.

Figure 3 shows the control and data signals needed to effect a temporary output change. DAC settings may be changed as many times as required and can be made to any of the four DACs in any order or sequence. The temporary setting(s) remain in effect long as CS remains high. When CS returns low all four DACs will return to the output values stored in EEPROM memory.

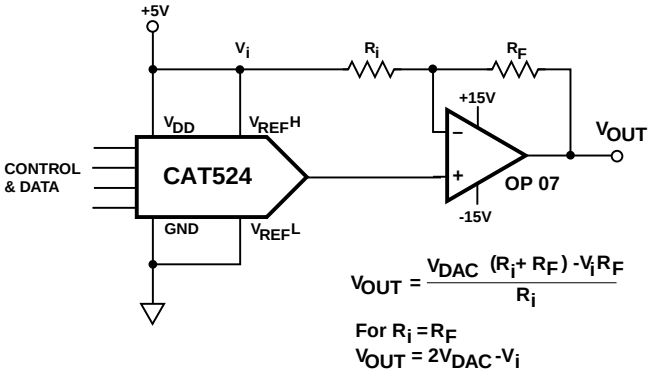
When it is desired to save a new setting acquired using this feature, the new value must be reloaded into the DAC control register prior to programming. This is because the CAT524's internal control circuitry discards the new data from the programming register two clock cycles after receiving it (after reception is complete) if no PROG signal is received.

Figure 3. Temporary Change in Output

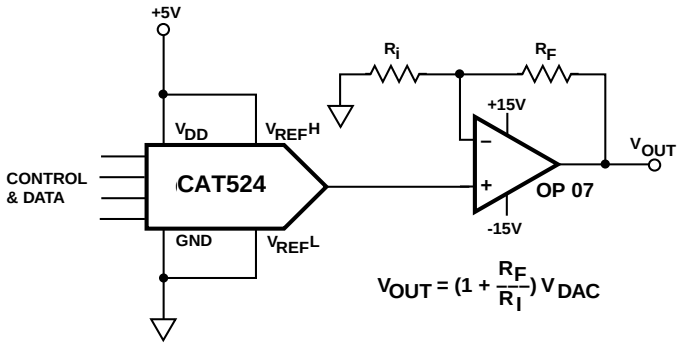


APPLICATION CIRCUITS

DAC INPUT MSB	DAC INPUT LSB	DAC OUTPUT $V_{DAC} = \frac{CODE}{255}(V_{FS} - V_{ZERO}) + V_{ZERO}$ $V_{FS} = 0.99\,V_{REF}$ $V_{ZERO} = 0.01\,V_{REF}$	ANALOG OUTPUT $V_{REF} = 5V$ $R_I = R_F$
1111	1111	$\frac{255}{255}(.98\,V_{REF}) + .01\,V_{REF} = .990\,V_{REF}$	$V_{OUT} = +4.90V$
1000	0000	$\frac{128}{255}(.98\,V_{REF}) + .01\,V_{REF} = .502\,V_{REF}$	$V_{OUT} = +0.02V$
0111	1111	$\frac{127}{255}(.98\,V_{REF}) + .01\,V_{REF} = .498\,V_{REF}$	$V_{OUT} = -0.02V$
0000	0001	$\frac{1}{255}(.98\,V_{REF}) + .01\,V_{REF} = .014\,V_{REF}$	$V_{OUT} = -4.86V$
0000	0000	$\frac{0}{255}(.98\,V_{REF}) + .01\,V_{REF} = .010\,V_{REF}$	$V_{OUT} = -4.90V$



