TC8129

4C\VDigit Auto-Ranging DMM ADC

FEATURES

- **High Resolution 10µV**
- **4¾ Digits**
- **20 Conversions/Second**
- **Complete DMM System ADC with TC8131**
  - **— Voltage (DC and AC) .... 5 Ranges**
  - **— Ohms .... 6 Ranges**
  - **— Current (DC and AC)**
  - **— Capacitance .... 5 Ranges**
  - **— Frequency .... 4 Ranges**
- **Separate High-Impedance mV Input**
- **Fast Continuity with Buzzer**
- **Diode Test**
- **Internal Op Amp for AC-DC Converter**
  - **— True RMS with External Converter**
- **Serial Data Interface to TC8131 or CMOS Microcomputer**
- **Single 9V Battery Operation**
- **Sleep Mode for Low Power Dissipation**
- **Provides Power Supply for TC8131 or CMOS Microcomputer**
- **Compact 44-Pin Flat Package**

ORDERING INFORMATION

Part No.	Resolution	Package	Temp. Range
TC8129CKW	4¾ Digits	44-Pin Plastic Flat Package	0°C to + 70°C

GENERAL DESCRIPTION

The TC8129 is a high resolution, autoranging A/D converter for 4¾ digit digital multimeters (DMMs). When combined with the TC8131 LCD controller, the TC8129 will measure voltage, current, resistance, capacitance, frequency and temperature. External components are kept to a minimum for low system cost, without compromising system performance.

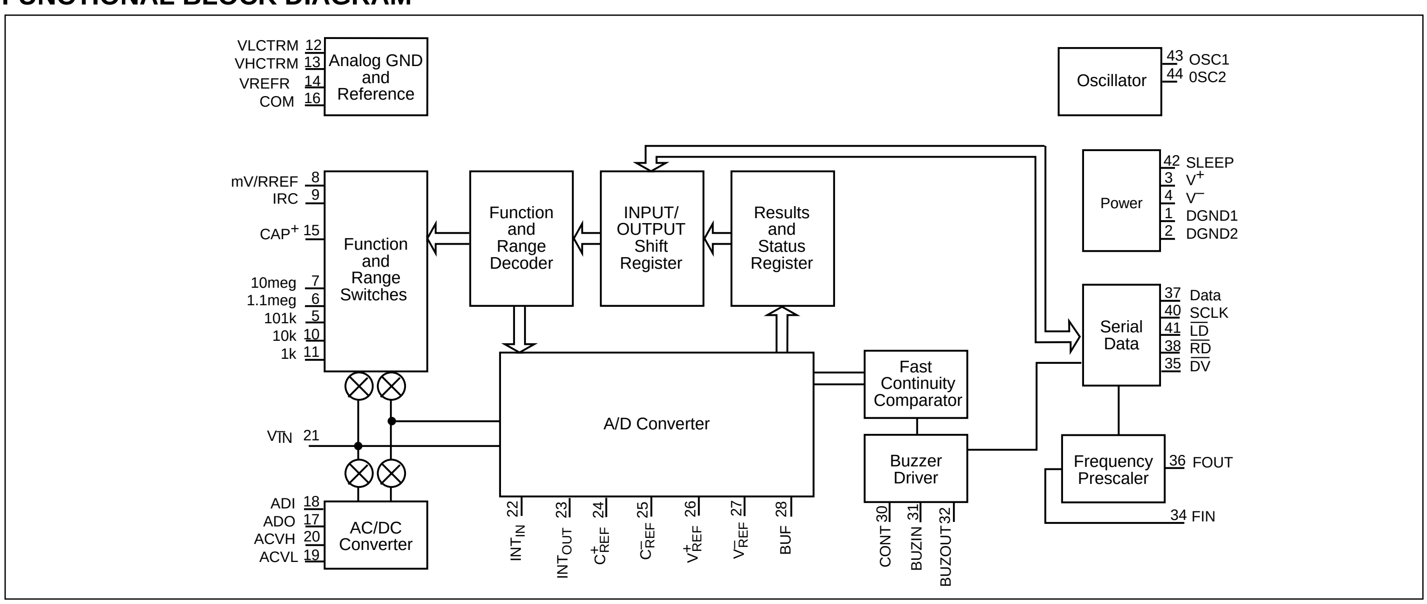
With an internal resolution of over 500,000 counts, the TC8129 produces stable readings when displaying 4¾ digits (±39,999 counts). The 50msec conversion time provides a fast bar graph which updates 20 times per second. In addition to the autoranging analog inputs, a separate direct input to the A/D converter ensures that low-level readings are both fast and accurate.

For AC voltage and current measurements, an on-chip op-amp can be configured as an AC-DC converter. An external AC-DC converter can also be added to provide true RMS measurements. A three-decade frequency prescaler allows autoranging frequency measurements from 4kHz to 4MHz, with 1Hz resolution in the 4kHz range.

Data is transferred between the TC8129 A/D converter and the TC8131 LCD controller via a serial bus that provides a simple, flexible, bidirectional interface while minimizing pin count.

The TC8129 operates from a single 9 volt battery, and provides an on-chip 3 volt power source for the TC8131. Power supply current for both ICs is only 1.6mA while operating, and 200µA in the "sleep" mode. The TC8129 is available in a 44-pin quad plastic flat package.

FUNCTIONAL BLOCK DIAGRAM



TC8129

ABSOLUTE MAXIMUM RATINGS

Item	Rated Values
Supply voltage (V_S^+ to V_S^-)	12V
Input voltage	(V_S^- – 0.3V) to (V_S^+ + 0.3V)
Reference voltage	(V_S^- – 0.3V) to (V_S^+ + 0.3V)

