Texas Instruments

CBL™ SYSTEM

GUIDEBOOK

Table of Contents ➥

Guidebook developed by: Texas Instruments
Instructional Communications

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If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, you can try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/television technician for help.

CAUTION: Any changes or modifications to this equipment not expressly approved by Texas Instruments may void your authority to operate the equipment.

Table of Contents

Safety Instructions

Observe all warnings, cautions, and other safety instructions indicated on the product and in the documentation. These instructions are intended to reduce the risk of injury, possible electrical shock, or damage to the unit.

AC Voltages

⚠**WARNING!** Never attempt to measure AC voltages from a wall outlet. Connecting 115/230 Volts AC to any input probe may cause serious injury or electrical shock, and may damage the unit.

Low-Voltage Unit

⚠**WARNING!** This product is designed for use with low voltages. Personal injury and damage to the unit may occur if voltages exceed 30 Volts DC on CH1, CH2, or CH3; or if voltages exceed 5.5 Volts DC on SONIC, DIG IN, or DIG OUT. To reduce risk of injury, do not connect probes to circuits that contain voltage sources more than 30 Volts DC. All voltage sources must be fully isolated from AC power lines.

External Power

⚠**CAUTION!** Use the correct power adapter with the CBL. Using a wrong power adapter may cause damage to the adapter and to the unit.

Analog Inputs

⚠**CAUTION!** 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.

Batteries

⚠**WARNING!** Do not heat, burn, or puncture batteries. Batteries contain hazardous chemicals and may explode or leak.

In Case of Difficulty

If this unit does not operate normally, refer to “In Case of Difficulty” in Appendix C.

Chapter 1: What is the CBL System? An Overview

This chapter provides a brief overview of the CBL system — its components, its features, and how it works.

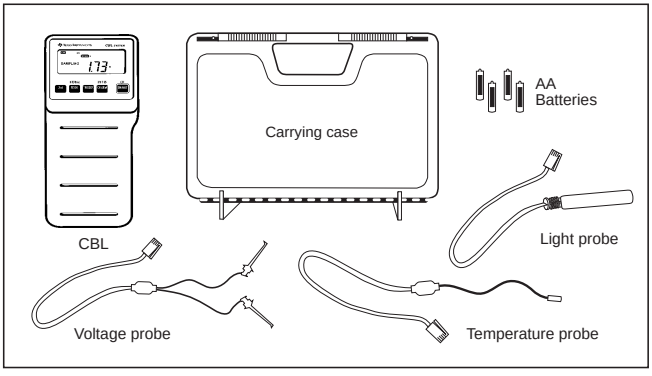
Chapter Contents

Note: Communications between different CBL-compatible calculators and the CBL are very similar. Specific differences are described in the *CBL™ Compatible Calculators Guidebook*.

What Is the CBL?

The Calculator-Based Laboratory System™ (CBL™) is a portable, handheld, battery-operated, data-collection device for collecting "real-world" data. The data collected with the CBL can then be retrieved by a calculator for further analysis. With the CBL system and appropriate sensors, you can measure motion, temperature, light, sound, pH, force, and more.

This Is What You Get



TI Probes

TI provides three probes to get you started with the CBL.

- **Temperature Probe:** This probe uses a thermistor to measure temperature.
- **Light Probe:** This probe uses a phototransistor to measure light intensity.
- **Voltage Probe:** This generic probe measures voltage between ±10 Volts (CH1 and CH2 only).

Note: Appendix A contains detailed technical information about these probes, pinout data, and other information to assist you in making your own probes.

Additional sensors and probes, used with CBL through optional adapters, can be purchased from other vendors.

Probes Used with the CBL

Probes (sensors), provide the means by which data is collected or sensed. In addition to the three probes provided, many existing third-party probes such as ultrasonic motion detectors, force probes, pH sensors, etc. can be used with the CBL system when connected with optional adapters.

Using CBL with CBR™ (Calculator-Based Ranger™)

You can use the Texas Instruments CBR as an ultrasonic motion detector with CBL. A special cable is required. See the CBR guidebook, *Getting Started with CBR™*, for information on features and commands.

Automatic Power Down™ (APD™)

To prolong battery life, the APD feature turns off the CBL automatically after 10 minutes without any activity. When you press [ON/HALT], the CBL will be exactly as you left it. The CBL does not APD while it is in Multimeter mode, nor when READY or SAMPLING is active.

Note that for sample times greater than five minutes, the connected calculator may power down automatically by its APD feature. The CBL cannot transfer the collected data to a calculator that is off. After turning the calculator back on, you must resend the commands to retrieve the collected data from the CBL.

About the Channels

Probes are connected to the CBL through input or output connections that are called "channels." There are six channels on the CBL to which to connect probes. There are three analog channels (CH1, CH2, and CH3), one ultrasonic motion detector channel (SONIC), one digital input channel (DIG IN), and one digital output channel (DIG OUT).

- You can collect data at rates of up to 10,000 points per second for up to 512 points per channel.
- You can collect data on up to five channels simultaneously.
- You can collect data and plot it in real-time at a rate of up to 14 points per second. (The exact limit depends on the calculator program and battery freshness.) You cannot collect and plot data in real-time for a sample time that is greater than the APD of the connected calculator (about five minutes).

How the CBL and Graphing Calculators Work Together

The CBL connects to a calculator through the input/output ports on the calculator and on the bottom left edge of the CBL. The cable used to connect the CBL and a calculator is the same input/output cable that is normally used to transfer data between two graphing calculators. This cable is provided with the graphing calculator.