Bipolar DPP Output



Amplified DPP Output

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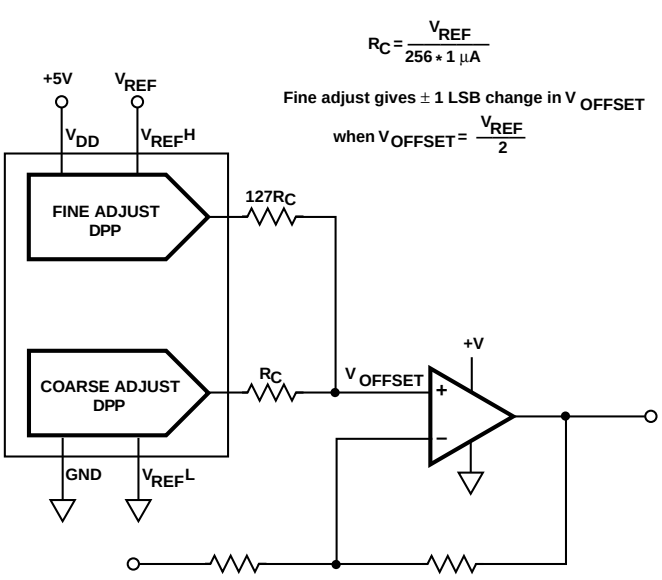
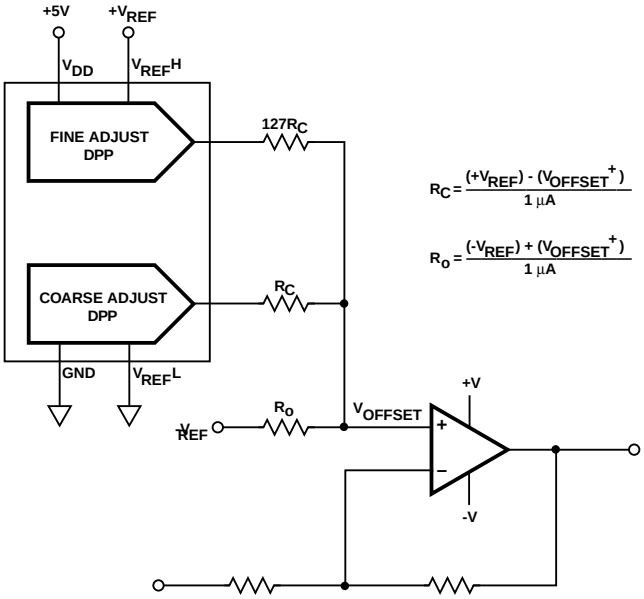
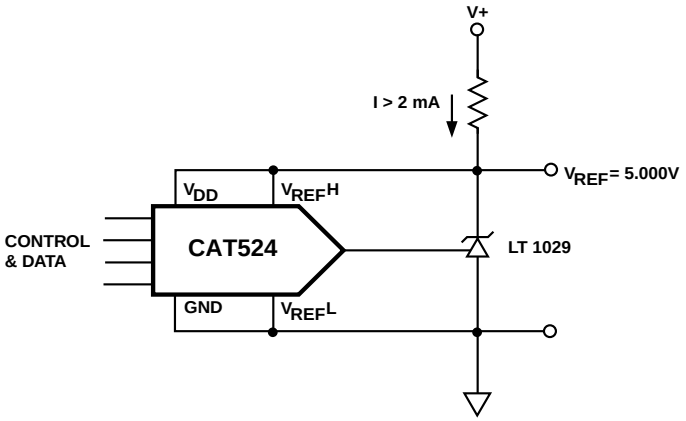
APPLICATION CIRCUITS (Cont.)



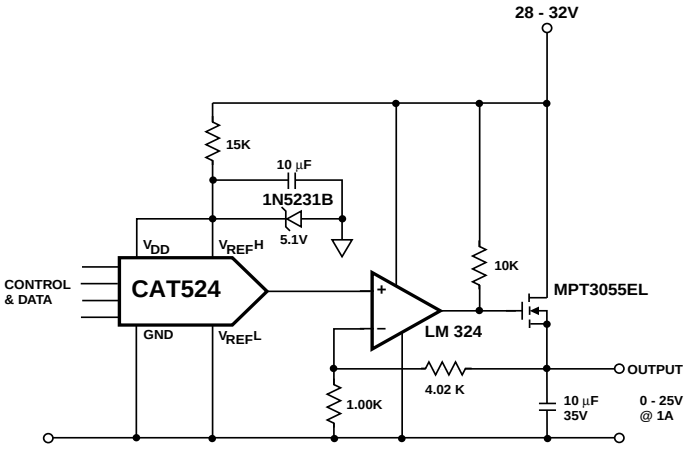
Coarse-Fine Offset Control by Averaging DPP Outputs for Single Power Supply Systems