ELECTRICAL CHARACTERISTICS: V_S = +7.5V to +10V, OSC Freq = 32.768 kHz

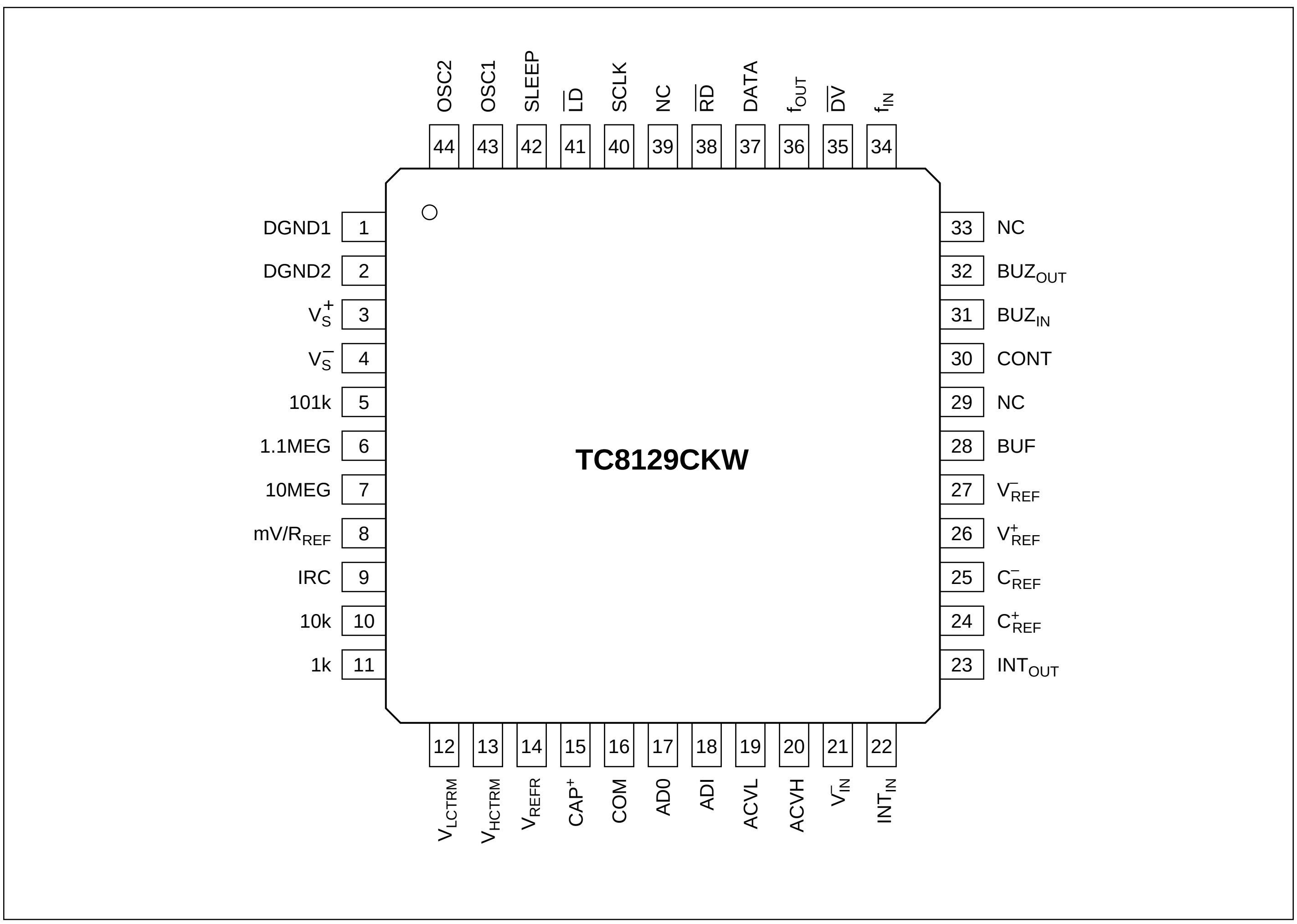
			T_A = +25°C			T_A = 0°C to +70°C			
Symbol	**Parameter**	**Test Conditions**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**
Analog Section									
OFFSET	A/D System Offset	Error Correction Mode	– 2500	±500	2500	– 2500	±500	2500	Counts
ZERO	Zero Reading (Offset Corrected)	400mV Direct Input, Pin #8 shorted to COMMON	– 10	0	10	– 12	0	– 12	Counts
RE	Roll-Over Error	400mV Direct Input, V_{IN} = ±400mV	– 20	0	20	– 20	0	20	Counts
NL	Nonlinearity	400mV Direct Input	—	—	0.05	—	—	0.05	% of V_{IN} ±10 Cnt's
E_N	Noise	400mV Direct Input	—	3	—	—	3	—	Counts
V_{TRIPH}	Input Voltage Detector Low to High Trip Point	400mV Direct Input, Pin 30 High	—	30	65	—	30	70	mV
V_{TRIPL}	Input Voltage Detector High to Low Trip Point	400mV Direct Input, Pin 30 High	10	30	—	10	30	—	mV
$I_{LEAKAGE}$	Input Leakage Current of Pin #7	With 10M Resistor Connected to Common	– 20	±1	20	– 20	±1	20	pA
V_{OFFSET}	On-Chip Op-Amp Input Offset Voltage		– 20	±10	20	– 20	±10	20	mV
TCV_{OFFSET}	Average Temperature Coefficient of Input Offset Voltage		—	—	—	—	6	—	µV/°C
Digital Section									
$FREQ_{Buzzer}$	Buzzer Frequency		—	2	—	—	2	—	kHz
V_{IL}	Input Low Voltage (Pins: 31, 37, 38, 40, 41)		—	—	V_{DGND2} + 0.5	—	—	V_{DGND2} + 0.5	V
V_{IH}	Input High Voltage (Pins: 31, 37, 38, 40, 41)		V^+ – 0.5	—	—	V^+ – 0.5	—	—	V
V_{OL}	Output Low Voltage (Pins: 35, 36, 37) (Note 2)		—	—	V_{DGND2} + 0.25	—	—	V_{DGND2} + 0.30	V
V_{OH}	Output High Voltage (Pins: 35, 36, 37) (Note 2)		V^+ – 0.4	—	—	V^+ – 0.45	—	—	V
t_{RD}	$\overline{RD}$ Delay Time		—	250	—	—	250	—	nsec
t_{RDS}	Data $\overline{RD}$ Setup Time		—	1	—	—	1	—	µsec
t_{DCK}	SCLK to D_{OUT} Delay Time		—	500	—	—	500	—	nsec
t_{LDS}	$\overline{LD}$ Set-Up Time		—	1	—	—	1	—	µsec
t_{DS}	Data $\overline{LD}$ Set-Up Time		—	150	—	—	150	—	nsec
t_{DH}	Data-$\overline{LD}$ Hold Time		—	100	—	—	100	—	nsec
t_{PWL}	Minimum Low Pulse Width		200	—	—	200	—	—	nsec
$_{PWH}$	SCLK Pulse Width, High		200	—	—	200	—	—	nsec

ELECTRICAL CHARACTERISTICS (Cont.)

Symbol	Parameter	Test Conditions	T_A = +25°C Min	T_A = +25°C Typ	T_A = +25°C Max	T_A = 0°C to +70°C Min	T_A = 0°C to +70°C Typ	T_A = 0°C to +70°C Max	Unit
Power Supply Section									
I_S	Operating Supply Current	V_S^+ = 9 V V_{IN} = 0.0 V	—	1.5	2.0	—	1.5	2.0	mA
I_{SLEEP}	Sleep Mode Supply Current	V_S^+ = 9 V V_{IN} = 0.0 V	—	0.2	0.4	—	0.2	0.4	mA
V_{DGND1}	Digital Ground, Output #1	V_S^+ = 9 V I_L = 0 mA	– 4.1	– 4.5	– 4.9	– 3.9	– 4.5	– 5.0	V
V_{DGND2}	Digital Ground, Output #2	V_S^+ = 9 V I_L = 0 mA	– 2.3	– 3.0	– 3.3	– 2.2	– 3.0	– 3.5	V
	Digital Ground, Voltage #2	V_S^+ = 9 V I_L = 500 µA	– 2.1	– 2.8	– 3.1	– 2.0	– 2.8	– 3.3	V
V_{COMMON}	Analog Common Voltage	V_S^+ = 9 V I_L = 2 mA	– 3.0	– 3.2	– 3.4	– 3.0	– 3.2	– 3.4	V

NOTES: 1. Resolution = ±39,999 counts, maximum.
2. Test Conditions, I_{OL} = 100µA.

PIN CONFIGURATION



TC8129

PIN DESCRIPTION

Pin No. (44-Pin flat Package)	Symbol	Description
1	DGND1	Internal logic digital ground. Nominally 5V below V_S^+.
2	DNGD2	Power supply ground connection for the TC8131 controller. Nominally 3V below V_S^+.
3	V_S^+	Positive power supply connection, typically 9V.
4	V_S^-	Negative supply connection. Connect to negative terminal of 9V battery
5	101k	Connection for 101kΩ range resistor.
6	1.1MEG	Connection for 1.1MΩ range resistor.
7	10MEG	Connection for 10MΩ range resistor.
8	mV/R_{REF}	Dual purpose input. In voltage mode, this pin provides an input which bypasses the 10MΩ input resistor to minimize the effect of leakages. In the resistance mode, this pin measures the voltage across the reference resistor.
9	IRC	In current, resistance and capacitance modes, this pin senses the voltage across the current sense resistor, unknown resistor, and capacitor, respectively.
10	10k	Connection for 10kΩ range resistor.
11	1k	Connection for 1kΩ range resistor.
12	V_{LCTRM}	Voltage reference input for lower range capacitance measurement. See Text.
13	V_{HCTRM}	Voltage reference input for upper range capacitance measurement. See Text.
14	V_{REFR}	Voltage reference input for resistance measurements. Typically 1.2V.
15	CAP^+	Current source output for capacitance measurements.
16	COM	Analog circuit ground reference point. Nominally 3.2V below V_S^+.
17	ADO	Output of AC to DC converter Op Amp.
18	ADI	Inverting input of AC to DC converter Op Amp.
19	ACVL	Ground input for AC to DC converter.
20	ACVH	DC result of AC to DC conversion.
21	V_{IN}^-	Low analog input signal connection.
22	INT_{IN}	Inverting input of the integrator Op Amp.
23	INT_{OUT}	Output of the integrator. Connect to integration capacitor.
24	C_{REF}^+	Positive connection for reference capacitor.
25	C_{REF}^-	Negative connection for reference capacitor.
26	V_{REF}^+	High differential reference input connection.
27	V_{REF}^-	Low differential reference input connection
28	BUF	Buffer output.
29	NC	No connection.
30	CONT	Output of the fast continuity comparator.
31	BUZ_{IN}	Control input for the on-chip buzzer driver.
32	BUZ_{OUT}	Buzzer output. Audio frequency output at 2048Hz, which drives a piezo buzzer.
33	NC	No connection.
34	f_{IN}	Frequency prescaler input.
35	$\overline{DV}$	Data Valid output. This pin goes LOW at the end of a conversion. It will stay LOW until data is read out of the TC8129.
36	f_{OUT}	Output of frequency prescaler. Used by controller to extend range of the frequency counter beyond 4kHz.
37	DATA	Bidirectional data input/output.
38	$\overline{RD}$	Data Read input. When $\overline{RD}$ is LOW, data can be read from the TC8129.
39	NC	No connection.

