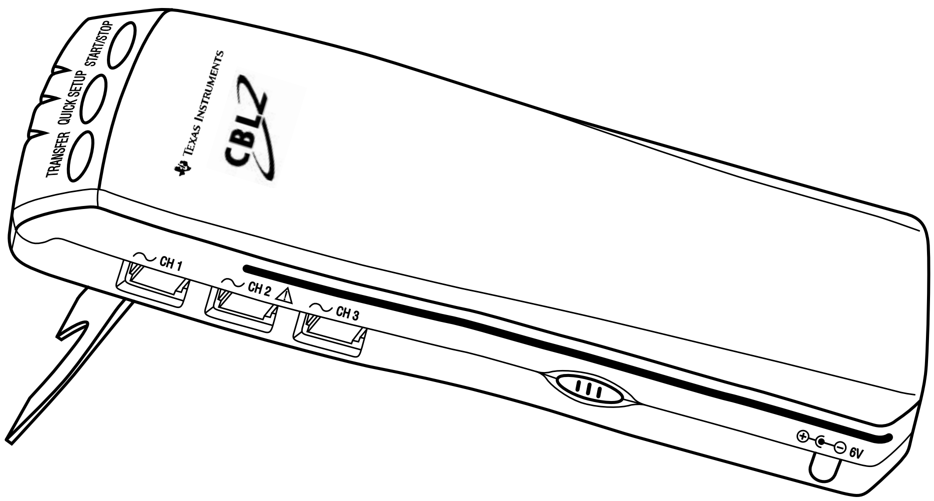
TEXAS INSTRUMENTS

CBL 2™



Technical Reference

Contents

Introduction

This technical reference is intended for CBL 2 users who want to write their own programs for CBL 2 and Texas Instruments graphing calculators. This document includes technical data such as specifications for sensors, syntax for CBL 2 commands, sample programs, error codes, and miscellaneous other topics.

Instructions for using CBL 2 with the DataMate program or app are given in ***Getting Started with CBL 2***, which is included in the CBL 2 package. The DataMate program is not addressed in this technical reference except for *Appendix C: DataMate Sensor Setup Default Settings*. This table shows the default sensor settings and calibrations used by the DataMate program.

Miscellaneous Reference Information

CBL 2 Software Upgrades

The CBL 2 uses *FLASH* technology, which allows you to easily upgrade to new software without buying a new CBL 2. As new functionality becomes available, you can download the software from the TI web site to your PC and then use the TI-GRAPH LINK™ (sold separately) to upgrade your CBL 2.

Check the TI website (**www.ti.com/calc**) for upgrades, paying special attention to compatibility statements. Directions for downloading upgrades will be given on the web site.

Data Collection Modes

On the CBL 2, data can be collected in one of three modes: realtime, non-realtime or FastMode.

- In *realtime* data collection, the CBL 2 collects data and sends it to the calculator after each point is taken.
- In *non-realtime* data collection, the CBL 2 collects data and stores it internally until all of the data points are taken and then sends it to the calculator.
- In *FastMode* data collection, the CBL 2 collects data on a single analog channel at a very fast sample rate, stores it internally until all of the data points are taken, and then sends it to the calculator.

It is the default to return the time with the data collected.

Realtime Sampling

In realtime data collection, the CBL 2 sends each data point to the calculator as it is taken, so some data can be lost if the calculator is not ready to accept the data. In addition, the quantity of data that can be collected is limited by the size of the calculator memory.

Realtime data collection is used for:

- Slower sampling where the user wants to see the data as it is being collected.
- Very long data collection times where the CBL 2 may run out of memory during data collection.
- Situations where the host calculator must process the data as soon as it becomes available (such as to control an output in response to a temperature input).

This data collection mode should not be used for data collection of more than a few points each second because the host calculator will not be able to keep up. In addition, because of the nature of realtime data collection, the period/frequency and Command 12 channels cannot be sampled in this mode.

Since the number of points to be collected may not be known at the start of sampling, set the "number of samples" to ⁻1 when sending Command 3. This tells the CBL 2 to take data but not send it to the host calculator until the calculator requests data.

Non-Realtime Sampling

In non-realtime data collection, the samples are taken and stored in the CBL 2 memory until all the data has been collected. Then the data is sent to the host calculator. The quantity of data collected is not limited by the size of the calculator memory, but is limited by the size of the CBL 2 memory. Up to 12,000 samples max (or less under some conditions) can be collected in non-realtime.

Non-realtime data collection is used for fast sampling of multiple channels and when triggering is required.

All of the channels can be used in this mode, and the Command 12 functions can be used. The sample time is limited by the number and types of channels enabled. For a single channel, the sampling can be as fast as 1E-4 second. In addition, normal calculator communication is maintained during the sampling. This allows the host calculator to issue a Command 7 or Command 8 to ascertain the progress of the sampling without disturbing the sampling process.

FastMode Sampling

FastMode sampling is designed to be used where a single channel must be sampled at very fast sample times. This mode is used primarily when sampling sound using the microphone.

In general, FastMode is identical to non-realtime sampling with the following exceptions:

- The sampling is limited to a single analog channel when doing FastMode sampling.
- The selected channel must not be in operation mode 5, 6, or 7.
- The communications with the host calculator are turned off during FastMode sampling.

Note: In FastMode sampling, it is very important that the program not issue a GET command until after sampling has been completed. If the CBL 2 receives a GET command it will abort FastMode sampling with an error in order to respond to the GET command.

In FastMode, the sample times can be as fast as 20 μsec (a sample frequency of 50KHz).

Mode Comparison Table

The table below shows some of the differences between the data collection modes.

	Realtime Mode	Non-Realtime Mode	FastMode
Order of data returned when doing the GETs from the host calculator	{ch1_1, ch2_1, … deltatime_1} {ch1_2, ch2_2, … deltatime_2} : : {ch1_n, ch2_n, … deltatime_n}	{ch1_1, ch1_2, … ch1_n} {ch2_1, ch2_2, … ch2_n} {ch3_1, ch3_2, … ch3_n} {time_1, time_2, … time_n}	Same as Non-Realtime
Number of samples limited?	Not by CBL 2, but may be limited by the host calculator	Yes, limited by available memory in CBL2	Same as Non-Realtime
Sample time limits (approximate)	Sample Time > .25 second to ≤ 16000 seconds	Sample Time ≥ 1e-4 seconds to ≤ 16000 seconds	Sample Time ≥ 2e-5 seconds to ≤ 1e-4 seconds
Number of channels limited?	Yes, only CH1-3 and 11	No	Yes, only a single channel from CH1 to CH3
Can use Triggering?	No	Yes	Yes
Communication maintained during sampling?	Yes	Yes	No

Beep Sequences

The CBL 2 makes four kinds of sounds:

- A low tone followed by a high tone (low-to-high beep).
- A medium tone followed by another medium tone (medium-medium beep).
- A high tone followed by another high tone (high-high beep).
- A “tick” sound when a key is pressed.

The following bullets explain when beep sequences normally occur and what the beep sequences mean.

- When the CBL 2 completes initialization, you will hear the startup sequence: high-high beep, medium-medium beep, low-to-high beep (6 total beeps, plus LEDs light up in this order: red LED, yellow LED, and green LED)
- When you press the QUICK SETUP button:
  - the medium-medium beep sounds if a sensor is attached to the CBL 2.
  - the high-high beep sounds if no sensors are attached to the CBL 2.
- When the CBL 2 is connected to a calculator during sampling commands:
  - the medium-medium beep sounds when initializing data collection.
  - the medium-medium beep sounds when starting data collection (transition from pre-store to store).
  - the medium-medium beep sounds when completing data collection.

Note: If the sampling timing causes the beeps to run together, the CBL 2 software may not sound all the beeps.

Note 2: You will not get all the beeps when Fast Sampling is enabled.

Note 3: You will not get all the beeps when using triggering.

- When you set the CBL 2 for manual trigger and press the START button, a medium-medium beep sounds.
- When you press the TRANSFER BUTTON:
  - the low-to-high beep sounds when the transfer succeeds.
  - the high-high beep sounds if the transfer fails for any reason.
- When an overcurrent condition is detected, five high-high beeps sound. (This causes an error, which causes even more beeps to sound.)
- When the CBL 2 begins a full self-test, three low-to-high beeps sound.
- When self-test completes:
  - the low-to-high beep sounds if self-test passes.
  - the high-high beep sounds if self-test fails.

- When the CBL 2's base code detects an error in the commands sent from the host, a high-high beep sounds twice.
- When the CBL 2 powers up:
  - two high-high beeps sound if the base code is not loaded.
  - three high-high beeps sound if the power-up self-test fails.
- During base code download, three high-high beeps sound when any errors occur. (The unit resets and then the two high-high beeps mentioned in the previous bullet sound.)

Archiving in CBL 2's *FLASH* Memory

The *FLASH* memory in the CBL 2 can be used for several purposes. In addition to allowing updates to the operating system and storing the DataMate programs, the *FLASH* memory serves as an archive space for other programs and data.

To preserve collected data so that it can be retrieved at a later time, data sets can be stored in the *FLASH* archive. To distinguish between different stored data sets, each data set can be given a name.

- You can write a program on the calculator to review the list of stored data sets and retrieve the desired one for further analysis. (See the sample archive program on page 56.)
- You can use the DATADIR program (available on the TI Resource CD or on the TI web site at **www.ti.com/calc**) to manage *FLASH* memory. Directions for using the DATADIR program are given in ***Getting Started with CBL 2***.

The *FLASH* archive can also store calculator programs and applications. This provides a convenient location for storing frequently used programs or as a temporary storage to create more available memory on the calculator.

Command 201, in conjunction with the Link menu on the calculator, provides access to these *FLASH* archive operations. For details about Command 201, see page 44.

Technical Specifications for Sensors

TI Light Sensor

The TI light sensor uses a phototransistor to measure relative irradiance. The units of irradiance are milliwatts per square centimeter. The light sensor's output is a voltage that is linearly proportional to the amount of irradiance it senses. The range of light over which the sensor is sensitive is $10\mu W/cm^2$ to $1mW/cm^2$.

The auto-ID resistor in the sensor causes the CBL 2 software to automatically convert the measured voltage to relative units. The sensor is direction dependent and achieves the highest output when the end of the sensor is pointed directly at the light source.

The light sensor is sensitive in the visible and near-infrared (IR) light range. This means you can use it with IR emitting diodes as well as all visible light sources. The light sensor is designed to work in air only—it is not waterproof.

The light sensor returns *relative* readings, not absolute irradiance readings. Values may vary from light sensor to light sensor. The light sensor readings are also sensitive to temperature.

TI Light Sensor Specifications

Channels	Connects to CH1, CH2, CH3 (analog channels)
Current drain	5 mA max.
Voltage range	0–5 Volts
Irradiance range	$10\mu W/cm^2$ to $1mW/cm^2$ (approximately)
Spectral response range	300nm to 1100nm (nanometers) (non-flat response)
Chemical tolerance	None (air only)
Pins used	2 ground 4 auto-ID resistor 5 +5 Volts DC 6 Signal

Stainless Steel Temperature Sensor

The Stainless Steel Temperature Sensor is an auto-ID general-purpose laboratory temperature sensor that comes with your CBL 2. The sensor is rugged and durable, and is designed to be used as you would use a thermometer for experiments in chemistry, physics, biology, earth science, and environmental science.

This probe uses the 20 kΩ NTC Thermistor. The thermistor is a variable resistor whose resistance decreases nonlinearly with increasing temperature. The best-fit approximation to this nonlinear characteristic is the Steinhart-Hart equation. The CBL 2 or CBL interface measures the resistance value, R, at a particular temperature, and converts the resistance using the Steinhart-Hart equation:

$$T = [K_0 + K_1(\ln 1000R) + K_2(\ln 1000R)^3]^{-1} - 273.15$$

where T is temperature (°C), R is the measured resistance in kΩ, $K_0 = 1.02119 \times 10^{-3}$, $K_1 = 2.22468 \times 10^{-4}$, and $K_2 = 1.33342 \times 10^{-7}$. Fortunately, CBL 2 and CBL take care of this conversion for you, and provide readings in °C (or other units, if you load a different calibration).