Coarse-Fine Offset Control by Averaging DPP Outputs for Dual Power Supply Systems

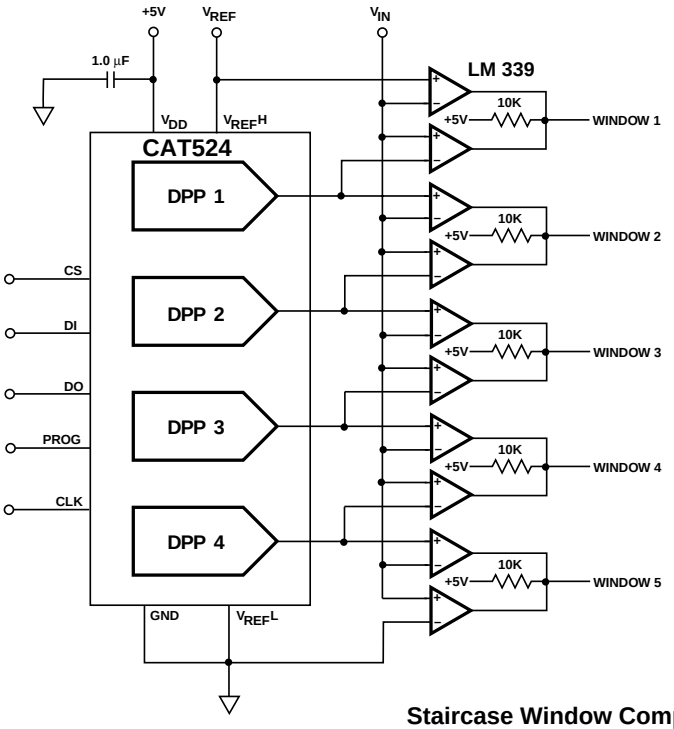


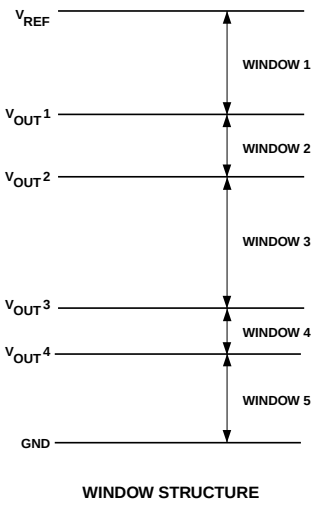
Digitally Trimmed Voltage Reference



Digitally Controlled Voltage Reference

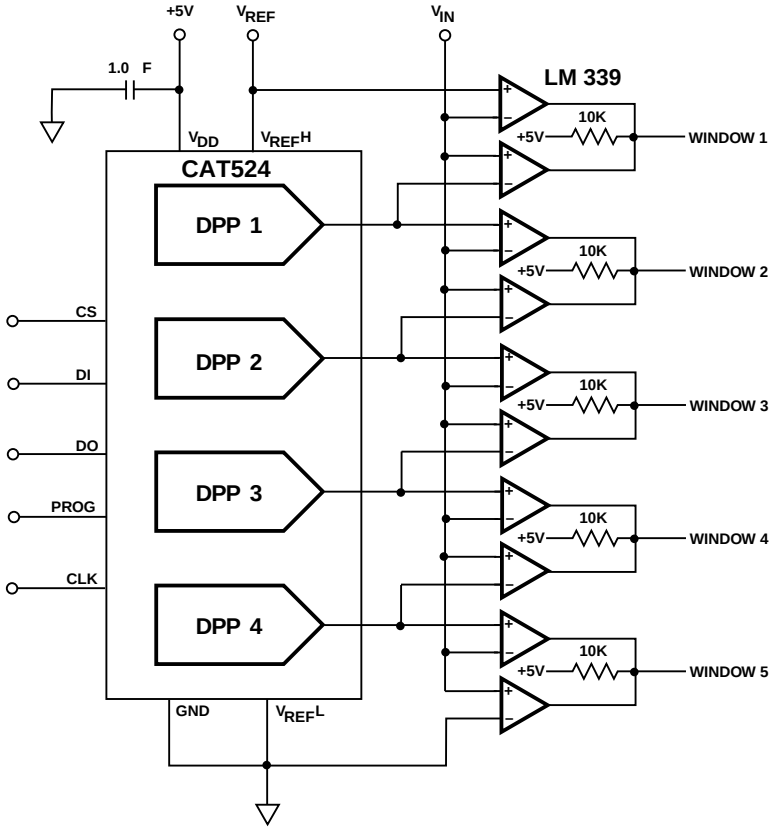
APPLICATION CIRCUITS (Cont.)