PIN DESCRIPTION (cont.)

Pin No. (44-Pin flat Package)	Symbol	Description
40	SCLK	Serial data clock input
41	$\overline{LD}$	Data Load input. When low, range and measurement mode commands can be loaded into the TC8129
42	SLEEP	Power shut down input, places TC8129 in low power mode.
43	OSC1	Crystal oscillator (input) connection
44	OSC2	Crystal oscillator (output) connection

GENERAL THEORY OF OPERATION

The TC8129 is a high-resolution analog to digital converter (ADC) with an input multiplexer for autoranging measurements and a serial digital output. When combined with the TC8131 controller, the TC8129 forms a 4¾ digit autoranging DMM which measures voltage, current, resistance, capacitance, frequency, temperature and transistor h_{FE}.

The TC8129 operates with the TC8131 controller or with a microcomputer. The TC8129 provides all analog measurement functions, while the TC8131 controls the LCD display and user interface, and sends measurement mode and range commands to the TC8129.

On-chip multiplexer provides five measurement ranges for voltage and capacitance, and six ranges for resistance.

The TC8129's 50msec conversion time supports a fast bar graph display as well as the high-resolution numeric display.

A/D CONVERTER

Multiple remainder conversion

The TC8129 uses a multiple-deintegration method of A/D conversion to provide over 500,000 counts of resolution in 50 milliseconds. Five separate deintegrate operations are performed on each conversion. After each deintegrate period, a residual voltage remains on the integration capacitor (C_{INT}). This residual voltage is multiplied by 10 and deintegrated again. After five deintegrations, the voltage at the input of the A/D converter has been converted into a 5¾ digit number. The least significant digit is normally discarded, leaving a 4¾ digit result.

The sign bit and value of each deintegration period are stored in the TC8129 output register, and transferred to the TC8131 at the end of each conversion.

The TC8131 converts the five deintegration values into a final A/D conversion result (see the Data Output Format section of this data sheet for details).

Zero Reading

The TC8129 does not do an autozero phase during each conversion. Instead, the controller may send a Offset Reading command which instructs the TC8129 to internally short the A/D converter inputs and make a conversion. This conversion represents the internal offsets of the TC8129 buffer, integrator and comparator. The Offset Reading value is subtracted from normal conversions to calculate the actual A/D conversion result.

50/60 Hz Rejection Control

Integrating A/D converters provide excellent rejection of periodic interference such as 60Hz line frequency, provided the integration period is a multiple of the interfering signal. The TC8129 can adjust its integration time to reject either 50Hz or 60Hz interference. The integration time is set with the command word which is sent to the TC8129 (see the serial data interface section of this data sheet). With a 32.768kHz clock, the integration times are:

Mode	Clock Cycles	Integration time
60Hz	545	16.63 msec
50Hz	655	19.99 msec

Autoranging Voltage Measurements

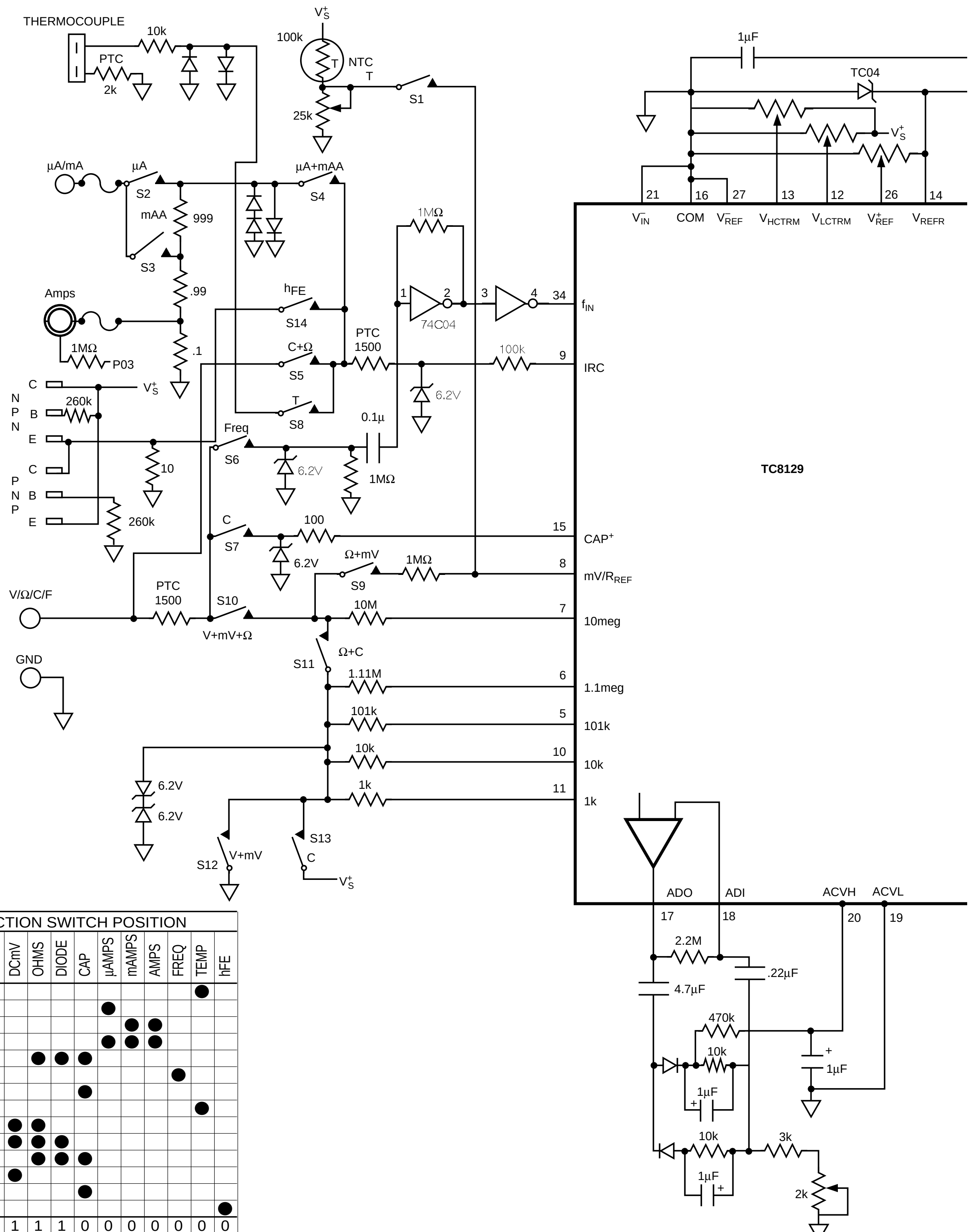
When combined with external attenuation resistors, (see the Typical Application diagram), the TC8129 will measure voltages from 400mV to 4000V. The TC8131 sends a range command to the TC8129 via the serial data bus, and the TC8129 connects internal switches to the appropriate tap on the resistor network.