Stainless Steel Temperature Sensor Specifications

Channels	Connects to CH1, CH2, CH3 (analog channels)
Current drain	0.5 mA max.
Temperature range	-25 to 125°C (-13 to 257°F)
Maximum temperature sensor can tolerate without damage	150°C
10-bit resolution	0.32°C (-25 to 0°C) 0.12°C (0 to 40°C) 0.4°C (40 to 100°C) 1.0°C (100 to 125°C)
Temperature sensor	20 kΩ NTC Thermistor
Accuracy	±0.2°C at 0°C, ±0.5°C at 100°C
Response time	95% of full reading: 11 seconds 98% of full reading: 18 seconds 100% of full reading: 30 seconds
Probe dimensions	Probe length (handle plus body): 16 cm Stainless steel body: length 11 cm, diameter 4.0 mm Probe handle: length 5.0 cm, diameter 1.25 cm
Pins used	2 Ground 3 Vres 4 auto-ID resistor 6 Signal

Temperature Accuracy

This probe provides very accurate temperature readings. Near 0°C, readings are accurate to ±0.2°C; near 100°C, readings are accurate to 0.5°C.

Important: Because of the non-linear nature of the Stainless Steel Temperature Probe, you cannot re-calibrate this sensor. Probe-specific calibrations should not be necessary when using this sensor.

Stainless Steel Temperature Sensor Chemical Tolerance

The body of this sensor is constructed from grade 316 stainless steel (0.08% carbon, 2.0% manganese, 0.75% silicon, 0.04% phosphorus, 0.03% sulfur, 16-18% chromium, 10-14% nickel, 2-3% molybdenum, and 0.1% nitrogen). This high-grade stainless steel provides a high level of corrosion resistance for use in the science classroom.

Here are some general guidelines for using this probe:

1. The probe handle is constructed of molded plasticized Santoprene®. While this material is very chemical resistant, we recommend that you avoid submerging the probe beyond the stainless steel portion.

2. Always wash the probe thoroughly after use.

3. The probe can be left continuously in water at temperatures within the range of –25° to 125°C. Continuous usage in saltwater will cause only minor discoloration of the probe, with no negative effect on performance.

4. You can leave the probe continuously in most organic compounds, such as methanol, ethanol, 1-propanol, 2-propanol, 1-butanol, n-hexane, lauric acid, paradichlorobenzene, phenyl salicylate, and benzoic acid. The probe should not be left in n-pentane for more than 1 hour.

5. The probe can be left in strong basic solutions, such as NaOH, for up to 48 hours with only minor discoloration. We do not recommend usage in basic solutions that are greater than 3 M in concentration.

6. The following chart provides the maximum length of time we recommend for probe exposure to some common acids. Probes left in an acid longer than these times may bubble and/or discolor, but will still be functional. We do not recommend probes be left in **any** acid longer than 48 hours.

Acid	Maximum Exposure Time
1 M HCl	20 minutes
2 M HCl	10 minutes
3 M HCl	5 minutes
1 M H_2SO_4	48 hours
2 M H_2SO_4	20 minutes

Acid	Maximum Exposure Time
3 M H_2SO_4	10 minutes
1 M HNO_3	48 hours
2 M HNO_3	48 hours
3 M HNO_3	48 hours
1 M $CH_3CO\ OH$	48 hours
2 M $CH_3CO\ OH$	48 hours
3 M $CH_3CO\ OH$	48 hours
1 M H_3PO_4	48 hours
2 M H_3PO_4	48 hours
3 M H_3PO_4	48 hours

7. Cole Parmer has an extensive listing of chemical compatibility of grade 316 stainless steel on their web site (**www.coleparmer.com/techinfo**). This listing can be used for general guidelines not covered in this summary.

TI Temperature Sensor Note

If a TI Temperature sensor (the flexible temperature sensor that came with the original CBL) is used with CBL 2, it will auto-ID as the Stainless Steel Temperature sensor. Both sensors use the same calibration that is built into the CBL 2.

TI Voltage Sensor

The TI voltage sensor is a generic sensor that you can use to read any voltage between ±10 Volts. The auto-ID resistor contained in the sensor causes the CBL 2 software to automatically measure voltage. No conversion equation is loaded. The black hook should be connected to ground and the red hook to the signal voltage.

Channels	Connects to CH1, CH2, CH3 (analog channels)
Voltage range	±10 Volts
Chemical tolerance	None (air only)
Pins used	1 Signal 2 Ground 4 auto-ID resistor

Note: It is very important that the ground connections of the analog inputs are never connected to different potentials. These ground connections are all in common. Connecting the grounds to different potentials may damage the CBL 2.

Auto-ID Sensors

The CBL 2 contains provisions for the auto-ID sensor resistor values listed below. If needed, a conversion equation is loaded automatically for some of the auto-ID values.

Channels 1, 2, and 3		
IDENT Value[1]	Sensor Type	Range
2.2K	Thermocouple °C	-200C to 1400°C
33K	TI Voltage sensor	-10 to +10 Volts
6.8K	Current sensor[2]	-10 to +10 Amps
3.3K	Resistance sensor	1K to 100KΩ
22K	Extra long temperature sensor for °C	-50°C to 150°C
68K	CO_2 gas sensor (PPM)	0 to 5000 ppm
100K	Oxygen gas sensor (PCT)	0 to 27%
150K	C V voltage sensor (V)	-6 to +6 Volts
220K	C V current sensor (A)	-0.6 to +0.6 Amps
10K	Stainless steel or TI temperature sensor[3] for °C	-25°C to 125°C
15K	Stainless steel or TI temperature sensor for °F	-13°F to 257°F
4.7K	TI Light sensor	0 to 1
1K	Ex heart rate sensor (BPM)	N/A
47K	Voltage sensor	0 to 5 Volts
1.5K	EKG	N/A

[1] IDENT values are resistance values in ohms (tolerance ±5%).

[2] Operation 3 is a mathematical conversion of voltage to a current reading (1V=1A). There is no circuitry inside the CBL 2 unit to convert current to voltage; this must be done in the external probe.

[3] Default units for the Stainless Steel and TI Temperature sensors is °C.

Channel 11 (SONIC)		
IDENT Value[1]	Sensor Type	Range
15K	Motion detector, meters	½ meter to 6 meters
22K	Motion detector, meters	½ meter to 6 meters
10K	Motion detector, feet	1½ feet to 18 feet
33K	Photogate sensor	N/A

[1] IDENT values are resistance values in ohms (tolerance ±5%).

Custom Sensors

To create custom-designed sensors or other circuits for the analog input channels, the sonic input channel, the digital input channel, or the digital output channel on the CBL 2, you can purchase sensor kits from TI (**1-800-TI-CARES**) or its Instructional Dealers.

- For a custom analog sensor, use the Analog Probe Kit (order entry no. CBL/CA/D). Each sensor kit includes a four-foot length of telephone cable with a connector attached to one end. The other end of the cable is not terminated.
- For a custom digital sensor, cut a CBR-to-CBL cable (order entry no. CBR/CA/C) into two pieces to get two lengths of cable with connectors. (The digital probe kit used with the original CBL will not work with CBL 2.)
- For a custom digital ID probe, contact Vernier Software and Technology (**www.vernier.com**) for more information.

Be very careful when designing a custom sensor or circuit. For more accurate operation, do not connect pins 1 and 6 together on the analog input channels. Pin 1 on the British Telecom-style connector is the pin farthest from the release lever as shown in the pictures below.

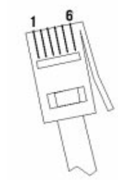
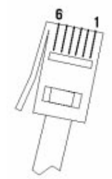
If you design a resistance-type sensor, connect pin 3 (Vres) to pin 6 (Vin-low) (refer to "Connector Pinouts" below). Connect the resistance to be measured from the junction of these pins to pin 2 (Gnd). The resistance range for useful measurements is limited from approximately 1 Kohms to 100 Kohms.

When the Operation parameter in Command 1 (page 23) is set to 2, 3, 5, 6, or 7, the data is measured on the Vin pin (pin 1). The data for all other operations is measured on the Vin-low pin (pin 6).

Note: The most current that can be drained from all three analog channels is 160 mA. This is limited by the hardware.

Connector Pinouts

The CBL 2 sensors use 6-pin British Telecom-style connectors.

Pin	Analog CH1, CH2, CH3	SONIC	DIG IN/OUT
	 (Right-hand Connector)	 (Left-hand Connector)	
1	Vin	Echo	DI0
2	Gnd	Init	DI1
3	Vres/Smart ID CLK	Auto-ID	DI2
4	Auto-ID	+5 Volts DC	+5 Volts DC
5	+5 Volts DC	Gnd	Gnd
6	Vin-low	Not Applicable	DI3

	Vin	Vin-low
Channels:	CH1, CH 2, CH 3	CH1, CH2, CH3
Input signal:	Analog data	Analog data
Input range:	±10 Volts	0 to 5 Volts
Resolution (using CBL 2's 10-bit A/D converter):	19.6 mV	5.6 mV
Input impedance:	1.046 MΩ	>10 MΩ

- Vres: Output reference voltage from the CBL 2 through a 15 Kohm resistor. When using this feature, Vres should be tied to Vin-low and the value to be measured should be connected between Vin-low and Gnd.
- Gnd: Ground (common for all channels).
- Auto-ID: Auto-ID sensor detection data input. (Auto-ID resistor connected from pin 4 to ground.)
- Echo: Ultrasonic motion detector input.
- Init: Distance initialization signal
- D0 In/Out to D3 In/Out: Input or output pins for digital pulses.
- Smart ID Clk: Clock to synchronize data transfer from smart probes.

Programming the CBL 2

Digital Output Buffer

The digital output buffer (DOB) is a circular buffer that contains up to 32 elements. The output from the buffer is 4-bits wide, and the outputs are CMOS (0-5V) compatible. The data in Command 1 is entered as decimal representation of the digital value that is output. For example, 0=0000, 5=0101, and 15=1111. At the beginning of each sample, a pointer into the digital output buffer is incremented and the next available data is sent to the output lines.

The electrical characteristics of the digital outputs are:

- Voutput-high ≥ 3.7V @ -400uA
- Voutput-low ≤ 0.65V @ 1.6mA

The number of times that the DOB outputs the contents of the buffer depends on the number of data elements defined in Command 1 and the number of samples defined in Command 3.

Digital Output Buffer Example

Command 1 list is {1,31,5,1,2,3,4,5} where:	Command 3 list is {3,1,100} where:
1=Channel Setup.	3=Sample and Trigger Setup.
31=DIG OUT.	1=One second sample time.
5=Five data elements.	100=One hundred samples.
1=0001 (digital nibble).	(Trigger Type defaults to manual triggering.)
2=0010 (digital nibble).	
3=0011 (digital nibble).	
4=0100 (digital nibble).	
5=0101 (digital nibble).	

The DOB outputs pulses that correspond to the five digital nibbles (1234512345...12345 etc.). This sequence is repeated 20 times (100 samples/5 data elements) to the DIG OUT channel. The diagram below shows a portion of this output for the first five data elements.

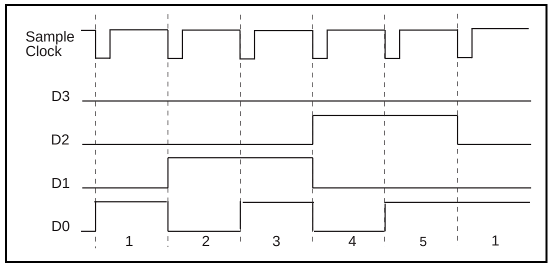


Figure 1. Digital Output Example

Triggering and Thresholds

Two types of triggering thresholds can be set in the CBL 2:

- *Hardware triggering* is set to trigger on a specific voltage level established by the trigger threshold parameter.
- *Software triggering* is set to begin data collection on either the rising edge or falling edge of the signal, depending on the trigger type and trigger threshold selected.

The THRESHOLD parameter specified in Command 3 can be used for two purposes:

- If the operation in Command 1 is frequency, period, or count (operation = 5, 6, or 7 on Channel 1 only), then the threshold parameter in Command 3 sets a voltage level in the CBL 2 hardware. The signal on the Vin pin of CH 1 must pass through this voltage for the CBL 2 to see the signal change states.
- If the operation in Command 1 is anything other than 5, 6, or 7, then the threshold parameter in Command 3 specifies a trigger level and is measured in the units of the sensor selected.