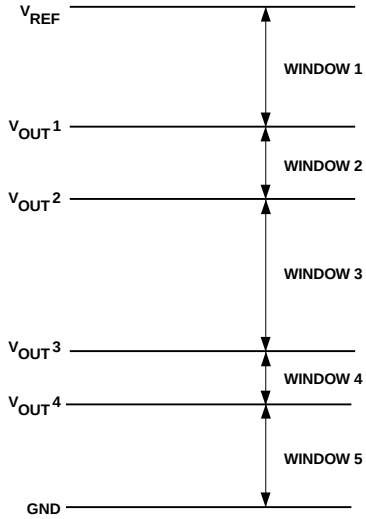




WINDOW STRUCTURE

Staircase Window Comparator

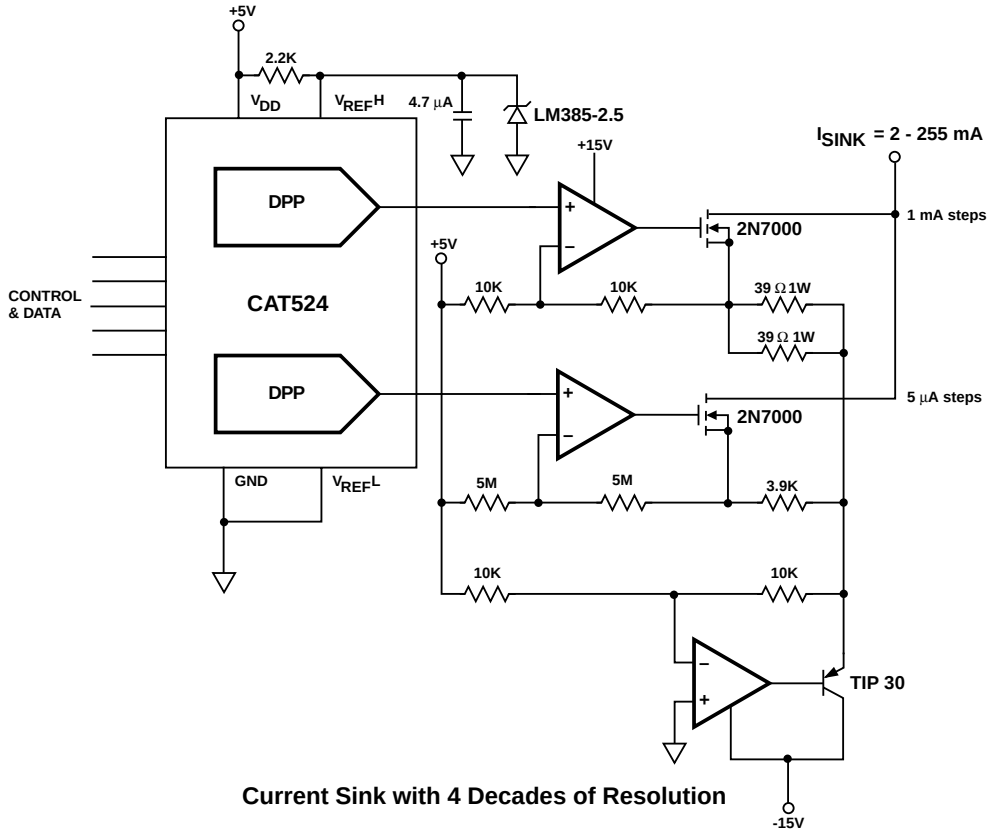




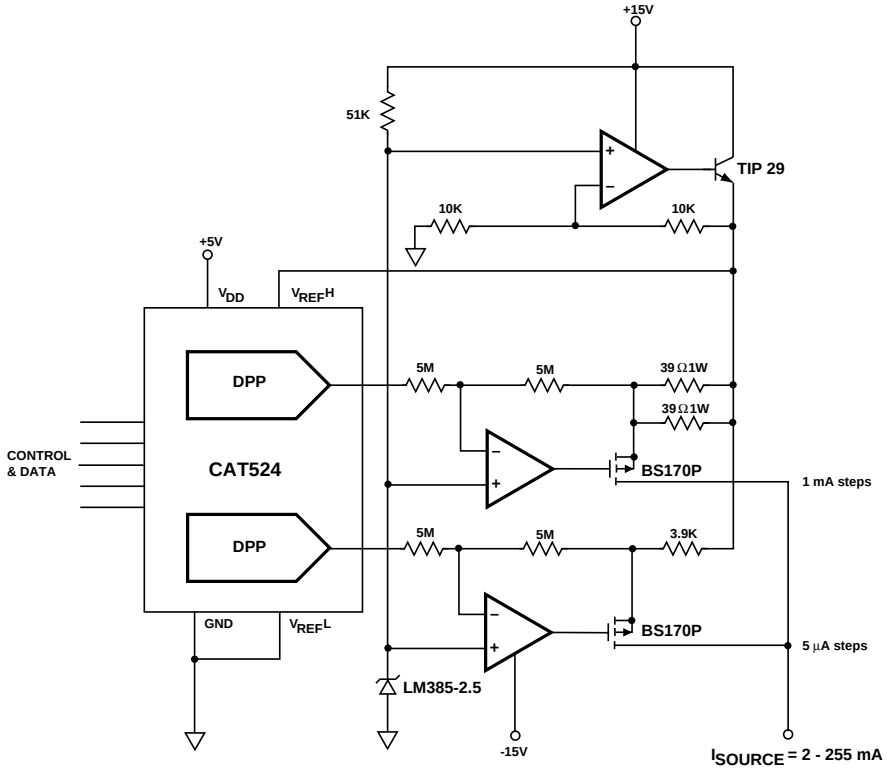
WINDOW STRUCTURE

Overlapping Window Comparator

APPLICATION CIRCUITS (Cont.)