AC Measurements

The integrating A/D converter of the TC8129 will not directly measure AC signals. When an AC measurement is desired, internal switches on the TC8129 connect the input to an internal op-amp. This op-amp, when combined with inexpensive discrete components, can be configured as an AC-to-DC converter. If true RMS measurements are desired, an external AC-to-DC converter can be added. See the applications section of this data sheet for details.

TC8129

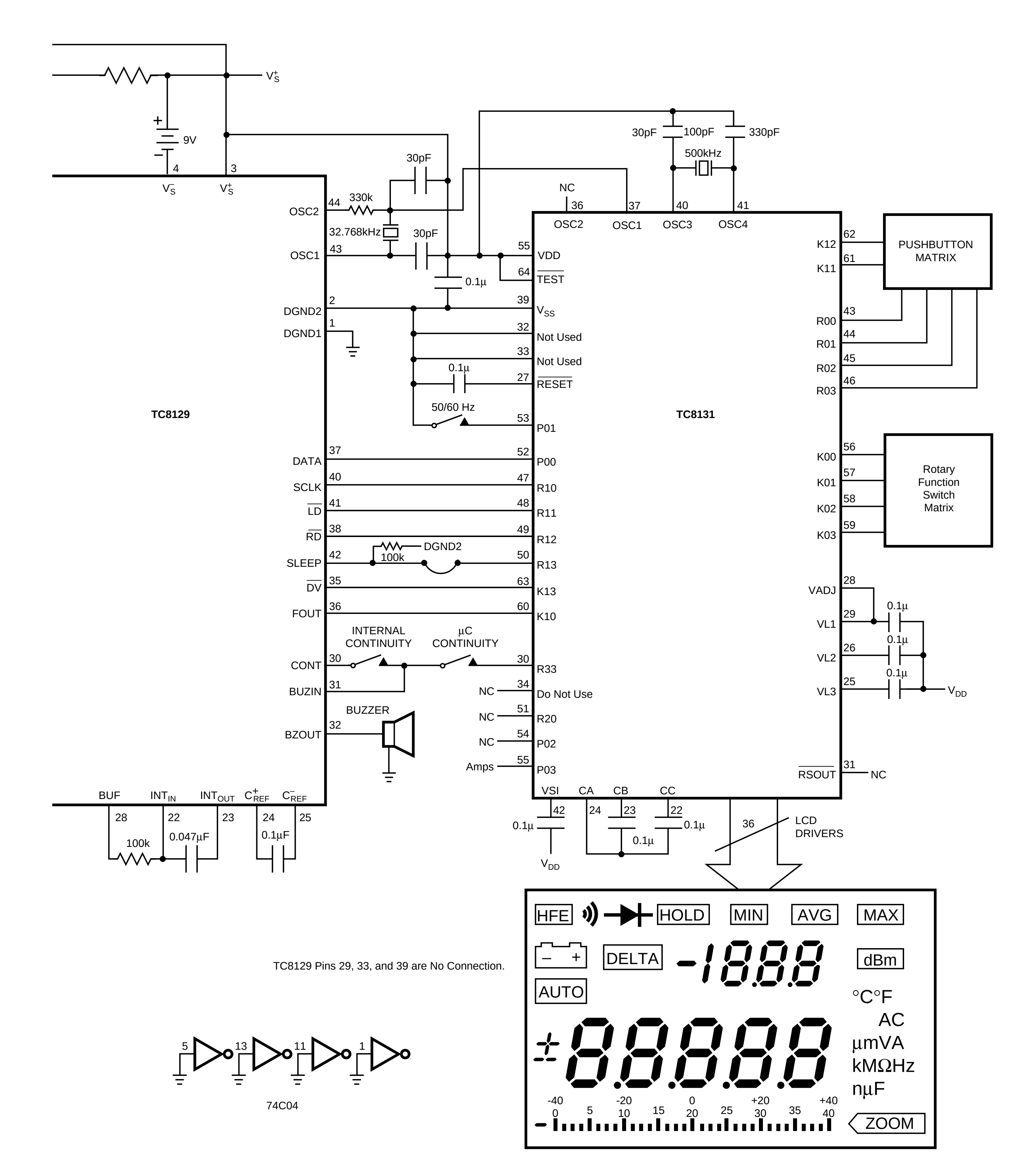
TYPICAL APPLICATION



		FUNCTION SWITCH POSITION												
		OFF	ACV	DCV	DCmV	OHMS	DIODE	CAP	µAMPS	mAMPS	AMPS	FREQ	TEMP	hFE
CONTACT	S1												●	
	S2								●					
	S3									●	●			
	S4								●	●	●			
	S5					●	●	●						
	S6											●		
	S7							●						
	S8												●	
	S9				●	●								
	S10		●	●	●	●	●							
	S11					●	●	●						
	S12	●	●	●	●									
	S13							●						
	S14													●
TC8131 PORTS	K00	1	1	1	1	1	1	0	0	0	0	0	0	0
	K01	0	0	0	0	1	1	1	0	0	0	0	1	1
	K02	1	1	0	0	0	1	1	1	1	1	0	0	0
	K03	0	1	1	0	0	0	0	0	1	1	1	1	0
	P03	X	X	X	X	X	X	X	1	1	0	X	X	X

● Closed
0 Logical Low
1 Logical High
X don't care

TYPICAL APPLICATION (CONT.)



Resistance

Resistance is measured ratiometrically. The ratiometric method uses the voltage across a known resistor as the reference voltage and the voltage across an unknown resistor as the input voltage. The integration time for resistance measurements is 500 counts and the A/D converter result is:

$$\text{Count} = \frac{R_{UNKNOWN}}{R_{REF}} \times 500000$$

The output of this measurement is only dependent on the ratio of the two resistors, so a precision reference voltage is not required.

To obtain the actual resistor value, the A/D converter result must be multiplied by two. For 40 MΩ measurements, the integration time is reduced to 100 clock cycles and the x2 multiplication is not required.

Diode

Diodes are measured by using the 1kΩ attenuator resistor as a current source. One end of this resistor is internally connected to V_S^+ and the other end, through the PTC protection resistor, to the diode. The integration time for diode measurements is 100 clock cycles. The diode forward voltage is obtained by multiplying the A/D converter result by 5.45 (for 60Hz operation) or by 6.55 (for 50Hz operation).

Current

Current measurements are made by measuring the voltage drop across external sense resistors (see typical application schematic). If current measurements are displayed with 3¾ digits of resolution, as is the case in typical DMM's, the high resolution of the TC8129 can be used to produce a two-level autorange effect. For example, full scale voltage in the 4mA range, using a 100Ω sense resistor, is 400mV. Using the same 100Ω resistor for a 400µA range produces a 'full scale' voltage of 40mV. The TC8129 can measure 40mV to 3¾ digits of resolution. Therefore the TC8131 formats input voltages from 0 to 40mV as the 400µA range and input voltages above 40mV as the 4mA range.

Capacitance

Capacitors are also measured using the external resistor network. 4nF, 40nF and 400nF are the three lower ranges. 4µF and 40µF are the two upper ranges. V_{LCTRM} and V_{HCTRM} are the voltages for trimming the accuracy of the lower and upper capacitance ranges. Typical voltages for the V_{HCTRM} and V_{LCTRM} are 150mV and 1.4V respectively. A polarized (electrolytic) capacitor should have its negative terminal connected to the COMMON input of the TC8129.

h_{FE}

Transistor h_{FE} is typically measured with a base current of 10µA. The base current is set with an external resistor that is nominally 260kΩ with a typical (V_S^+ – COM) voltage of 3.2V (Figure 1). Collector current is measured across a 10Ω resistor, using the IRC input (with the TC8129 in measurement mode 001).