When triggering, sampling does not start until the signal on the trigger channel (also specified in Command 3) passes through this level once in the direction specified. This comparison of trigger level and signal level occurs in software, so any level in the proper range can be selected. Also, either the Vin or VinLow pin (on any of the analog channels or the sonic channel) can be used as the trigger channel. CBL 2 knows whether to use the Vin or VinLow pin by looking at which operation was set up in Command 1.

If a conversion equation is enabled for the trigger channel, then the threshold specified in Command 3 should be a converted level. For example, if a pH probe is plugged into CH 2 with a conversion equation loaded into CBL 2 and the trigger channel specified as CH 2, the threshold level should be entered as a pH level in the range 0-14, not as a voltage in the range 0-5V.

Measuring Period and Frequency

Period and frequency apply only to CH1 and only CH1 can be active if the operation is set to 5 (Period) or 6 (Frequency). Period and frequency are measured on Vin pin (pin 1) of CH1. Period and frequency measurements always use the hardware threshold.

The CBL 2 measures period and frequency by counting edges for 0.25 seconds, or by measuring the time between the selected edges for one period—whichever is larger (see figure below). If a significant number of edges are counted during the 0.25-second period, the count is used to compute both period and frequency; otherwise, the period and frequency are computed from the time interval for one period.

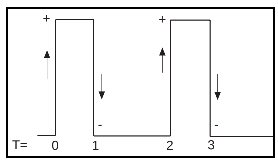


Figure 2. Period and Frequency Measurement

Trigger Type	Measuring Points
2	+ + (T=0 to 2)
3	– – (T=1 to 3)
4	– + – (T=0 to 1)
5	– – + (T=1 to 2)

The crossover point between the two computations is about 600 Hz. Because there can be a one-count uncertainty during the 0.25-second period, the accuracy around 600 Hz is approximately ±4 Hz (about 0.7%). The resolution of the timer measuring the time between edges is 6.4 microseconds; therefore, the percentage accuracy improves for frequencies above and below 600 Hz.

If the CBL 2 is set up using Command 3 to make multiple measurements at a particular sample time, the CBL 2 waits for the sample time that you specified after it completes the current measurement. It then initiates the next cycle of period/frequency measurement. The minimum sampling time for period and frequency is 0.25 seconds.

Note: Period and frequency measurements using Trigger Type 4 or 5 are only possible on non-repetitive signals or on repetitive signals that are less then 600 Hz. This is because at 600 Hz, the edge counts will prevail.

The parameters shown in this table are used when measuring period or frequency.

Trigger Type	Edge Polarity Used	Hardware Threshold Used
0	Rising (+)	Trigger Threshold parameter
2–5	Specified by trigger type	Trigger Threshold parameter
6	Not allowed (E.34 error).	

Example: Measuring Frequency

Assume a frequency measurement is requested on CH 1, and 20 measurements are desired at a .5 second sample time. The following commands would set up the CBL 2 for this example:

{1,1,6}
{3,.5,20,2,0,1}

3 = Sample and Trigger setup command
.5 = Sample time of 0.5 seconds
20 = Number of samples to take
2 = Trigger from rising edge to rising edge for frequency
0 = Trigger channel not applicable
1 = Trigger at 1 Volt

Assume a ±10 Volt, 20 Hz sine wave is the input signal on pin 1. The CBL 2 follows the sequence of steps indicated below when the first trigger occurs (a trigger occurs every 0.05 seconds).

1. Trigger occurs on the rising edge.
2. Start counter and timer.
3. Stop timer at next rising edge.
4. Wait until 0.25 seconds has elapsed.
5. Stop counter (count should be about 5).
6. Count is less than 150 (or 600 Hz); therefore, frequency is computed from the time interval for one period.
7. Wait for 0.5 seconds specified in Sample Time.
8. Wait for additional processing time to complete. (This time depends on what processing is currently being performed and is typically about 0.25 additional seconds.)
9. Repeat steps 1 through 8 for nineteen more samples.

In this example, the CBL 2 takes approximately 15 seconds to complete all the sampling and turn on the DONE indicator in the display.

Asynchronous/ Synchronous Triggering versus Record Time

Actual triggering is asynchronous from the internal sampling clock when Trigger Type in Command 3 is set to 1 or 6 (manual triggering). If sampling at very fast rates, the actual trigger may be slightly different from the commanded trigger. The user should take this into account when calculating prestore and trigger levels.

The actual sample time for the trigger point depends on whether or not prestore is selected in Command 3.

When prestore and relative record time are selected, the sample time for the trigger point will generally not be identical to times around it. The time recorded for the trigger point will be the actual time between the previous sampled point on the internal sampling clock interval and the asynchronous trigger event. The sample taken after the trigger point will be at the specified sample time since the clock is reset each time the trigger event occurs (pressing START/STOP or the hardware threshold trigger event).

When Trigger Type is set to 6 (Manual and Sample Trigger) in Command 3, the recorded sample times are the actual relative times when START/STOP is pressed.

When no prestore is selected, the first sample time will be the trigger point. Its recorded time will not be the internal sample clock time because the CBL 2 is always sampling on the internal clock interval that you selected and is storing points (if you selected prestore) until the trigger event occurs.

Example

Assume the following:

- Input to CH1, set to measure ±10 Volts, is a 0.01 Hz sine wave.
- Sample Time is set to 10 seconds and Number of Samples is set to collect 30 points.
- Trigger Channel is set to 1.
- Trigger Threshold is set to 1.0 and Trigger Type is set to 2 (trigger on rising edge).

The CBL 2 will collect and store a sample every 10 seconds. The recorded time for each sample will be 10 seconds. The trigger event (signal rising through 1.0 Volts) occurs 1.5 seconds after the previous sample, so a sample collected at the trigger point is taken and stored with a recorded time of 1.5. The next sample is taken 10 seconds after the trigger sample, not 8.5 seconds later as would have happened if the internal sample clock had not been reset.

The Record Time returned (around the trigger point) will be the list: {...10,10,10,1.5,10,10,...}.

CBL 2 Command Summary

The table below lists the commands you can use in writing programs for CBL 2. Detailed explanations of each command and its syntax can be found beginning on the page number shown in the third column.

Command Number	Command Description	See Page
0	**Reset:** Resets all channels to default conditions.	23
1	**Channel Setup:** sets up a channel for data collection.	23
2	**Data Type:** *This command is not used and should not be sent. It is included only for compatibility with older CBL programs.*	26
3	**Trigger Setup:** Sets up the trigger parameters for an experiment.	26
4	**Conversion Equation Setup (Analog Channels):** Sets up parameters to convert physical units measured by CBL 2 into a more useful measurement unit such as Newtons or °C. **Sonic Temperature Compensation (Sonic Channel):** Sets the unit of measurement for sonic data.	28 30
5	**Data Control:** Selects the type of data to be retrieved, as well as the starting and ending data points to be retrieved by a TI calculator.	30
6	**System Setup:** Turns sound on or off; sets an ID number for the CBL 2; selects a filter to be applied to data.	30
7	**Request System Status:** Generates and prepares to return status information.	31
8	**Request Channel Status:** Generates and prepares to return sensor type, last valid data, and last valid data position for the requested channel.	32
9	**Request Channel Data:** Generates and prepares to return one data point before sampling starts. Used to verify that setup is correct.	33
10	**Advanced Data Reduction:** Sets up CBL 2 to process certain time-intensive algorithms instead of processing them in the calculator.	33
12	**Digital Data Capture:** Sets up the capture or measurement of motion data from the digital input channel.	34
102	**Power Control Command:** Sets the power to always on; power-saving; or designated power up.	41

Command Number	Command Description	See Page
115	**Check Set-up Information:** Returns status information for the designated channel.	41
116	**Check Long Sensor Name:** Returns long sensor name.	42
117	**Check Short Sensor Name:** Returns short sensor name.	43
1998	**Set LED Command:** Turns LEDs on and off on command.	43
1999	**Sound Command:** Specifies length and frequency of CBL 2 sounds.	43
2001	**Direct Output to Digital-Out Port:** Outputs data to the digital output port during a sampling run.	43
201	**Archive Operations Command:** Allows the calculator to determine the contents of the CBL 2's *FLASH* memory.	44

Detailed information about each command is given below. The table following each syntax lists valid values. Default values appear in **boldface** type.

Command 0 Reset CBL 2 RAM

Syntax: {0}

This command has no parameters or options. Clears data memory back to power-up state. Clears error information. Resets only the RAM; does not clear *FLASH* memory.

This command should be sent at the beginning of each program.

Command 1 Channel Setup

This command sets up a channel for data collection. It has six syntaxes, as shown below.

Syntax: {1,0}

Clears all channels.

Syntax: {1,channel,0}

Turns off the selected channel.

Channel
1-3 = Analog
11 = Sonic
21 = Digital Input
31 = Digital Output

Syntax: {1,channel,operation,post-processing,(delta)[1],equ}

Use this syntax to set up analog channels.

Channel	Operation/ Sensor Type	Post-Processing	Conversion Equation
1-3 = Analog	**0 = Turn channel off** 1 = Auto-ID this sensor (default is 0-5V sensor) 2 = TI Voltage ±10V 3 = Current ±10A 4 = Resistance 5[4] = Measure period on ±10V input line (CH 1 only) 6[4] = Frequency on ±10V input line (CH 1 only) 7[5] = Count transitions on ±10V input line (CH 1 only) 10 = TI Temperature or Stainless Steel Temperature (Centigrade) 11 = TI Temperature or Stainless Steel Temperature (Fahrenheit) 12 = TI Light 14 = Low voltage (0-5V)	**0 = None (RT[2] and NON-RT[3])** 1 = d/dt (NON-RT) 2 = d/dt and d^2/dt^2 (NON-RT)	**0 = Off** 1 = On (must also send Command 4)

[1] This parameter is ignored.
[2] RT: REALTIME mode sampling.
[3] NON-RT: NON-REALTIME mode sampling.
[4] When using Command 1 operation 5 or 6, Trigger Type in Command 3 must be 2, 3, 4 or 5.
[5] When using Command 1 operation 7, Trigger Type in Command 3 must be 0.

Syntax: {1,11,operation,post-processing,(delta)[1] ,equ}

Use this syntax to set up the sonic channel.

Operation	Post-Processing	Conversion Equation
0 = Resets channel 1 = Meters – Returns distance and Δtime (RT and NON-RT) 2 = Meters – Returns distance and Δtime (RT and NON-RT) 3 = Feet – Returns distance and Δtime (RT and NON-RT) 4 = Meters – Returns distance, velocity, and Δtime (RT) or distance and Δtime (NON-RT) 5 = Feet – Returns distance, velocity, and Δtime (RT) or distance and Δtime (NON-RT) 6 = Meters – Returns distance, velocity, acceleration, Δtime (RT) or distance and Δtime (NON-RT) 7 = Feet – Returns distance, velocity, acceleration, Δtime (RT) or distance and Δtime (NON-RT)	**0 = None (RT[2] and NON-RT[3])** 1 = d/dt (NON-RT) 2 = d/dt and d^2/dt^2 (NON-RT)	**0 = Off** 1 = On (must also send Command 4 for temperature compensation)

[1] This parameter is ignored.
[2] RT: REALTIME mode sampling.
[3] NON-RT: NON-REALTIME mode sampling.

Note: When post-processing is enabled in non-realtime sampling mode, all operations will return the first derivative and the second derivative.

Syntax: {1,channel,operation}

Use this syntax to set up the digital input channel.

Channel	Operation
21 = Digital Input	**0 = Off** 1 = On

Syntax: {1,channel,operation,list of values}

Use this syntax to set up the digital output channel.

Channel	Operation	List of Values
31 = Digital Output	**0 = Clears the channel** 1-32 = Count (number of data elements in list)	Lists values output to digital output port

Note: the list of values must have one value for each count.

The CBL 2 outputs one element for each sample. Between samples, the output returns to 0 unless the user has commanded the power to remain on (using Command 102, -1).

Caution: Using Command 102, -1 can drain the CBL 2 batteries.

Command 2 Data Type

This command is not used and should not be sent. However, it is included for compatibility with older CBL 2 programs.

Command 3 Trigger Setup

This command sets up the trigger parameters for an experiment. It has three syntaxes.