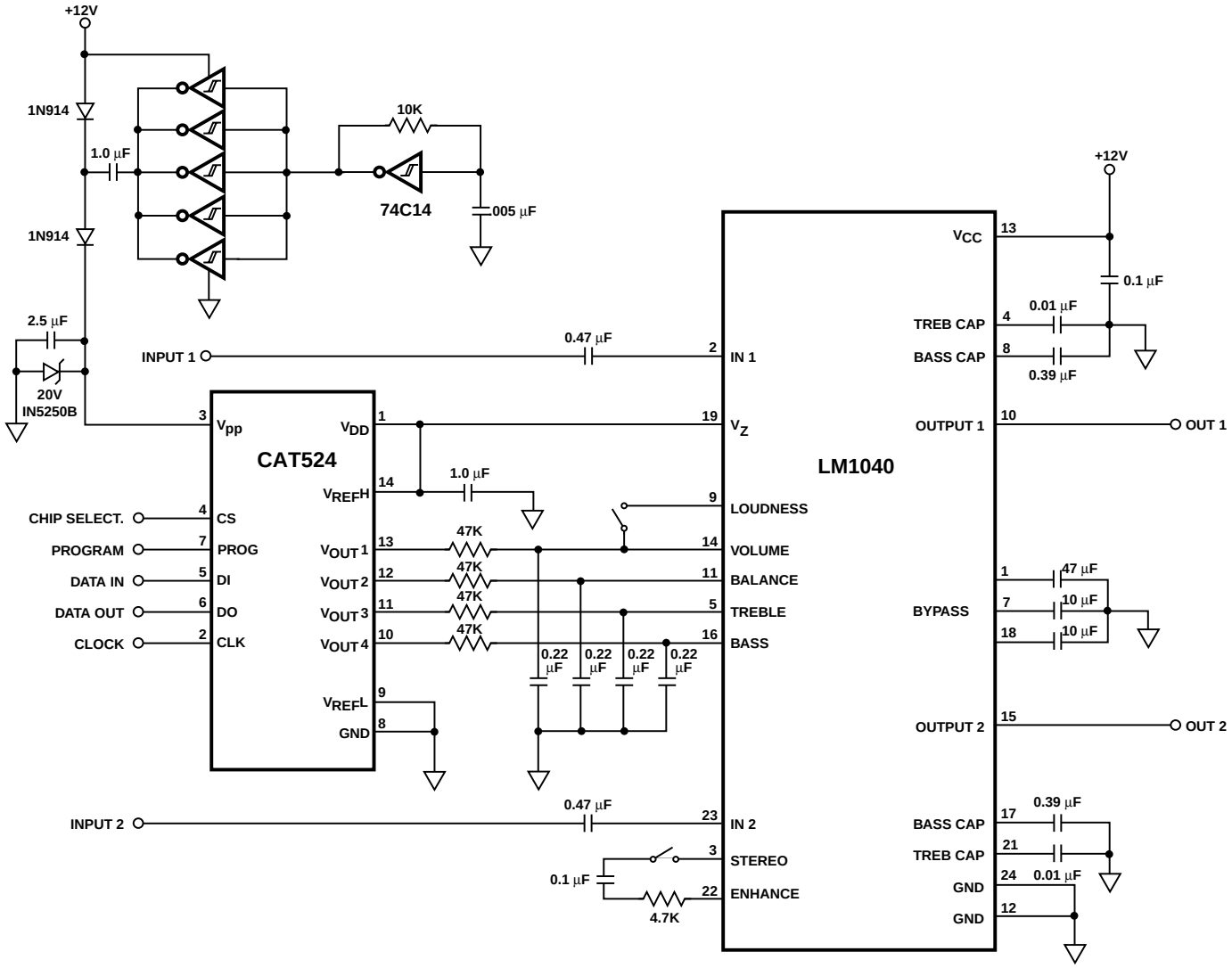


Current Sink with 4 Decades of Resolution



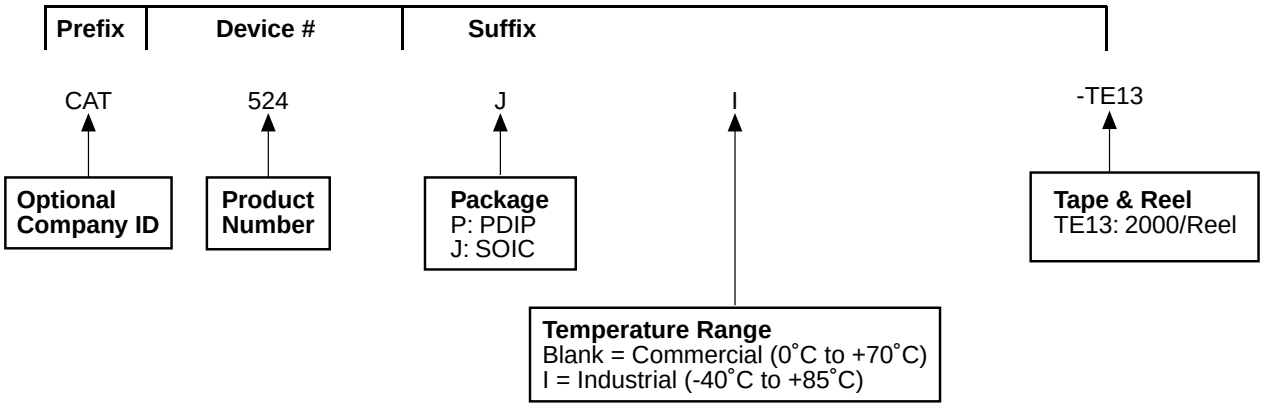
Current Source with 4 Decades of Resolution

APPLICATION CIRCUITS (Cont.)



Digital Stereo Control

ORDERING INFORMATION



Notes:
(1) The device used in the above example is a CAT524JI-TE13 (SOIC, Industrial Temperature, Tape & Reel)