The voltage across the 10Ω resistor is converted to h_{FE} by the TC8131, using the formula:

$$h_{FE} = \frac{V_{IRC} / 10\ \Omega}{10\ \mu A}$$

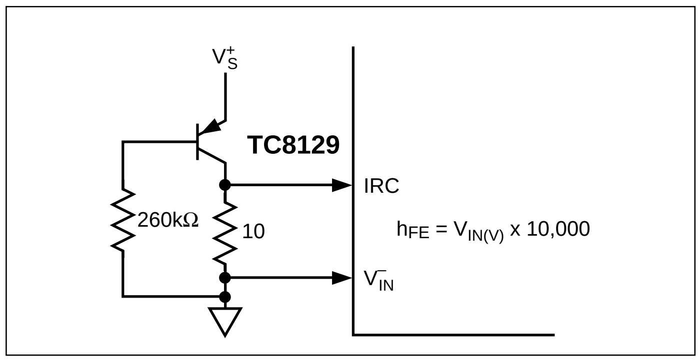


Figure 1. Typical h_{FE} Measurement Circuit

Temperature

The TC8129 measures temperature using a type K thermocouple (see typical application schematic). The measurement range extends from – 270°C to +1370°C.

Since thermocouples have a nonlinear output voltage characteristic, temperature measurements require several steps. First, the thermocouple output voltage (nominally about +40µV/°C) is measured using the TC8129's IRC input. This result is transmitted to the TC8131. Then the ice point compensation voltage is measured using a thermistor attached to the mV/R_{REF} input, and this value is also sent to the TC8131. Finally the TC8131 subtracts the ice point correction, applies a linearization process to the result, and displays the temperature on the LCD.

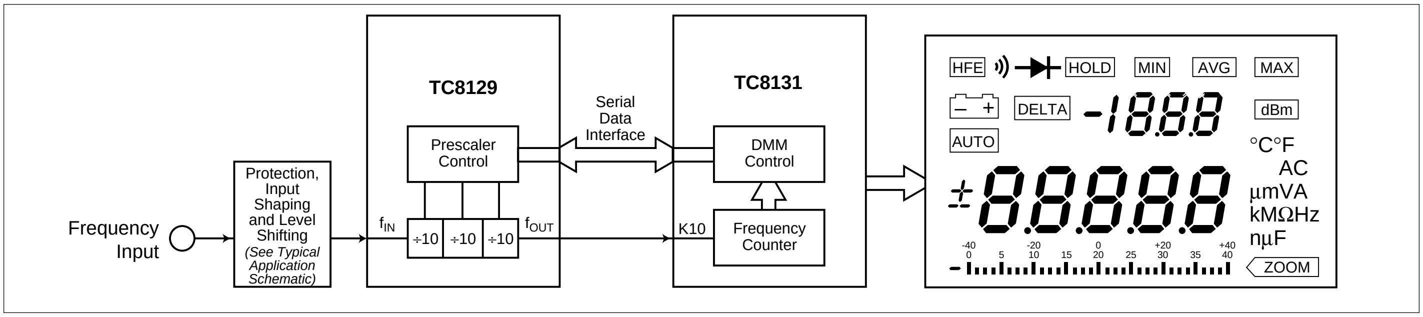


Figure 2. Simplified Block Diagram of the Frequency Counter Prescaler

Frequency

The TC8129 includes a 3-decade prescaler (Figure 2) which extends frequency measurements to 4MHz. The prescaler can be programmed to divide by 1, 10, 100 or 1000. The signal to be measured is applied to the TC8129's f_{IN} input and comes out on the f_{OUT} output.

The TC8131 contains the frequency counter. Pulses on the TC8131's K10 input are counted with a one second time base, to a maximum of 4kHz. If the input to the TC8129 exceeds 4kHz, the overrange bit is set, and the TC8131 selects the TC8129's next higher prescaler value.

Data Interface

The TC8129 incorporates a 5-line serial interface for exchanging data with the TC8131 or with a microcomputer (Figure 3). The TC8131 sends measurement function and range commands to the TC8129, and the TC8129 sends A/D conversion results to the TC8131. The serial data interface reduces pin count and simplifies interfacing to both low- and high-end microcomputers.

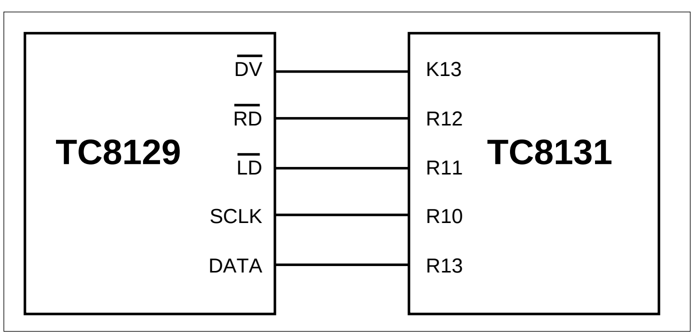


Figure 3. Serial Data Interface

PIN DESCRIPTIONS, I/O

Data Valid ($\overline{DV}$, Pin 35)

The $\overline{DV}$ output of the TC8129 goes LOW at the end of each conversion. This output signals the TC8131 that a new A/D value can be read from the TC8129. When the TC8129's $\overline{RD}$ input is driven LOW to start the data transfer, $\overline{DV}$ will go HIGH. $\overline{DV}$ will also go HIGH if data is not read within 25 msec.

Read ($\overline{RD}$, Pin 38)

The $\overline{RD}$ input controls data transfer from the TC8129 to the TC8131 (Figure 4). When $\overline{RD}$ goes LOW, the TC8129's Data output switches to its low impedance state and the first data bit (the overrange bit) is placed on the DATA pin. Succeeding output bits are transferred to the DATA pin on the falling edge of SCLK. $\overline{RD}$ is held LOW until all data is clocked out of the TC8129. When $\overline{RD}$ goes HIGH, the DATA output will return to its HIGH impedance state.

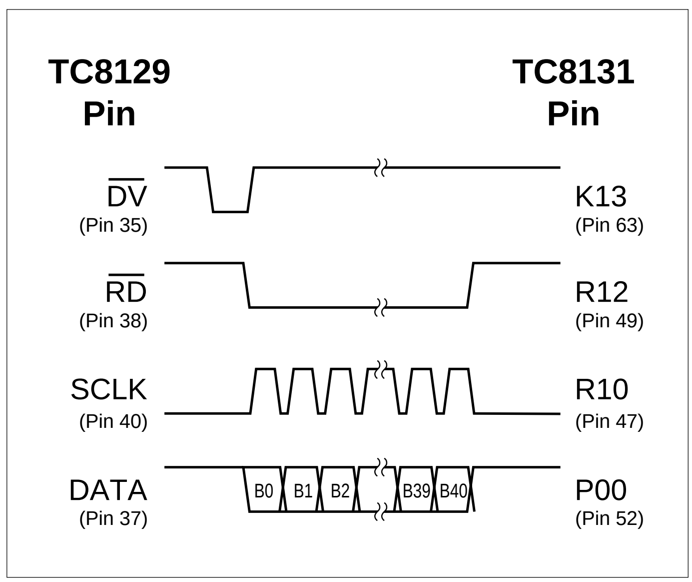


Figure 4. TC8129 to TC8131 Serial Data Transfer

Load ($\overline{LD}$, Pin 41)

Measurement mode and range commands are clocked into the TC8129 when the LD input is LOW (Figure 5). Data must be stable on the rising edge of SCLK.

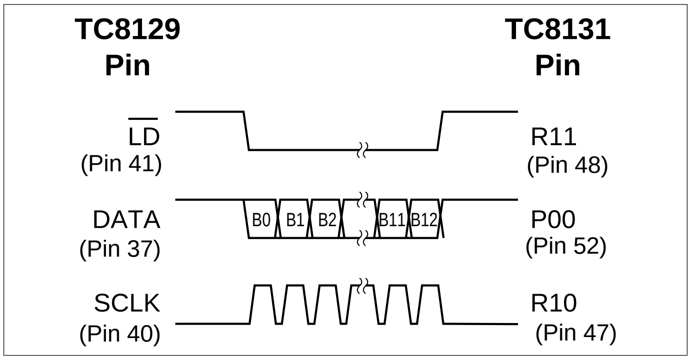


Figure 5. TC8131 to TC8129 Serial Data Transfer

Serial Clock (SCLK, Pin 40)

The SCLK input is used to control data transfer to and from the TC8129. The SCLK input is completely asynchronous, which simplifies the interface to a wide variety of single-chip microcomputers.