Syntax: {3, -1}

Repeats last Command 3 (used to quickly collect new data).

Syntax: {3,samptime,numpoints,0,0,0,0,0,0,filter }

Use this syntax for realtime data collection.

Sample Time	Number of Points	Filter
>0 to ≤16000 **Default = 0.5**	-1 = REALTIME mode 0 = Invalid	**0 = None** 7 = Light Realtime tracking filter 8 = Medium Realtime tracking filter 9 = Uses Heavy Realtime tracking filter

Syntax: {3,samptime,numpoints,trigtype,trigchan,trigthresh, pre-store,(extclock)[1],rectime,filter,fastmode}

Use this syntax for non-realtime data collection.

Sample Time	Number of Points	Trigger Type	Trigger Channel	Trigger Threshold
>0 to ≤16000 **Default = 0.5**	0 = Invalid 1 to 12,000 = NON-REALTIME mode and number of points to collect	0 = Immediate **1 = Manual** 2 = Rising edge/ rising edge 3 = Falling edge/ falling edge 4 = Rising edge/ falling edge 5 = Falling edge/ rising edge 6 = Single sample	**0 = Disables trigger** 1 = CH1 (channel must be active)[2] 2 = CH2 (channel must be active)[3] 3 = CH3 (channel must be active)[3] 11 = CH11 (channel must be active)[3]	– channel limit to + channel limit (channel limit is determined by sensor attached to the channel) **Default = 1V**

Pre-store Data	Record Time	Filter	FastMode[5]
0% to 100%[4]	0 = None **1 = Absolute** 2 = Relative *Note: This is different from the original CBL. Default on CBL was 0.*	**0 = None** 1 = Savitzky-Golay 5-point filter 2 = Savitzky-Golay 9-point filter 3 = Savitzky-Golay 17-point filter 4 = Savitzky-Golay 29-point filter 5 = Uses Median Pruning 3-point filter 6 = Uses Median Pruning 5-point filter	**0 = OFF (normal operation)** 1 = ON (FASTMODE sampling)[6]

[1] This parameter is ignored.

[2] Hardware trigger only for Command 1 operation 5, 6, or 7; software trigger for all others.

[3] Software trigger only.

[4] Prestore is not valid for manual trigger or immediate trigger. Due to the delay in determining the start of sample, the actual amount of prestore may be smaller than the selected amount.

[5] FASTMODE does not apply to the Sonic/Digital channels.

[6] In FASTMODE, only one channel can be active, and it must be an analog channel. Sampling can be as fast as 20µs/sample in this mode. FASTMODE is operational only for sample rates from 50,000 sample/second to 5,000 samples/second.

Each probe has a minimum sample time, which is listed in the table below:

Probe Type	Minimum Sample Time
Analog probes	100µsec/per probe
Sonic probes	8 milliseconds
Digital In/Out	100µsec/per probe

Note: TrigTypes 0, 1, and 6 cannot be used with frequency measurements (operation 6) or with period measurements (operation 5).

Note 2: TrigTypes 2, 3, 4, 5, and 6 cannot be used with count transition (operation 7).

Note 3: TrigTypes 1 and 6 cannot be used with FASTMODE sampling.

Note 4: While CBL 2 is waiting for TrigThresh, you can press the START/STOP to start sampling immediately.

Command 4 Conversion Equation Setup (Analog)

This command sets up parameters to convert physical units measured by CBL 2 into a more useful measurement unit such as Newtons or °C. It has six syntaxes.

Syntax: {4,0}

Clears the equation for all channels.

Syntax: {4,channel,⁻1}

Channel
1, 2, or 3

Sets unary equation; returns raw data for the channel.

Syntax: {4,channel,1,N,K_0, . . .K_n}

Channel	N	K
1 = Sets CH 1 2 = Sets CH 2 3 = Sets CH 3	N = 1 through 9	No restrictions except overflow.

Sets up polynomial equation:

$K_0 + K_1X + K_2X^2 + ... + K_nX^n$

Syntax: {4,channel,2,M,N, K_m, K_{m-1},. . .K_0, . . .K_n }

Channel	M	N	M +N	X
1 = Sets CH 1 2 = Sets CH 2 3 = Sets CH 3	M = 0 through 4	N = 0 through 4	M + N > 0	$X \neq 0$

Sets up mixed polynomial equation:

$K_{-m}X^{-m} + \ldots + K_{-1}X^{-1} + K_0 + K_1X + \ldots + K_nX^n$

Syntax: {4,channel,equtype, K_0,K_1}

Channel	Equation Type
1 = Sets CH 1 2 = Sets CH 2 3 = Sets CH 3	3 = Power 4 = Modified power 5 = Logarithmic 6 = Modified logarithmic 7 = Exponential 8 = Modified exponential 9 = Geometric 10 = Modified geometric 11 = Reciprocal logarithmic 12 = Steinhart-Hart Model

Equation Type	Equation	Restrictions
3 Power	$K_0X^{(K_1)}$	X>0
4 Modified Power	$K_0K_1^{(X)}$	$K_1>0$
5 Logarithmic	$K_0 + K_1\ln(X)$	X>0
6 Modified Logarithmic	$K_0 + K_1\ln(1/X)$	X>0
7 Exponential	$K_0\, e^{(K_1X)}$	No restrictions other than overflow.
8 Modified Exponential	$K_0\, e^{(K_1/X)}$	$X\neq0$
9 Geometric	$K_0X^{(K_1X)}$	$X\geq0$
10 Modified Geometric	$K_0X^{(K_1/X)}$	X>0
11 Reciprocal Logarithmic	$[K_0 + K_1\ln(K_2X)]^{-1}$	$K_2X>0$
12 Steinhart-Hart Model	$[K_0 + K_1\,(\ln 1000X) + K_2(\ln 1000X)^3]^{-1}$	X>0

Command 4 Sonic Temperature Compensation (Sonic)

This command sets the unit of measurement for sonic data.

Syntax: {4,channel,equtype,temperature,units}

Channel	Equation Type	Temperature	Units
4 = Sets SONIC if *equtype*=13 11 = Sets SONIC	**0 = Clears the equation for the selected channel** 13 = Sonic temperature compensation	Temperature value for which you want to compensate	0 = temperature in °Celsius 1 = temperature in °Fahrenheit 2 = temperature in °Celsius 3 = temperature in Kelvin 4 = temperature in Rankin

Command 5 Data Control

This command selects the type of data to be retrieved, as well as the starting and ending data points to be retrieved by a TI calculator.

Syntax: {5,channel,dataselect,databegin,dataend}

Channel	Data Select	Data Begin	Data End
-1 = Sets recorded time **0 = Lowest active channel** 1-3 = Analog 11 = Sonic 21 = Digital input	**0 = raw collected data (filtered)** 1 = d/dt (filtered) 2 = d^2/dt^2 (filtered) 3 = raw collected data (unfiltered) 4 = d/dt (unfiltered) 5 = d^2/dt^2 (unfiltered)	**0 = first point collected** 1 through *n* = point selected	**0 = last point collected** 1 through *n* = point selected

Note: If Data Select = 0, 1, or 2 and Command 3 Filter = 1-6, data will be filtered according to the filter selected in Command 3. If Data Select = 3, 4,or 5; the filter setting in Command 3 will be ignored.

Note 2: Data End must be greater than or equal to Data Begin (unless Data End = 0). Both DataBegin and DataEnd must be less than or equal to the number of samples sent to the CBL 2 in the last Command 3.

Note 3: Each Command 5 must be followed by a Get statement.

Note 4: Sampling must be completed before sending Command 5 to control the data. Before sending Command 5, do a Get statement to ensure that sampling is completed or send Command 7 to check the status and verify that sampling is completed.

Command 6 System Setup

This command has three syntaxes. The first turns sound on or off, the second sets an ID number for the CBL 2, and the third selects a filter to be applied to data.

Syntax: {6,command}

Command
0 = Abort sampling
2 = Abort sampling
3 = Turns sound off
4 = Turns sound on

Syntax: {6,command,parm}

Command	Parameter
5	number you specify (any floating point number between $^{-}10^{38}$ to + 10^{38}) = Sets an ID number for CBL 2 that is used to identify a specific CBL 2 when multiple units are linked together

Syntax: {6,command,filter}

Command	Filter
6	0-6 = number of new filter to be applied **Default = 0**

Command 7 Request System Status

Syntax: {7}

This command generates and prepares to return the following status information:

softwareID	Current software ID in format: X.MMmms where X=product code number, MM=major ID number, mm=minor ID number, and s=step ID number.
error	If non-zero, CBL 2 should be reset and the cause of the error corrected
battery	Battery status. Can return the following values: 0 Battery is OK for use 1 Battery is low during sampling 2 Battery is low all the time

8888	Constant value. If the correct list location is set to zero prior to requesting and getting the list, this value can be used to ensure that the status message was received correctly.
Sample time	Sample time that was commanded by the host during the last sample run
trigger condition	Triggering condition that was commanded by the host during the last sample run
channel function	Triggering channel that was commanded by the host during the last sample run
channel post	Post-processing setting that was commanded by the host during the last sample run
channel filter	Filter that was commanded by the host during the last sample run
num samples	Number of samples that was commanded by the host during the last sample run. (If sampling was aborted, this parameter reflects the actual number of samples taken.)
record time	This can have the following values: 0 No time was recorded in the last run 1 Absolute time was recorded in the last run 2 Relative time was recorded in the last run
temperature	Temperature used for the temperature correction of the sonic data during the last run if a sonic sensor was selected
piezo flag	This is the buzz/no-buzz value that was last commanded. Values are: 0 Sound is disabled (OFF) 1 Sound is enabled (ON)
system state	The following values are used for the system state: 1 Idle 2 Armed 3 Busy 4 Done 5 Self-test 99 Initializing code
data start	First point of data available for transmission to the host unless the host has sent Command 5 to override this value
data end	Last point of data available for transmission to the host unless the host has sent Command 5 to override this value
systemID	The System ID that was set using Command 6

Command 8 Request Channel Status

Syntax: {8,channel,request type}

Channel	Request Type
1, 2, 3, or 11	0 = returns current sampled data 1 = returns data stored when channel was last set up

This command generates and prepares to return a list with three elements: E_1, E_2, E_3:

E_1 = sensor type (one of the *operation* options shown under Command 1)

E_2 = last valid data read from sensor, if any [only valid when sampling is active] (not applicable to CH1 ops 5, 6, 7 or CH21 Digital In or CH31 Digital Out)

E_3 = last valid data position (sample number where stored in the resulting list) [only valid when sampling is active]

Note: Each Command 8 must be followed by a Get statement.

Command 9 Request Channel Data

Syntax: {9,channel,mode}

Channel	Mode
1, 2, 3, or 11	0 = Re-test input auto-ID value 1 = Return stored auto-ID value

This command generates and prepares to return one data point before sampling starts. Used to verify that setup is correct.

Note: Each Command 9 must be followed by a Get statement.

Command 10 Advanced Data Reduction

This command sets up CBL 2 to process certain time-intensive algorithms instead of processing them in the calculator.

Syntax: {10,channel,alg,P1,P2,P3}

Channel	Algorithm	P1	P2	P3
1, 2, 3, 11	1 = HeartBeat algorithm	0% to 100% Lower Thld	0% to 100% Upper Thld	RejectThld in the units of the channel selected

P1 value determines when data transitions from “high” to “low.”

P2 value determines when data transitions from “low” to “high.”

P3 value determines the minimum difference in data between UpperThld and LowerThld.

Note: P1 must be less than P2.

Notes on Operation

Certain algorithms are very time intensive to run in the calculator, and the CBL 2 product team has made an effort to include those algorithms in the CBL 2's optimized code. This allows large data sets to be processed much more quickly.

Currently only one algorithm has been defined. This algorithm determines the number of cycles of a repetitive waveform in the sampling buffer. (This routine is known as the *heartbeat algorithm* for its frequent use in measuring the heart rate.)

This algorithm works as follows:

1. First, the normal data collection (using commands {1, …} and {3, …}) must be completed.
2. Next, the algorithm must be started using the command {10,*channel*,1,P1,P2,P3}.
3. The CBL 2 starts by finding the maximum and minimum points of the data set. The lower threshold is set at P1 percent of the maximum point, and the upper threshold is set at P2 percent of the minimum point.
4. The CBL 2 checks the difference between the maximum point and minimum point against P3. If the difference is less than P3, the algorithm is aborted and a 0.0 is returned. (This is the case where the user expected the input data to have a certain variation but, for some reason, the variation was not found.)
5. The CBL 2 then finds the number of "rising edges" where the data in the data set is increasing from below the upper threshold and the number of "falling edges" where the data is decreasing to below the lower threshold. The total number of rising edges and falling edges is stored.
6. Next the CBL 2 determines how many samples are between the first edge and the last edge. The frequency is then determined as the number of edges divided by the number of samples and is returned to the host calculator or computer.
7. The user program is responsible for taking the result from the CBL 2 and dividing it by the sample time to get the true frequency in Hz.

Command 12 Digital Data Capture

This command sets up the capture or measurement of motion data from the digital input channel. It has seven syntaxes.

Command Sequence

In general, when you want to sample data, you should send commands in this sequence: Reset the unit, setup the channels, start sampling, retrieve the data.

The commands used to do this are shown below:

- Command 6,0 to force the CBL 2 to stop executing any prior commands (This command may not be needed.)
- Command 0 to reset CBL 2 to a known state
- Command(s) 1 to set up any channels needed for sampling

- Command(s) 4 to send the equations for any sensors that need special equations (use only if needed)
- Command 3 to start the sampling process
- GET commands (one or more) to retrieve data from the CBL2.

It is important to notice that the channels get setup before sampling starts and that the Command 3 starts the actual sampling. The GET command forces the host calculator to wait until the data is ready and then transfer the data from the CBL 2 into the calculator.

Only a few of the commands that can be sent during sampling are useful; many of these commands will abort the sampling. For example, if you send a Command 1 during sampling, the sampling aborts, your data is lost, and the new channel is set up according to the new command.

A more useful command to send during sampling is Command 7. If you send this command, you can then do a GET and see the status of the CBL 2. The status will show the sampling (ARMED – meaning that the unit has not gotten to the trigger condition yet, or BUSY – meaning that sampling is in progress).

Another useful command to send while sampling is the Command 8, which reads back the most recent data sample collected for a single channel. This allows a sophisticated program to monitor data collection while the CBL 2 is collecting the data.

One of the new features of the CBL 2 is its ability to automatically work with many digital sensors such as photogates. With a photogate, the timing of the data transitions is the parameter of interest. Using the standard command order defined above, the user would:

- Send {1, 21, …} to command a digital input channel
- Send a command 3 to start sampling
- Send a GET to retrieve the data.

In order to find the transition times, the data collection program must scan the data looking for each transition and then subtract the time of the start and end points to get the transition time. Using Command 12 automates this process (and makes it more accurate).

There are a few things to be aware of, though. When using Command 12, the number of samples collected is not the same as the number of samples taken. If the photogate only transitions 12 times, there will be 12 transitions recorded. Even if there are 1000 analog data samples taken, there will still only be 12 transitions of the photogate data. Therefore, you should command a SEND {12, 41, 0} to find out how many transitions were recorded before requesting photogate data from the CBL 2. After getting the number of transitions, you can retrieve the actual transition timing.

When using a photogate, or other digital sensor, your command sequence should be as follows:

- Command 6,0 to force the CBL 2 to stop executing any prior commands (may not be needed)
- Command 0 to reset CBL 2 to a known state
- Command(s) 1 to setup any channels needed for sampling (you must setup at least 1 analog channel)
- Command 12, 41,3 to enable the photogate mode for digital CH 41 (Digital Input Port 1)
- Command(s) 4 to send the equations for any sensors that need special equations (only if needed)
- Command 3 to start sampling
- GET commands to retrieve the data from the CBL 2 (This forces the calculator to wait for sampling to finish.)
- Command 12,41,0 to command the CBL 2 to return the number of transitions recorded
- GET command to retrieve the number of transitions from the CBL 2
- Command 12, 41,-1 to command the CBL 2 to return the transitions recorded
- GET command to retrieve the number of transitions from the CBL 2
- Command 12, 41,-2 to command the CBL 2 to return the transition times recorded
- GET command to retrieve the number of transitions from the CBL 2

General Information

There are six types of motion capture commands. Each digital data capture command is designed to support the capture or measurement of data from the digital input. Some commands capture data at periodic intervals while others are triggered by changes in the data.

Each of the digital data commands is designed for a specific sensor and/or experiment as shown in the following table:

Send {12, 41, mode}	Use
Mode = 1	Sample Mode. This mode is used when none of the other modes (below) are useful. In this mode, each time the data changes, it is recorded in the CBL 2. This allows for any new digital probes to be used if the user is willing to write the program to process the data.
Send {12, 41, mode}	Use
Mode = 2 and Mode = 3	Measures pulse width of the data on the D0 line. This mode is used with a photogate to get very accurate measurement of the time the photogate is blocked. Generally, this measurement is used to determine the speed of an object (must know object’s length).

Send {12, 41, mode}	Use, *continued*
Mode = 4	Measures period of the data on the D0 line. This mode is used with a photogate to get very accurate measurement of the times between when the photogate becomes blocked. Generally, this measurement is used to determine the speed of a wheel or a picket fence.
Mode = 5	Counts the transitions on the D0 input line of the Digital input port. This mode is used when the frequency of a source with a TTL (or CMOS compatible) output must be measured.
Mode = 6	Measures the outputs of a Vernier Rotary Motion sensor. Generally this indicates the position of a wheel on the sensor.

The sections that follow explain more fully how to use the digital data capture commands.

Note: Command 12 is valid only in non-realtime mode; it is not valid in realtime mode.

Digital Input Syntax: {12,41,1}

At each transition of the digital inputs, the absolute time and state of the inputs is reported. See Fig 1.

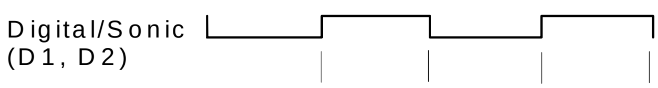


Figure 3. Digital Input Measurement

Inputs will be value 0-3 corresponding to 00, 01,10, or 11. Each transition stored takes three data point locations.

This command can be run at the same time as analog sampling.

After "getting" the analog channels, send the following commands to return the data from the CBL 2 to the host:

Command Syntax:	Comment:
{12,41,1}	collect digital input data; *send before Command 3*
{12,41,0}	return number of points collected on next get statement; *send after "getting" the analog channels*
{12,41,-1,*Start,Stop*}	return state list on next get statement
{12,41,-2,*Start,Stop*}	return time list on next get statement

Notes on Operation

The digital inputs are sampled 10,000 times/second in the main timer ISR. (Transitions that are so short that they are not seen in the ISR will be lost.) Each time a change in the input bits is found, the time and the new value are written to a data buffer area. When the data buffer area overflows, data collection is halted and an error message is sent.

Pulse Width – Continuous Pulse Mode Syntax: {12,41,*2 or 3,direction*}

Direction
0 = low active pulse
1 = high active pulse

This mode is designed to measure the widths of pulses in a continuous stream of pulses. Each pulse is measured. See Figure 3.

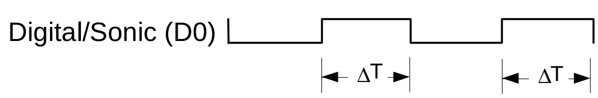


Figure 4. Continuous Pulse Period Measurement

After "getting" the analog channels, send the following commands to return the data from the CBL 2 to the host:

Command Syntax:	Comment:
{12,41,3}	collect pulse width data in continuous pulse mode; *send before Command 3*
{12,41,0}	return number of points collected on next get statement; *send after "getting" the analog channels*
{12,41,-1,*Start,Stop*}	return Δtime list on next get statement
{12,41,-2,*Start,Stop*}	return time list on next get statement

Notes on Operation

The Sonic Timer is used to record the time of the rising and falling edges. The resolution is 1.6µsec. At the start of the pulse the time is recorded and again at the end of the pulses. The difference (properly scaled) is returned to the host.

Period – Continuous Pulse Mode Syntax: {12,41,*4,direction*}

Direction
0 = low active pulse
1 = high active pulse

This mode is designed to measure the periods of pulses in a continuous stream of pulses. Each pulse is measured. See Figure 4.

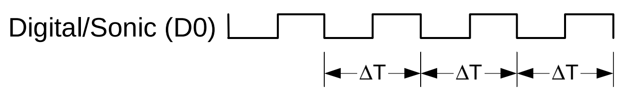


Figure 5. Continuous Pulse Period Measurement

After "getting" the analog channels, send the following commands to return the data from the CBL 2 to the host:

Command Syntax:	Comment:
{12,41,4}	collect period data in continuous pulse mode; *send before Command 3*
{12,41,0}	return number of points collected on next get statement; *send after "getting" the analog channels*
{12,41,-1,*Start,Stop*}	return Δtime list on next get statement
{12,41,-2,*Start,Stop*}	return time list on next get statement

Notes on Operation

The Sonic Timer is used to record the time of the rising and falling edges. The resolution is 1.6µsec. At the start of the pulse the time is recorded and again at the end of the pulses. The difference (properly scaled) is returned to the host.

Counter Mode Syntax: {12,41,5}

This mode is designed to count the transitions on the DIGITAL input line. (Use Command 1,1,7 to count the transitions on the ANALOG Channel 1 Hi input line.) The ECHO pin (D0) must be used for the input.

After “getting” the analog channels, send the following commands to return the data from the CBL 2 to the host:

Command Syntax:	Comment:
{12,41,5}	collect data in counter mode; *send before Command 3*
{12,41,0}	return number of points collected on next get statement; *send after “getting” the analog channels*
{12,41,-1,*Start,Stop*}	return count list on next get statement

Notes on Operation

The Sonic Timer is re-configured as a counter and will count the input transitions. The transitions count is limited to 65535 transitions per cycle. The cycle time is the same as the sample time. In other words, one count will be returned for each analog sample returned.

Rotary Motion Mode Syntax: {12,41,6,scalefactor,startpos}

Scale Factor	Start Position
Number of user units to increment/decrement for each count change	Initial position (in user units)

This mode is designed to measure the position of a rotary motion sensor. Rotational motion information is determined by counting clockwise and counterclockwise signals from the Vernier Rotary Motion Sensor. See Figure 5.

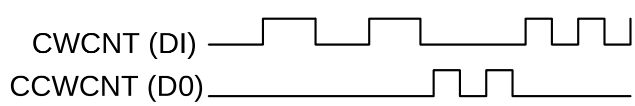


Figure 6. Rotary Motion Mode

Each rising edge of the CWCNT (D1) line will cause the position to be incremented by 1. Each rising edge of the CCWCNT (D0) line will cause the position to be decremented by 1. The position will start at StartPos. Only a 16-bit counter will be used, giving a count range from -32K to +32K.

One data point will be saved for each sample. Sampling will be commanded by the normal Command 3.

After "getting" the Analog channels, send the following commands to return the data from the CBL 2 to the host:

Command Syntax:	Comment:
{12,41,6}	collect data in rotary motion mode; *send before Command 3*
{12,41,0}	return number of points collected on next get statement; *send after "getting" the analog channels*
{12,41,-1,*Start,Stop*}	return position list on next get statement

Additional Notes on Command 12

A few additional things to be aware of when using Command 12:

- When Command 12 is used, the power generally stays on all during sampling. (This is because the processor must look for the data at all times during the sample interval and not just at the sample times.) As a result, this mode tends to deplete the batteries very quickly.
- The number of data samples taken is limited only by the available memory after memory is reserved for the Command 1 channels that are set up. The CBL 2 has about 12,000 available memory locations. If X channels are setup and Y samples are selected using Command 3, the number of samples on CH 41 is limited to (12,000 – X*Y)/3.
- You absolutely must have at least one analog channel activated before sending the Command 3 to start sampling. You must do a GET of the analog data (to force the calculator to wait for the end of sampling) before retrieving the Command 12 CH 41 data.