Measurement mode and range commands are entered into the TC8129 (when $\overline{LD}$ is LOW) and A/D conversion data is read from the TC8129 (when $\overline{RD}$ is LOW) by pulsing the SCLK input. Data must be stable on the rising edge of SCLK when $\overline{LD}$ is LOW. New data is available on the falling edge of SCLK when $\overline{RD}$ is LOW.

Data Input/Output (DATA, Pin 37)

Commands and A/D results are transferred via the DATA pin. This pin provides bidirectional, 3-state I/O. The DATA pin's function is controlled by the $\overline{RD}$ and $\overline{LD}$ inputs. When $\overline{RD}$ is LOW, the DATA pin is an output for the A/D converter results. When $\overline{LD}$ is LOW, DATA is a high impedance input for measurement and range commands.

Data Interface Timing

The TC8129 input and output timing specifications are contained in Table 1 and timing diagrams are shown in Figure 6. The serial data interface is static, so that a microcomputer or other logic only needs to meet the minimum setup times to ensure correct operation. No critical timing patterns are required to read data from or write data to the TC8129.

Table 1. TC8129 Input/Output Timing Specifications

Parameter	Symbol	Min	Units
$\overline{RD}$ Delay Time	t_{RD}	250	nsec
Data $\overline{RD}$ Setup Time	t_{RDS}	1	µsec
SCLK to D_{OUT} Delay	t_{DCK}	500	nsec
$\overline{LD}$ Setup Time	t_{LDS}	1	µsec
Data $\overline{LD}$ Setup Time	t_{DS}	150	nsec
Data $\overline{LD}$ Hold Time	t_{DH}	100	nsec
SCLK Pulse Width Low	t_{PWL}	200	nsec
SCLK Pulse Width High	t_{PWH}	200	nsec

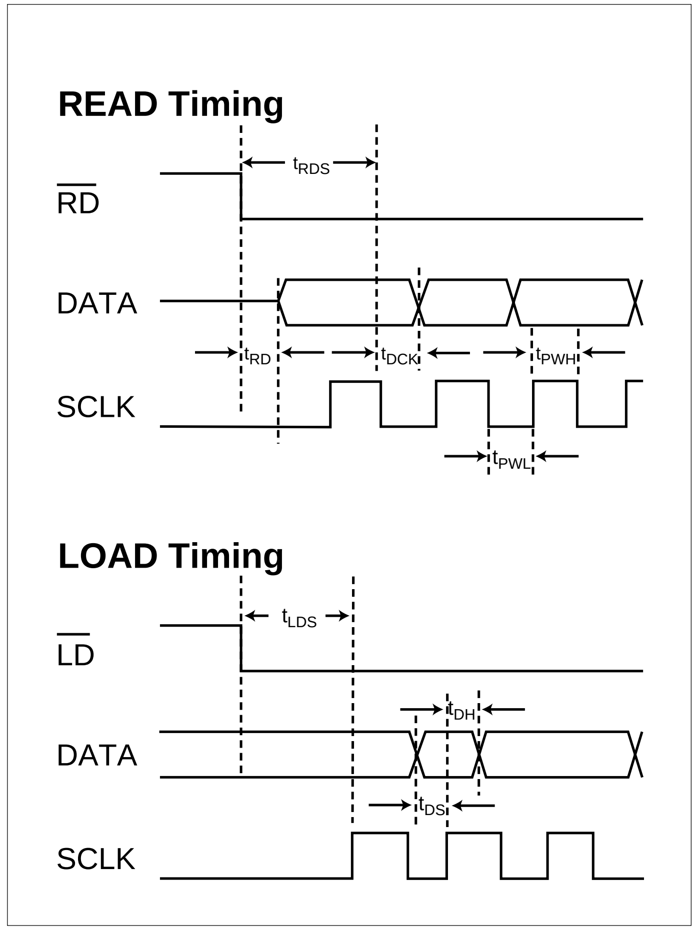


Figure 6. TC8129 Input/Output Timing Specifications

FUNCTION AND RANGE COMMANDS

The TC8129's operation is controlled by the TC8131 or by an external microcomputer. Measurement functions and ranges are set by sending a 12-bit serial word to the TC8129. The serial word is shifted into a register in the TC8129. At the end of each conversion, the contents of the register are decoded to set the function and range.

The format for sending commands to the TC8129 is shown in Figure 7. Data bits are sent to the TC8129 in B0, B1,..., B11 order (i.e. B0 is the first bit clocked into the TC8129).

Configuration Word:

AC/DC Mode Select

B0	Definition
0	DC
1	AC

Digit Select

B1	Definition
0	Normal Operation

Range Select

B4	B3	B2	Definition
0	0	0	DIV1
0	0	1	DIV10
0	1	0	DIV100
0	1	1	DIV1k
1	0	0	DIV10k
1	0	1	Millivolts
1	1	0	Range switches off
1	1	1	Range switches off

Measurement Mode Select

B7	B6	B5	Definition
0	0	0	V
0	0	1	I
0	1	0	R
0	1	1	Capacitance-lower range
1	0	0	Frequency

Measurement Mode Select (Cont.)

B7	B6	B5	Definition
1	0	1	Diode
1	1	0	Capacitance-upper range
1	1	1	Undefined

AC Line Frequency Select

B8	Definition
0	60Hz
1	50Hz

Integration Time Select

B9	Definition
0	Normal integration (545 CLKS @ 60Hz; 655 CLKS @ 55Hz; 500 CLKS @ resistance mode
1	Short integration (100 CLKS) for 40MΩ and diode modes only

Offset Reading Mode Select

B10	Definition
0	Normal Operation
1	Measurement System Offset

Programmable Buzzer Enable

B11	Definition
0	Disable Buzzer when "CONT" is High
1	Enable Buzzer when "CONT" is High

Note: Bits are sent to the TC8129 from the TC8131 Bit 0 First

Figure 7. Data Format for Setting TC8129 Operating Modes

Formatting the Configuration Word

B0, is the leading bit of the configuration word, selects whether AC or DC measurements will be made. If B0 is a logic “1” then the voltage at the input of the TC8129 will be switched through the AC-to-DC converter.

B1 sets the internal resolution of the TC8129. This bit should always be set to a logic “0”.

B2-B4 selects the measurement ranges. These bits control the switches which connect the TC8129 analog input to the desired tap on the external input attenuator. The TC8131 or controller adjust the range after each conversion, to maintain a maximum input voltage of 400 mV into the TC8129’s A/D converter.

A separate voltage input, mV/R_{REF} (pin 8), can also be selected with bits B2-B4. Selecting mV/R_{REF} (range code 101) will reduce input leakage errors in the 400 mV voltage range by bypassing the 10MΩ attenuation resistor.

B5-B7 selects the measurement mode. The TC8129 configures internal switches to connect the A/D converter input to the desired measurement function pin (10MEG, IRC, mV/R_{REF}, etc). The IRC and mV/R_{REF} pins are also used to add additional functions, such as h_{FE} and temperature.

B8 adjusts the A/D converter’s integration time to maximize line frequency rejection. Set this bit to a logic "0" to select 60Hz rejection or to a logic "1" to select 50Hz rejection.

B9 modifies the integration time. This bit is normally a logic "0", but should be set to a logic "1" when the 40MΩ resistance range is selected.

B10 instructs the A/D to measure its system offset. Normal measurements are made with B10 LOW. Setting B10 HIGH will cause the TC8129 to perform a system offset conversion. The TC8131 stores the system offset value and subtracts this value from subsequent measurements to obtain the correct A/D conversion result.

TC8129

Configuration Word	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
DC Volts												
400mV	0	0	0	P	0	0	0	0	0	0	0	0
4.0V	0	0	0	P	0	0	0	0	0	1	0	0
40V	0	0	0	P	0	0	0	0	1	0	0	0
400V	0	0	0	P	0	0	0	0	1	1	0	0
4000V	0	0	0	P	0	0	0	1	0	0	0	0
AC Volts												
400mV	0	0	0	P	0	0	0	0	0	0	0	1
4.0V	0	0	0	P	0	0	0	0	0	1	0	1
40V	0	0	0	P	0	0	0	0	1	0	0	1
400V	0	0	0	P	0	0	0	0	1	1	0	1
4000V	0	0	0	P	0	0	0	1	0	0	0	1
DC Millivolts												
400mV	0	0	0	P	1	1	1	1	0	1	0	0
AC Millivolts												
400mV	0	0	0	P	1	1	1	1	0	1	0	1
DC Current												
	0	0	0	P	0	0	1	1	1	1	0	0
AC Current												
	0	0	0	P	0	0	1	1	1	1	0	1
Resistance: (Multiply the result by 2 to get the correct final result)												
400 Ohms	0	0	0	P	0	1	0	1	0	0	0	0
4K	0	0	0	P	0	1	0	0	1	1	0	0
40K	0	0	0	P	0	1	0	0	1	0	0	0
400K	0	0	0	P	0	1	0	0	0	1	0	0
4MEG	0	0	0	P	0	1	0	0	0	0	0	0
Resistance												
40MEG	0	0	1	P	0	1	0	0	0	0	0	0
Capacitance												
4nF	0	0	0	P	0	1	1	0	0	1	0	0
40nF	0	0	0	P	0	1	1	0	1	0	0	0
400nF	0	0	0	P	0	1	1	0	1	1	0	0
4µF	0	0	0	P	1	1	0	0	1	1	0	0
40µF	0	0	0	P	1	1	0	1	0	0	0	0
Frequency												
DIV1	0	0	0	P	1	0	0	0	0	0	0	0
DIV10	0	0	0	P	1	0	0	0	0	1	0	0
DIV100	0	0	0	P	1	0	0	0	1	0	0	0
DIV1000	0	0	0	P	1	0	0	0	1	1	0	0

Legend: P: Determined by TC8131 or Programmer SO: Previous State

Figure 8. TC8129 Configuration Codes (part 1)

Configuration Word	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
Offset Measurement												
Short Integration	0	1	1	P	SO	SO	SO	SO	SO	SO	0	0
Normal Integration	0	1	0	P	SO	SO	SO	SO	SO	SO	0	0
Diode Measurement: Multiply the output by 5.45 for 60Hz operation or 6.55 for 50Hz operation to get the final result												
	0	0	1	P	1	0	1	1	0	0	0	0

Legend: P: Determined by TC8131 or Programmer SO: Previous State

Figure 8. TC8129 Configuration Codes (part 2)

B11 enables the buzzer when the CONT pin is HIGH. A voltage comparator connected in parallel with the internal terminals of the A/D monitors the input signal level. When the signal level is lower than the threshold voltage, typically 30mV, the CONT pin will be set to a logic "1". Buzzer will also be activated once the "B11" of the configuration word is set "HIGH". This feature can facilitate the "FAST CONTINUITY" check in the resistance measurement mode.

To simplify programming of the TC8129, configuration codes for all measurement modes and ranges are shown in Figure 8.

Data Output Format

The TC8129 communicates the A/D converter result via a 41-bit serial word (Figure 9). The first two bits of the output word are status bits and the last 39 bits provide the polarity and magnitude of the conversion.

The first bit of the output word is the overrange bit. This bit is normally 0. If B0 is a 1, the A/D converter is overranged.

Bit B1 is a logic 1 if the output data represents a system offset reading. For normal conversions, B1 is a 0.

The TC8129 uses a five-deintegration method of A/D conversion (see the A/D theory of operation section). The result of each deintegration period is included in the data output word. These five values are labeled DATA1 through DATA5 (Figure 9). Each of these data words is a sign-magnitude binary number. DATA1 is 10 bits plus sign and DATA2 through DATA5 are 6 bits plus sign. The TC8129 conversion result is obtained by adding and multiplying the five data words as follows:

Result = (DATA1 + DATA2) x $3E8_{16}$ - (DATA3) x 64_{16} + (DATA4) x $0A_{16}$ - (DATA5)

(Note: $3E8_{16}$, 64_{16}, and $0A_{16}$ equate to decimal numbers 1000, 100, and 10, respectively.)

The result of this operation will be a binary representation of a 5¾ digit number. Figure 10 illustrates this conversion of typical data from the TC8129 into a 5¾ digit number. Before displaying this number, three operations are required:

1. The system offset must be subtracted.
2. The binary number is converted to decimal format.
3. The least significant digit is discarded to yield a 4¾ digit result.

For microcomputer applications of the TC8129, the A/D conversion result can also be calculated by the following method:

1. Add DATA1 and DATA2 (observing polarity of both)
2. Multiply by $3E8_{16}$.

40	39	38	37	36	35	34
D55	D54	D53	D52	D51	D50	S5
MSB					LSB	
DATA 5						

33	32	31	30	29	28	27
D45	D44	D43	D42	D41	D40	S4
					LSB	
DATA 4						

26	25	24	23	22	21	20
D35	D34	D33	D32	D31	D30	S3
MSB					LSB	
DATA 3						

19	18	17	16	15	14	13
D25	D24	D23	D22	D21	D20	S2
MSB					LSB	
DATA 2						

12	11	10	9	8	7	6	5	4	3	2	1	0
D19	D18	D17	D16	D15	D14	D13	D12	D11	D10	S1	T	OR
MSB									LSB			
DATA 1												

OR (Overrange) Codes

OR	DECODE
0	Normal
1	Overrange

T (Data Type) Codes

T	DECODE
0	Data
1	Offset

S (Sign) Codes

S1,S2,S3, S4, S5	DECODE
0	Negative
1	Positive

RESULT = (DATA1 + DATA2) x 1000 – (DATA3) x 100 + (DATA4) x 10 – (DATA5) IN 400,000 COUNTS

Figure 9. TC8129 Serial Data Output Format

Bit#	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20
Function	DATA5							DATA4							DATA3						
Name	D55	D54	D53	D52	D51	D50	S5	D45	D44	D43	D42	D41	D40	S4	D35	D34	D33	D32	D31	D30	S3
Typical Data	0	1	0	0	1	1	1	0	1	0	0	0	0	0	0	1	0	0	0	1	1
Hexidecimal Value		1		3			+		1		0			–		1		1			+

Bit#	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Function	DATA2							DATA1												
Name	D25	D24	D23	D22	D21	D20	S2	D19	D18	D17	D16	D15	D14	D13	D12	D11	D10	S1	T	OR
Typical Data	0	0	0	0	1	1	0	0	1	1	0	0	0	1	0	1	0	1	0	0
Hexidecimal Value		0			3		–		1		8				A			+		

Calculation:	DATA1		(+18A)				
	DATA 2	+	(–03)				
			(+187)	* 3E8	=	+	5F758
	DATA3	–	(+11)	* 64	=	–	6A4
	DATA4	+	(–10)	* 16	=	–	A0
	DATA5	–	(+13)		=	–	13
					=	+	$5F001_{16}$
					=	+	389121_{10}

Figure 10. Calculating the Conversion Result

3. Subtract DATA3.
4. Multiply by 64_{16}.
5. Add DATA4.
6. Multiply by $0A_{16}$.
7. Subtract DATA5.

BUZIN (Pin 31)

The buzzer can be used for a variety of user-interface features, such as audible continuity or signaling of range changes. The buzzer will turn on when BUZIN is set HIGH.

APPLICATIONS

Power

The TC8129 is designed to operate from a single 9 Volt battery. The converter also provides a common mode reference point for analog measurements, power for the TC8131 controller, and power for the frequency counter buffer. The TC8129 internal power supply schematic is shown in Figure 11.