Command 102 Power Control Command

Syntax: {102,*pwrctl*}

Power Control
-1 = Always ON; will automatically power down (APD) if running on batteries. 0 = Normal mode 1-1000 = Powers up this many seconds before data taken

Command 115 Check Set-up Information

Syntax: {115,channel}

Channel
1, 2, 3, 11

This command returns the following status information:

CBL 2 sig	CBL 2 significant figures
LabPro™ sig	LabPro significant figures
Y-min	Suggested Y-min for graphing
Y-max	Suggested Y-max for graphing
Y-scale	Suggested Y-scale for graphing
sample rate	Typical sample rate
number of samples	Typical number of samples to collect
operation command	Typical operation command
calculation equation	Suggested calculation equation for Command 4
sensor warm-up time	Sensor warm-up time (in seconds)
first coefficient	Suggested first coefficient for Command 4
second coefficient	Suggested second coefficient for Command 4
third coefficient	Suggested third coefficient for Command 4
number of pages	Sensor's number of calculation pages (usually 0)
active page	Sensor's active calculation page (usually 0)

Command 116 Check Long Sensor Name

Syntax: {116,channel}

Channel
1, 2, 3, 11

This command returns the following information:

long sensor name	Returns long sensor name in a format the calculator can handle

Command 117 Check Short Sensor Name

Syntax: {117,*channel*}

Channel
1, 2, 3, 11

This command returns the following information:

short sensor name	Returns short sensor name in a format the calculator can handle

Command 1998 Set LED Command

Syntax: {1998,*P1*,*P2*}

P1	P2
1 = Red LED 2 = Yellow LED 3 = Green LED	0 = Off 1 = On

Note: Leaving a LED turned on will run down the batteries in the CBL 2.

Command 1999 Sound Command

Syntax: {1999,$length_1$,Pd_1,$length_2$,Pd_2, . . .}

Length	Pd
Sound stays on this long (in 100µs steps)	Tone half period in 100µs steps

Note: You can enter up to 32 pairs of values.

Command 2001 Direct Output to Digital-Out Port

Syntax: {2001,*data1,data2,data3. . .,dataN*}

Data1. . .DataN
Must be between 0-15. For values outside this range, behavior is undefined.

This command outputs data to the digital output port during a sampling run, thus giving the user interactive control of some types of hardware using the CBL 2 digital output lines. Please note the following:

- ♦ You can send from 1 to 16 data points. If you send more than one point, all the points will be sent out at about 200µsec intervals before the next command is parsed. This allows you to clock data into a latch with a single command.
- ♦ The data you send goes to the SONIC channel. If you are collecting data on the SONIC channel and send this command, your data will be lost.
- ♦ Sending this command does not stop the sampling, and it should not affect the analog channels.

CAUTION: No protection of any kind is provided. Operation is not guaranteed; use this command at your own risk. If you are sampling via the sonic port, sending this command will corrupt your data.

Command 201 Archive Operations Command

Syntax: {201,*operation,operand1,operand2,related_info_list*}

This command allows the calculator to determine the contents of *FLASH* memory.

Operation	Operand 1[1]	Operand 2[1]	Related Information List[2]
0 = Delete/Write Enable	Not used	Not used	2.46802 = enable writing data to *FLASH* 1.35791 = enable deletion of data from *FLASH*
1* = Get directory size	Not used	Not used	Calculator type[3]
2* = Get directory information	Directory type[4] (except Saved Program)	n	
3* = Get directory Label (n) [5]	Directory type[4]	n	Calculator type[3]

Operation	Operand 1[1]	Operand 2[1]	Related Information List[2]
4 = Label directory entry[6]	Directory type[4] (except Saved Program)	n	
11 = Clear directory entry (n)	Directory type[4]	n	Calculator type[3]
12 = Clear all directory entries	Directory type[4]	Not used	Calculator type[3]
13 = Clear all built-in user programs[7]	Not used	Not used	Calculator type[3]
21† = Save current data set	Number of elements in list	Not used	Ident 1 Ident 2[8]
22 = Close data set (n)	n	Not used	
23 = Restore data set (n)	n	Not used	
24 = Save data set supplemental list (n)[9]	n	Starting position to store in archive	List data (maximum 40 elements)
25* = Get data set supplemental list size (n)[9]	n	Not used	
26* = Retrieve data set supplemental list (n)[9]	n	Starting position (default = 1)	Number of elements (default = 0 {all})
31† = Allocate saved list	Number of elements in list	Not used	Ident 1 Ident 2[8]
32 = Save list data (n)	n	Starting position to store in archive	List data (maximum 40 elements)
33 = Close list (n)	n	Not used	
34* = Get list size (n)	n	Not used	
35* = Retrieve List (n)	n	Starting position (default = 1)	Number of elements (default = 0 {all})
41 = Select programs[10]	Not used	Not used	First item is calculator type (73, 83, etc.) followed by items to retrieve
42 = Deselect programs[11]	Not used	Not used	
43 = Retrieve supplemental programs[12]			
931-935, 941-945, 951-955 (RESERVED)			
1001† = Perform garbage collection			

[1] Operand information relating to whatever operation is being performed. (must be integer)

[2] Additional information about the operation to be performed.

[3] The Calculator Type specifies the model of the calculator on which the user program is running. This determines which programs in the CBL 2 archive will be shown in the directory information. Available choices are: 73, 82, 83, 83.1 (for 83 Plus), 86, 89, 92, and 92.1 (for 92 Plus).

[4] The Directory Type specifies the entries in the archive on which to perform the operation. Available choices are: 0 (Sample Data Set), 1 (Saved List), and 2 (Saved Program).

[5] If a directory entry does not have a label assigned to it, the CBL 2 reports the label as '???????????????????'.

[5,6] Because the TI-82, TI-89, TI-92, and TI-92 Plus do not receive string variables, the program names in the directory cannot be passed directly as strings. The Numeric List option in operation 3 provides an indirect way of representing the names. The list contains the ASCII code for each character in the name. These ASCII codes can be interpreted by the user program to display the correct letters on the calculator.

[6] Send a command with Operation 4 to set up label directory entry; then follow it with another command that contains the label.

[7] Built-in user programs: The CBL 2 stores a collection of calculator programs (DataMate) and look-up tables in its *FLASH* memory. These programs are intended to simplify the task of data collection and analysis. Because these programs are designed to work together, they can only be stored and deleted as a group. To free up memory in the CBL 2, you can delete the programs for calculators that you do not use.

Upgrading User Programs: The *FLASH* Download software provides a way to update the user programs and lookup tables for all calculator platforms. The *FLASH* Download process automatically deletes all existing user programs (all calculator models) from the archive. The new look-up tables and programs are then installed into the archive. (Instructions for downloading new software are given on the TI web site at **www.ti.com/calc**.)

[8] Two optional identifying numbers can be used when saving a data set or list. These numbers are saved with the data in addition to the supplied label.

[9] Operations 24, 25, and 26 are provided to facilitate saving configuration information in the same data structure as a saved experiment, rather than in a separate file.

[10] Operation 41 allows you to retrieve programs saved on the CBL 2. You can save programs to the CBL 2 by enabling writing {201,0,0,0,2.46802} and then sending programs from the calculator's LINK/SEND menu.

[11] Operation 42 cancels operation 41 or 43. If the TRANSFER key is not pressed within one minute, operations 41 and 43 cancel automatically.

[12] The CBL 2 can store additional built-in programs in the same storage area as DataMate (for example, programs such as DataDir and Photogate). Because of memory space considerations, these supplemental programs are normally not transferred to the calculator with DataMate when the TRANSFER key is pressed. Operation 43 allows you to retrieve these supplemental programs by overriding the normal operation of the TRANSFER key.

*Operations with an asterisk return values as explained below: (Use the GET command after sending the command with this operation.)

- Operation 1:
  - If the data type in the GET command is a list, will return: {# Saved data sets, # Lists, # Saved programs/applications, Reserved for DataMate, Reserved for DataMate, Reserved for DataMate, Bytes free in archive}
  - If the data type in the GET command is a real number, will return Bytes free in archive.
- Operation 2:
  - If the data type in the GET command is a list, will return: {Ident 1, Ident2}. (See footnote 8 for explanation of these values.)
  - If the data type in the GET command is a real number, will return Ident 1.
- Operation 3:
  - If the data type in the GET command is a string, will return: 20-character name of item.
  - If the data type in the GET command is a categorical list (TI-73 only), will return 4 elements of 5 characters each. Concatenate to form name of item.
  - If the data type in the GET command is a list, will return 20-element list, each element representing a character code in the name of the item.
- Operation 25 or 34:
  - If the data type in the GET command is a list, will return: {# of elements}.
  - If the data type in the GET command is a real number, will return # of elements.
- Operation 26 or 35:
  - If the data type in the GET command is a list, will return a list of the elements specified in the request.

General Notes:

- All data types are stored in the CBL 2 directory in the same order in which they are received. The CBL 2 does not attempt to sort these entries in any other order.
- If you transfer to the CBL 2 a program with the same name as a program already in storage, the old program will be deleted and the new program will be added to the end of the directory. (A program with the same name but a different calculator model will not be affected.)

- The labels and numeric information for data sets and lists can be the same as other data sets and lists. The CBL 2 does not check for duplicate descriptions. The uniqueness of the individual directory entries is preserved by their unique directory entry numbers.

†Notes on Garbage Collection:

Operations 21, 31, and 1001 may cause the CBL 2 to automatically perform garbage collection on the *FLASH* memory. For full or heavily used archives (many deleted items), garbage collection can take over one minute to complete. Therefore, when executing these operations, you must poll the CBL 2 to determine when the operation is complete and it is safe to move to the next command. The CBL 2 will return a real number or a single-element list (depending on the data type used by the calculator) with the following values:

- 2 = Performing garbage collection (operation may take extra time to complete)
- 1 = Performing requested operation (wait for operation complete flag)
- 0 = Requested operation is complete. Proceed with next command.

Continue to send GET commands until the CBL 2 returns the 0.

Notes on Battery Status:

Operations 11, 12, 13, 21, and 31 will generate an error if the battery status is low. The other operations do not check the battery status because it is expected that the program checks the results of these preliminary operations. This allows a full sequence of operations (such as Allocate/Save/Label/Close list) to complete even if the battery status should go low after the sequence has started. Therefore, it is important that programs using these commands check and honor the error conditions reported by these initial commands. (Use Command 7 to check the battery status.)

Programming Examples

Programs are created on a TI calculator to set up specific CBL 2 operations, depending on the experiment that you want to perform. Samples of various types of programs follow. Each program includes both program commands and comments explaining what the commands do.

Example 1: Temperature Non-Realtime Data Collection

`:ClrAllLists`	
`:ClrHome`	
`:Send({0})`	Reset CBL 2. (This clears CBL 2 RAM.)
`:Send({6,4})`	Turn CBL 2 sound on.
`:Send({1,1,1})`	Set up Channel 1 for data collection.
`:Send({3,.1,100,0})`	Take temperature sample every .1 second.
`:Get(L2)`	Retrieve temperature data to L2.
`:Get(L1)`	Retrieve time data to L1.
`:Plot1(Scatter,L1,L2,.)`	Plot temperature versus time.
`:ZoomStat`	

Example 2: Temperature Realtime Data Collection

`:ClrAllLists`	
`:PlotsOff:Func`	Initalize graphing functions.
`:FnOff:AxesOn`	
`:1→Xmin:30→Xmax:1→Xscl`	Set up the min/max range and scale factors as needed.
`:-20→Ymin:60→Ymax:.1→Yscl`	
`:ClrHome`	
`:Send({0})`	Reset CBL 2. (This clears CBL 2 RAM.)
`:Send({6,4})`	Turn CBL 2 sound on.
`:Send({1,3,1})`	Set up Channel 3 for data collection.
`:30→dim(L2)`	Dimension List
`:Send({3,1,-1,0})`	Take a sample once every second; re-arm immediately and get next sample.
`:ClrDraw`	
`:For(I,1,30,1)`	Get a sample and plot it on the graph for 30 points.
`:Get(L2(I))`	
`:Pt-On(I,L2(I))`	
`:End`	

Example 3: Distance and Velocity Non-Realtime Data Collection

`:PlotsOff`	
`:ClrAllLists`	
`:ClrHome`	
`:ClrDraw`	
`:Send({0})`	Reset CBL 2. (This clears CBL 2 RAM.)
`:Send({6,4})`	Turn CBL 2 sound on.
`:Send({1,11,1,1})`	Set up Channel 11 (Sonic) for data collection (distance and velocity).
`:Send({3,.1,100,0})`	Take a sample every .1 second.
`:Get(L2)`	Retrieve distance data to L2.
`:Get(L3)`	Retrieve velocity data to L3.
`:Get(L1)`	Retrieve time data to L1.
`:Plot1(Scatter,L1,L2,.)`	Plot distance versus time.
`:Plot2(Scatter,L1,L3,+)`	Plot velocity versus time.
`:ZoomStat`	