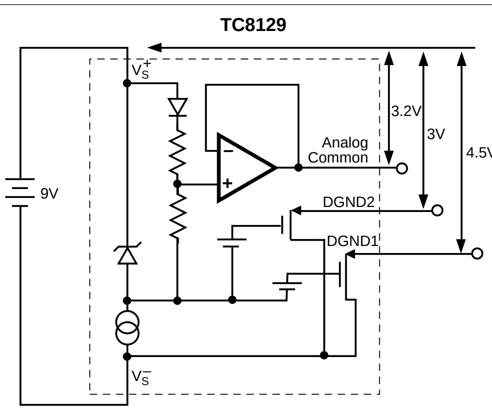


Figure 11. TC8129 Internal Power Supply, Simplified Block Diagram

Oscillator

The TC8129 normally operates with a 32.768kHz clock, which produces a conversion rate of (20 conversions/sec). A typical oscillator is circuit is shown in Figure 12.

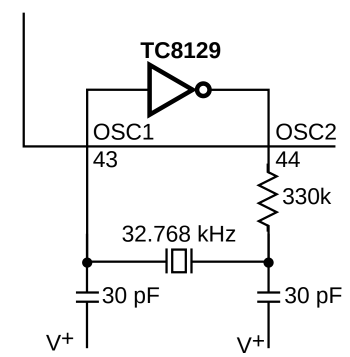


Figure 12. Clock Oscillator

COMPONENT SELECTION

Integrate Resistor (R_{INT})

A 100kΩ resistor is recommended for R_{INT}. This will limit integrator output current to about 4µA at full scale.

Integrate Capacitor (C_{INT})

The normal value for C_{INT} is 0.047µF. This value, combined with an integrate resistor of 100kΩ and clock frequency of 32.768kHz, will produce an integrator swing of about 1.5V at full scale. To reduce rollover errors, a capacitor with low dielectric absorption is required. A polypropylene capacitor is recommended for best performance, but polycarbonate, polyphenylene sulfide, or polystyrene capacitors can be used in less demanding applications.

Reference Capacitor (C_{REF})

For best performance, the reference capacitor must have very low leakage. Polypropylene dielectric is recommended, but polyester or other dielectrics may also give acceptable results. A value of 0.1µF is recommended.

Reference Voltages

The TC8129 requires three reference voltages for resistance, voltage and capacitance measurements. All three voltages can be derived from one external voltage reference, such as the TC04.

The resistor reference voltage, V_{REFR}, sets an internal bias voltage for resistance measurements. V_{REFR} is typically 1.25V. Resistance is measured ratiometrically, so the absolute value of V_{REFR} will not affect the accuracy of resistance measurements.

The reference voltage for voltage measurements is applied to the V^{+}_{REF} pin. This voltage should be adjusted to +545mV for 60Hz measurements or +655mV for 50Hz measurements.

Capacitance measurements are trimmed by adjusting the V_{HCTRM} and V_{LCTRM} voltages. Typical voltages for the V_{HCTRM} and V_{LCTRM} are 150mV and 1.4V respectively. Typical trim range required is ±20mV and ±150mV for V_{HCTRM} and V_{LCTRM} respectively.

AC TO DC CONVERTER

The TC8129 will measure voltage and current in both DC and AC modes. When the AC mode is selected, the input signal is internally switched to an AC-to-DC converter. The AC mode is selected by setting bit B0 of the command word to a logic “1”.

Internal AC to DC Converter

The TC8129's on-chip op-amp can be combined with external components to form an AC-to-DC converter. See typical application schematic.

External AC to DC Converter

An external AC-to-DC converter, such as the Analog Devices AD737, can also be used (Figure 13). This circuit will provide true RMS conversions.

Frequency Buffering

The frequency input of the TC8129 requires a logic swing from V^{+}_{S} to DGND1. An external buffer, to boost the input signal amplitude, will be required in most applications. In addition, the signal to be measured is typically referenced to the DMM's COMMON input, which is connected to the TC8129's analog COMMON. Therefore a level shifter is required to shift the logic LOW level from analog COMMON to DGND1. The AC-coupled buffer shown in the Typical Application diagram provides both level shifting and voltage amplification.

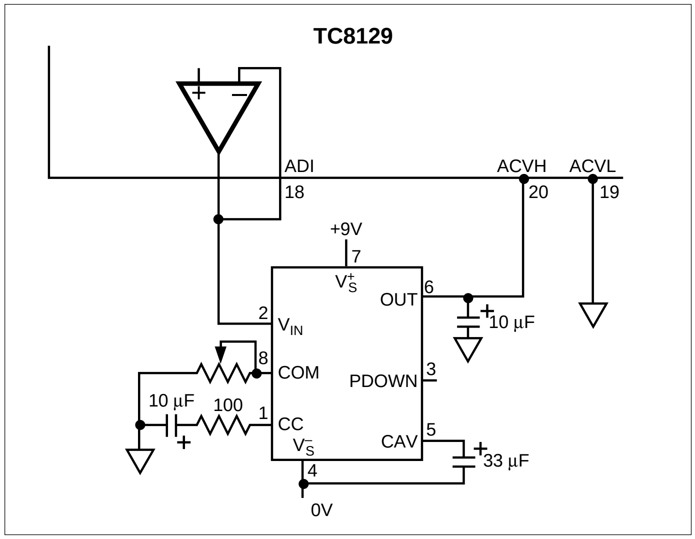


Figure 13. Truer RMS AC -to-DC Conversion

COMPONENT SOURCES

Multiple sources are available for most external components used with the TC8129. Prototyping quantities of the crystal are available from:

Digikey		1-800-344-4539
Thief River Falls, MN		
Crystal:		
	Mfg:	**EPSON AMERICA**
	Part#:	C-002RX 32.738K-A
	Digikey#:	SE3202

A test socket for the TC8129 44-Pin package is available from:

ENPLAS
Part# FPQ-80-0.8-11A
Vendor: TESCO International Inc.
Phone: (415) 572-1683 FAX: (415) 341-1509

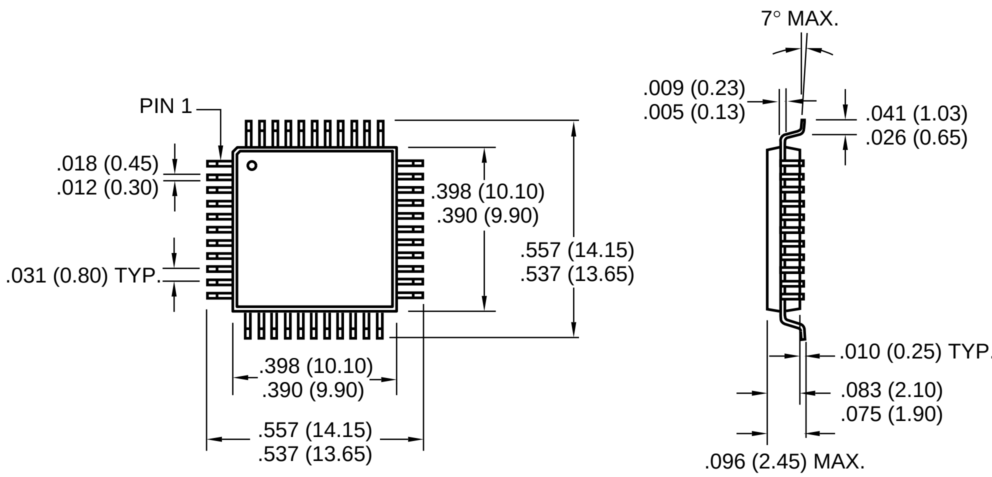
A suggested source for the input voltage divider resistor network is:

Caddock Electronics
1717 Chicago Ave.
Riverside, CA 92507
Phone: (909) 788-1700 FAX: (909) 369-1151
Part# 1776-C441

TC8129

PACKAGE DIMENSIONS

44 PQFP



Dimensions: inches (mm)

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