Example 4: Multiple Channels Non-Realtime Data Collection

:PlotsOff	
:ClrAllLists	
:ClrHome	
:Send({0})	Reset CBL 2. (This clears CBL 2 RAM.)
:Send({6,4})	Turn CBL 2 sound on.
:Send({1,1,10})	Set up Channel 1 for temperature data collection in Centigrade.
:Send({1,2,11})	Set up Channel 2 for temperature data collection in Fahrenheit.
:Send({1,3,12})	Set up Channel 3 for light intensity data collection.
:Send({3,.1,100,0})	Take a sample every .1 second.
:Get(L2)	Retrieve temperature in Centigrade data to L2.
:Get(L3)	Retrieve temperature in Fahrenheit data to L3.
:Get(L4)	Retrieve light intensity data to L4.
:Get(L1)	Retrieve time data to L1.
:Plot1(Scatter,L1,L2,.)	Plot temperature in Centigrade versus time.
:ZoomStat	
:Pause	
:ClrHome	
:PlotsOff	
:Plot2(Scatter,L1,L3,.)	Plot temperature in Fahrenheit versus time.
:ZoomStat	
:Pause	
:ClrHome	
:PlotsOff	
:Plot3(Scatter,L1,L4,.)	Plot light intensity versus time.
:ZoomStat	

Example 5: Conversion Equation Setup (Command 4)

:ClrAllLists	
:ClrHome	
:Send({0})	Reset CBL 2. (This clears CBL 2 RAM.)
:Send({6,4})	Turn CBL 2 sound on.
:Send({1,1,1,0,0,1})	Set up Channel 1 for data collection with conversion equation enabled.
:Send({3,.1,100,0})	Take a sample every .1 second.
:Send({4,1,-1})	Apply unary equation to return the raw data.
:Get(L2)	Retrieve raw data to L2.
:Get(L1)	Retrieve time data to L1.
:Send({4,1,7,50,5})	Apply exponential equation type to the raw data.
:Get(L3)	Retrieve the converted data to L3.
:Plot1(Scatter,L1,L2,.)	Plot raw data versus time.
:ZoomStat	
:Pause	
:ClrHome	
:PlotsOff	
:Plot2(Scatter,L1,L3,.)	Plot the converted data versus time.
:ZoomStat	

Example 6: Data Control Setup (Command 5)

`:ClrAllLists`	
`:ClrHome`	
`:Send({0})`	Reset CBL 2. (This clears CBL 2 RAM.)
`:Send({6,4})`	Turn CBL 2 sound on.
`:Send({1,2,11})`	Set up Channel 2 for temperature data collection in Fahrenheit.
`:Send({3,.1,100,0})`	Take a sample every .1 second.
`:Get(L2)`	Retrieve temperature in Fahrenheit data to L2.
`:Get(L1)`	Retrieve time data to L1.
`:Send({5,2,0,35,45})`	Process temperature data 35 through 45 for retrieval.
`:Get(L3)`	Retrieve temperature data 35 through 45 to L3.

Example 7: Digital In Data Collection

`:ClrAllLists`	
`:ClrHome`	
`:Send({0})`	Reset CBL 2. (This clears CBL 2 RAM.)
`:Send({6,4})`	Turn CBL 2 sound on.
`:Send({1,21,1})`	Set up Channel 21 (Digital In) for digital data collection.
`:Send({3,.1,100,0})`	Take a sample every .1 second.
`:Get(L2)`	Retrieve collected digital data to L2.
`:Get(L1)`	Retrieve time data to L1.
`:Disp L2`	Display collected digital data.
`:Disp L1`	Display time.

Example 8: Digital Out

`:ClrAllLists`	
`:ClrHome`	
`:Send({0})`	Reset CBL 2. (This clears CBL 2 RAM.)
`:Send({6,4})`	Turn CBL 2 sound on.
`:Send({102,-1})`	Turn power on if external LED is to display the Digital Out.
`:Send({1,31,16,0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15})`	Set up Channel 31 (Digital Out) to output listed values to digital in source.
`:Send({3,.5,10,0})`	Every .5 second send the digital out value to the digital in source.
`:Disp "WHEN SAMPLING"`	
`:Disp "COMPLETED"`	
`:Disp "PRESS ENTER"`	
`:Disp "TO TURN"`	
`:Disp "POWER OFF"`	
`:Pause`	
`:Send({0})`	Reset CBL 2 to turn power off.

Example 9: CBL 2 LED Display

This program is just for fun. It makes the CBL 2's lights blink on and off.

`: For(M,1,10,1)`	Repeat 10 times to make the lights flicker on and off.
`: For(N,1,3,1)`	
`: Send({1998,N,1})`	Turn all three lights on.
`: End`	
`: For(N,1,3,1)`	
`: Send({1998,N,0})`	Turn all three lights off.
`: End`	
`: End`	

Example 10: Playing Music on the CBL 2

This program plays "We Wish You a Merry Christmas."

`:1500→K`	K = 0.15 second

`:{2*K,2*K,K,K,K,K,2*K,`
`2*K,2*K,2*K,K,K,K,K,`
`2*K,2*K,2*K,2*K,K,K,K,K,`
`2*K,2*K,K,K,2*K,2*K,2*K,2*K}→L1`
	Play the short notes for 0.15 seconds and the long ones for 0.3 seconds.

`:{182,136,136,121,136,144,162,`
`162,162,121,121,108,121,136,`
`144,182,182,108,108,102,108,121,`
`136,162,182,182,162,121,144,136}→L2`
	Enter each note value in the list.

`:For(N,1,30,1)`	
`:Send({1999,L1(N),L2(N)})` `:End`	Send each time and note to the CBL2 so that it can play every note in the order of the lists.

Example 11: Command 8 Program

This is a program to receive data points while sampling.

`:Send({0})`	Clear sampling settings.
`:Send({1,1,1})`	Set up Channel 1 with auto-ID.
`:Send({3,.2,100,0})`	Take 100 samples in 20 seconds.
`:For(N,1,80,1)`	Use a loop to get samples as they are taken.
`:Send({8,1,0})`	Ask for Channel 1's last sampled data point.
`:Get(L2)`	Get the sensor type, most recent data point, and position in resulting list.
`:Disp L2`	Display the three-element list to the screen.
`:End`	
`:Get(L1)`	Get the resulting list of data.

Example 12: Command 9 Program

This is a program used to read a single data point.

`:Send({0})`	Clear sampling settings.
`:Send({1,1,1})`	Auto-ID a TI temperature sensor.
`:Send({9,1,0})`	Send Command 9 to get a single data point from Channel 1.
`:Get(A)`	Get the single data point.
`:Disp A`	Display the one data point.

Example 13: Command 10 Program

This program uses Command 10 with the TI temperature sensor. This test is used to find a sinusoidal-like pattern in temperature as it rises and falls constantly in an experiment that lasts 10 minutes.

`:Send({0})`	Clear sampling settings.
`:Send({1,1,1})`	Auto-ID the TI temperature sensor.
`:Send({3,6,100,0})`	Collect 1 sample every 6 seconds for 10 minutes.
`:Get(L1)`	Get the data for later use or display.
`:Send({10,1,1,20,80,5})`	Send the advanced data reduction command with the heartbeat algorithm. Set the lower threshold to 20% above the minimum point. Set the upper threshold to 80% above the minimum point. Set the standard temperature variance to 5°C. If the maximum temperature minus the minimum temperature is less than 5°C, then the test proves there are no oscillations in temperature outside of 5°C in the 10-minute experiment. If the variance is more than 5°C, then this will count how many times it goes over the 80% threshold level plus how many times it goes below the 20% threshold level.
`:Get(A)`	Get the number of times the samples went above the upper threshold and went below the lower threshold (the edge count). If the data range was less than 5°C, the result is zero.
`:A/6→B`	Divide the edges per sample by the sample time. This returns true frequency (edges per second).
`:Disp B`	Display the frequency.

Example 14: Archive Program (Command 201)

This program stores and retrieves a data set.

`:Send({201,0,0,0,2.46802})`	Enable “writes” to the CBL 2 *FLASH* memory.
`:Send({201,21,5,0,1.1,2.0}`	Save the data. Make room for 5 list elements. Give some optional
`)`	identification (e.g., data from Section 1.1, Experiment 2).
	Wait for operation to complete.
`:2→X`	
`:While X≠0`	
`:Get(X)`	
`:End`	Locate newest data set in *FLASH* memory. Its entry number will be in
`:Send({201,1,0,0,83.1})`	$L_1[1]$.
`:Get(L1)`	Save associated data from L_2 into the record.
`:{1,2,3,4,5}→L2`	
`:{201,24,L1(1),1}→L3`	
`:augment(L3,L2)→L4`	
`:Send(L4)`	Label the data set.
`:"SEC 1.1, EXP 2"→Str1`	
`:Send({201,4,0,L1(1)})`	
`:Send(Str1)`	Close the data set. Saving is complete.
`:Send({201,22,L1(1),0})`	
	Reset the CBL 2 and calculator.
`:ClrAllLists`	
`:Send({0})`	Locate the most recently saved data set.
`:Send({201,1,0,0,83.1})`	
`:Get(L1)`	Get and display the identifying label and numbers.
`:Send({201,2,0,L1(1)})`	
`:Get(L2)`	
`:Send({201,3,0,L1(1),83.1})`	
`:Get(Str1)`	
`:Disp Str1,L2`	Get and display the saved list data.
`:Send({201,26,L1(1),1})`	
`:Get(L3)`	
`:Disp L3`	Restore and display the sample data. Data can be retrieved using
`:Send({201,23,L1(1),0})`	Command 5, which is described elsewhere in this document.
`:Get(L2)`	
`:Disp L2`	

Appendix A: Glossary

The following terms are used in the CBL 2 documentation.

Term	Definition
accuracy	The degree of conformity of a measure to a standard or a true value
archive	Store data or programs in the FLASH memory of the CBL 2. (See page 9.)
auto-ID	Automatic Identification. Feature that allows the CBL 2 to automatically identify specific sensors when they are connected to a CBL 2 channel.
CMOS	Complementary Metal Oxide Semiconductor
FASTMODE	A data collection mode in which the CBL 2 collects data on a single analog channel at a very fast sample rate, stores it internally until all of the data points are taken, and then sends it to the calculator.
FLASH	*FLASH* is a technology built into CBL 2 that lets you electronically upgrade the CBL 2's operating system by downloading future releases from TI's web site.
non-realtime	A data collection mode in which the CBL 2 collects data, stores it internally until all the data is collected, and then sends it to the calculator.
precision	The degree of refinement with which an operation is performed or a measurement stated
realtime	A data collection mode in which the CBL 2 collects data and sends it to the calculator as each point is taken.
resolution	The process or capability of making distinguishable the individual parts of an object
TTL	Transistor-Transistor-Logic

Appendix B: CBL 2 Error Messages

Error messages that may occur when using CBL 2 without the DataMate program are listed in this section.

In almost all cases, an error result causes the unit to sound the "low tone" three times and to illuminate the red LED three times. When this happens, send the request for status message and then observe the "error" parameter of the list returned. The "error" parameter will be one of the values in the table below.

Error Number	Error Cause
0	This is normal. No corrective action is needed.
1	Invalid FASTMODE. An attempt to select fast sampling mode was made. When in FASTMODE, only a single analog channel can be active. This error number also displays if the FASTMODE selection is a value other than 0 or 1.
2	FASTMODE ABORT. During FASTMODE, an attempt to communicate with the CBL 2 was made while it was waiting for a trigger. As a result, sampling was aborted.
5	The list being sent contains a number that is too large to be represented internally. This can only happen when the list being sent contains an error.
6	The list being sent contains a non-integer number where only integers are allowed. For example, command numbers must be integers and a command of 3.5 will produce this error.
8	The list being sent contained too many numbers for proper conversion. In general, no more than 32 numbers can be sent for some commands and no more than 44 numbers for other commands.
9	The command number sent (first number of the list) did not specify a valid command.
12	The channel selected for setup did not exist. Channel numbers must be 1-3, 11, 21, 31.
13	The operation selected for the channel being setup is invalid. For example, sonic channels cannot be setup for a voltage probe.
14	An invalid value was selected for the post processing parameter. This must be a number from 0 to 2.
16	An invalid equation on/off parameter was found. The equation on/off parameter must be a 0 or a 1.
17	An invalid Frequency/Period selection parameter was found. This error usually occurs when a second channel is selected for a measurement during Frequency/Period measurements.

Error Number	Error Cause
18	Multiple channels are not allowed to be selected at the same time for the Digital/Sonic inputs. This error usually means that the sonic port and a corresponding digital port have been selected.
22	Command 2 contains invalid data.
30	The filter type must be between 0 and 6 for NON-REALTIME data collection mode and 0, 7, 8, or 9 for real time data collection mode. This error results from a filter selection outside of this range.
31	Command 3 was sent prior to performing any channel setups.
32	Sample time must be greater than 0 and less than 16000 seconds. The value is normally rounded to the nearest 100 µsec, but can be rounded to the nearest 50 µsec in FASTMODE. If the selected channels cannot support the rate selected, a slower sample rate will be used.
33	The number of samples must be -1 for real time sampling and between 1 and 12,000 for NON-REALTIME sampling. 0 is not allowed except for a special case of real time sampling with manual entry.
34	Trigger type must be an integer between 0 and 6. Any other value will produce this error.
35	The trigger channel must be a valid channel number (e.g., 1-3 or 11) and must be have been enabled using the channel select command.
36	The trigger threshold must be a value between the maximum and minimum legal values for the sensor selected. For example, for the +/-10V probe, legal values are from –10V to +10V.
37	The prestore value must be an integer between 0 and 100%. Any other values will produce this error message.
38	The external clock parameter is limited to values of 0 or 1. Any other value will produce this error.
39	The record time parameter is limited to values between 0 and 2. Any other values will produce this error message.
40	This error will occur when too few parameters are sent in the list. For example, when setting up an equation with 5 constants, if only 4 are sent, this error will result.
42	The equation channel number must be a 0 to reset equation, or a 1-3 for the analog channels or 11 for the sonic channel. Equation numbers outside of this range will produce this error.
43	The equation number must be in the range of -1 to 12 for analog channels and either 0 or 13 for the sonic channel. Equation numbers outside of this range will produce this error.
44	The order of the equation must be appropriate for the equation type selected. For example, an equation order of 5 is not valid for the mixed polynomial equation.

Error Number	Error Cause
45	This error occurred because (1) equations were enabled when sending Command 1, but the equation was never sent using Command 4, or (2) GET statement was issued before sending Command 4.
49	Invalid units were selected for temperature when sending the temperature for the sonic to use. Valid values are from 0 to 4.
52	A channel was selected that is not a valid channel. The channel numbers are 1-3, 11, 21, and 31.
53	A data group was selected that is not valid. Valid values are from 0 to 5.
54	The beginning-of-data selector must be 0 (for start of data) or 1 through the number of points collected. A number outside of this range will produce this error message.
55	The end-of-data selector must be 0 (for end of data) or 1 through the number of points collected. A number outside of this range will produce this error message. In addition, the end of the data must not be before the beginning of the data.
59	Digital probe has failed to read or write as commanded by the host.
61	An attempt has been made to collect more data than can be stored in one data collection. This unit has 24K of memory dedicated to data storage, allowing up to 12K samples to be stored. (for example, 3072 samples per channel for 4 channels.) If more than this is attempted, an error will result.
62	This error results when an attempt to return data is made and data has not been collected.
63	This error results when sending Command 6 and an invalid second parameter.
76	This error results when sending Command 10 for a channel that does not have data stored.
77	This error results when sending a Command 10 and selecting an algorithm that has not been defined.
78	This error results when advanced algorithm is selected and the input parameters for it are not correct.
80	This error indicates that the battery voltage is too low to safely write to *FLASH* memory and an attempt has been made to write to *FLASH* memory. The batteries should be replaced immediately for the unit to continue to perform properly.
81	This error indicates that an attempt to write to the *FLASH* memory failed and that the *FLASH* memory did not retain the value written. This problem can occur under several circumstances including the batteries becoming low after a *FLASH* write has been started (or removing the AC9920 adapter during *FLASH* writes). If the problem occurs often, this could indicate a hardware failure.

Error Number	Error Cause
82	This error indicates an attempt was made to change the contents of *FLASH* memory without properly enabling *FLASH* writes.
83	This error indicates that the *FLASH* memory directory is full and an attempt to write to the *FLASH* memory occurred. If this occurs, delete some items from *FLASH* memory and repeat.
84	This error indicates an attempt was made to access an item in the *FLASH* memory that does not exist.
85	This error indicates that an attempt was made to access an item that is in the *FLASH* memory, but hasn't been properly opened for access.
86	This error indicates that the archive data type is not one of the data formats supported. This error can result from trying to archive a data set that has not been properly stored.
87	The data to be archived must be NON-REALTIME data. Real time data cannot be archived. This error results when trying to archive real time data.
88	This error results when an attempt is made to archive data during sampling. Archive operations must occur only when the unit is idle.
97	This error indicates an attempt to use a channel that does not exist on CLB2 (for example, channel 42).
98	This error indicates an undefined error has occurred.
99	This error indicates that the current load on the analog or digital ports is more than can be supplied by the unit and the power has been turned off to prevent damage. Do not attempt to restart sampling until the problem has been corrected.

Appendix C: DataMate Sensor Setup Default Settings

The table that follows shows the default settings used by the DataMate program. This sensor and calibration information applies only to Vernier and TI sensors. The use of other manufacturers' sensors may require calibration or the input of that sensor's calibration information into DataMate.

Note: Default settings apply only when using a single sensor that is connected to Channel 1.

Sensor Name	Short Name	Y-Min	Y-Max	Sample Interval (in seconds)	No. Of Samples
Dir connect Temp (C)	TEMP(C)	-15	110	1	180
Dir connect Temp (F)	TEMP(F)	0	250	1	180
Extra Long Temp (C)	TEMP(C)	-50	150	1	180
Stainless Temp (C)	TEMP(C)	-20	125	1	180
Stainless Temp (F)	TEMP(F)	-5	260	1	180
Thermocouple (C)	TEMP(C)	-200	1400	1	180
pH	PH	0	14	2	60
Conduct 200 (μS)	CONDUCT (MICS)	0	200	1	180
Conduct 100(MG/L)	TDS(MG/L)	0	100	1	180
Conduct 2000(μS)	CONDUCT (MICS)	0	2000	1	180
Conduct 1000(MG/L)	TDS(MG/L)	0	1000	1	180
Conduct 20000(μS)	CONDUCT (MICS)	0	20000	1	180
Conduct 10000(MG/L)	TDS(MG/L)	0	10000	1	180
Gas Pressure (KPA)	PRESS (KPA)	50	150	10	90
Gas Pressure (MMHG)	PRESS (MMHG)	400	1200	10	90
Gas Pressure (ATM)	PRESS (ATM)	0.5	1.6	10	90
Gas Pressure (INHG)	PRESS (INHG)	0	65	10	90
Pressure (KPA)	PRESS (KPA)	0	700	1	180

Sensor Name	Short Name	Y-Min	Y-Max	Sample Interval (in seconds)	No. Of Samples
Pressure (ATM)	PRESS (ATM)	0	700	1	180
Pressure (MMHG)	PRESS (MMHG)	0	5200	1	180
Bio Pressure (KPA)	PRESS (KPA)	76	156	10	90
Bio Pressure (MMHG)	PRESS (MMHG)	550	1200	10	90
Bio Pressure (ATM)	PRESS (ATM)	0.75	1.6	10	90
Bio Pressure (INHG)	PRESS (INHG)	20	50	10	90
Dual R Force (5N)	FORCE(N)	-5	5	0.05	100
Dual R Force (10N)	FORCE(N)	-10	10	0.05	100
Dual R Force (50N)	FORCE(N)	-50	50	0.05	100
Student Force (N)	FORCE(N)	-40	10	0.05	100
EX Heart Rate (BPM)	Heart RT(BPM)	45	170	5	180
Heart Rate (BPM)	Heart RT(BPM)	45	170	5	180
25G Accel (M/S^2)	ACCEL (M/S^2)	-250	250	0.05	100
Low G Accel (M/S^2)	ACCEL (M/S^2)	-50	50	0.05	100
Colorimeter	ABSOR-BANCE	0	0.6	5	180
CO_2 Gas (PPM)	CO_2 GAS (PPM)	0	5000	10	30
CO_2 Gas (PPT)	CO_2 GAS (PPT)	0	5	10	30
CBL Microphone	MICRO-PHONE	0	5	1.00E-04	200
ULI Microphone	MICRO-PHONE	0	5	1.00E-04	200
MPLI Microphone	MICRO-PHONE	-5	5	1.00E-04	200
TI Light Sensor	LIGHT	0	1	0.05	180

Sensor Name	Short Name	Y-Min	Y-Max	Sample Interval (in seconds)	No. Of Samples
Light 600(LX)	LIGHT(LX)	0	600	0.05	180
Light 6000(LX)	LIGHT(LX)	0	6000	0.05	180
Light 150000(LX)	LIGHT(LX)	0	150000	0.05	180
D. Oxygen (MG/L)	DO(MG/L)	4	12	2	60
EKG	EKG	-0.5	4	0.01	200
CA ISE (MG/L)	CA(MG/L)	0	40000	1	180
NH4 ISE (MG/L)	NH4(MG/L)	0	18000	1	180
NO3 ISE (MG/L)	NO3(MG/L)	0	14000	1	180
CL ISE (MG/L)	CL(MG/L)	0	36000	1	180
Flow Rate (M/S)	FLOW RT (M/S)	0	4	1	180
Flow Rate (FT/S)	FLOW RT (FT/S)	0	13	1	180
Respiration (BPM)	RESP RT (BPM)	0	30	10	180
Turbidity (NTU)	TURBID (NTU)	0	50	1	180
C V Current (A)	CURRENT (A)	-0.6	0.6	0.1	180
C V Voltage (V)	VOLTAGE (V)	-6	6	0.1	180
Voltage ⁻10 to 10 (V)	VOLTAGE (V)	-10	10	0.1	180
Voltage 0 to 5 (V)	VOLTAGE (V)	0	5	0.1	180
Hi Magnet Fld (MT)	MAGNET F(MT)	-0.32	0.32	0.05	180
Hi Magnet Fld (G)	MAGNET F(G)	⁻3.2	3.2	0.05	180
Lo Magnet Fld (MT)	MAGNET F(MT)	-10	5	0.05	180
Lo Magnet Fld (G)	MAGNET F(G)	-100	50	0.05	180
Barometer (KPA)	BARO(KPA)	80	110	600	180
Barometer (MMHG)	BARO (MMHG)	600	800	600	180

Sensor Name	Short Name	Y-Min	Y-Max	Sample Interval (in seconds)	No. Of Samples
Barometer (INHG)	BARO (INHG)	24	32	600	180
Barometer (MBAR)	BARO (MBAR)	810	1060	600	180
Relative Humidity (PCT)	REL HUM (PCT)	0	100	600	180
Oxygen Gas (PCT)	O2 GAS (PCT)	15	25	15	40
Oxygen Gas (PPT)	O2 GAS (PPT)	150	250	15	40
Custom 0 to 5 (V)	CUSTOM	0	5	1	180
Custom ⁻10 to 10 (V)	CUSTOM	⁻10	10	1	180
Motion (M)	MOTION (M)	0	6	0.05	100
Motion (FT)	MOTION (FT)	1	20	0.05	100
Current Probe (A)	CURRENT (A)	⁻10	10	0.1	180
Resistance (OHMS)	RES (OHMS)	0	100000	0.1	180

The values in the table are valid for all calculator versions of DataMate except the TI-73, TI-82, TI-83, and TI-92. Because of memory limitations on these calculators, the number of data points is reduced.

- For the TI-73, the number of samples will be reduced if it exceeds 100 and multiple samples are set up.
- For the TI-82, all default number of samples will be limited to 99 points.
- For the TI-83, the number of samples will be reduced if it exceeds 200 points and multiple samples are set up.