The CBL is an "intelligent" device with its own microprocessor and memory for collecting and temporarily storing data. The CBL can be used to collect data as a stand-alone device and display the results on its built-in LCD display. But its real power is apparent when it is used interactively with a calculator.

To control the CBL, you send a list such as {1,2,3} from a calculator to the CBL. The CBL interprets the lists as commands, which then control what the CBL does.

There are eight commands defined for the CBL system (CMD0 to CMD7). These commands tell the CBL such things as which channel to use for data collection, what kind of data to collect, how often to collect data, and how many data points to collect.

The elements of the command lists are the parameters for the commands. The first element of every command list must be the command number.

The manual trigger option lets you disconnect the CBL from the calculator to collect data. After the data has been collected, the calculator can be reconnected and the data retrieved from the CBL.

Communicating with CBL

Commands are sent to the CBL using instructions appropriate for the calculator. Refer to the *CBL™ Compatible Calculators Guidebook* or the TI website at **www.ti.com/calc/docs/sgraph** for information specific to your calculator.

Automatic Probe Identification

The CBL has a feature called Automatic Probe Identification (AutoIDENT). This lets the CBL automatically identify specific probes connected to the CBL.

When you connect any of the provided TI probes to a CBL channel, the AutoIDENT feature does the following:

- It detects the probe and turns on the indicator for that channel in the CBL display.
- It determines what kind of data is going to be measured.
- It loads an equation for converting the data into the appropriate measurement unit.

Conversion Equations and Post-Processing

Conversion Equations: The three analog channels and the ultrasonic channel each have an associated conversion equation. These equations convert the physical unit measured by the CBL into a more useful measurement unit.

For example, a thermistor is an electronic component whose resistance changes with temperature. The CBL can measure only the resistance of the thermistor. But an appropriate conversion equation can transform the measured resistance value into a temperature value. The data displayed on the CBL and retrieved by the calculator will then be in temperature units.

Post-Processing: The CBL can perform certain calculations on collected data when requested. These calculations are referred to as post-processing (processing performed after data is collected).

The CBL supports three types of post-processing calculations: first derivative, first and second derivatives, and statistics. For example, if first and second derivative post-processing is selected, the first and second derivatives of the collected data are computed and stored in the CBL.

If statistics is selected, the mean, standard deviation, minimum, and maximum values for the collected data are computed and stored in the CBL. This computed data can then be retrieved into the calculator in the same manner as the collected data.

Data Filtering

Sometimes collected data is affected by extraneous “noise” that may cause false or spurious signals to show up in the data when it is retrieved.

The CBL uses a sophisticated data-filtering algorithm to help resolve these problems. Various degrees of data filtering can be selected.

Record Time

The absolute time (time from beginning of the sample in seconds) or relative time (time between samples) can be stored as data is collected and then retrieved into the calculator.

Viewing Collected Data

As data is collected, it is displayed on the CBL screen. Pressing CH VIEW alternates among active channels and displays data as it is collected on each channel in the CBL display.

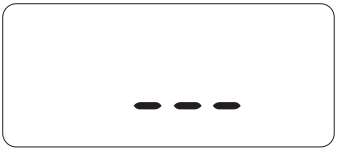
The CBL display also contains several status indicators to inform you when the status has changed. The status might be changed by a CBL command sent from a calculator, the AutoIDENT feature, or a key press.

Summary

On the following pages you will learn more about the CBL and how to use a calculator to send commands and retrieve collected data. Although the CBL can perform complex experiments and complex operations, its use is simplified by many built-in automatic features and supplied programs.

Installing Batteries

1. Holding the CBL upright, push the latch on the battery cover down with your finger and pull the cover out.
2. Install all four AA alkaline batteries. Position the batteries according to the diagram inside the battery compartment. Replace the cover.
3. Press [ON/HALT] to turn on the CBL. The initial power-on display is shown below. Press [2nd] [OFF] to turn off the CBL.

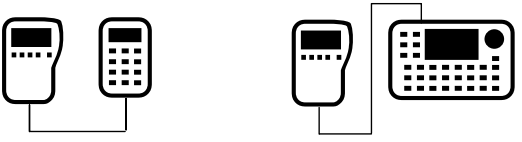


Automatic Power Down™ (APD™)

To prolong the life of batteries, the APD feature turns off the CBL automatically after 10 minutes without any activity. When you press [ON/HALT], the CBL will be exactly as you left it. The CBL does not APD while it is in Multimeter mode, nor when READY or SAMPLING is active.

How to Connect the CBL to a Calculator

Connecting the CBL to a calculator is as simple as connecting two graphing calculators together.



1. Connect one end of the input/output cable that was provided with the calculator into the input/output port of the calculator.
2. Connect the other end of the cable to the port on the bottom left edge of the CBL.

Note: Push in all connectors firmly. If there is a communication problem, one or both ends of the cable are probably not fully inserted.

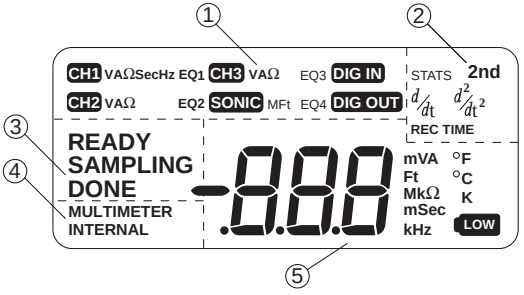
Chapter 2: Getting Started

This chapter describes the contents of the display, the functions of the keyboard keys, and the six probe connections.

Chapter Contents

Display Panel

The display shows you information about the mode, the active channels (input/output), and other data pertaining to the experiment in progress.

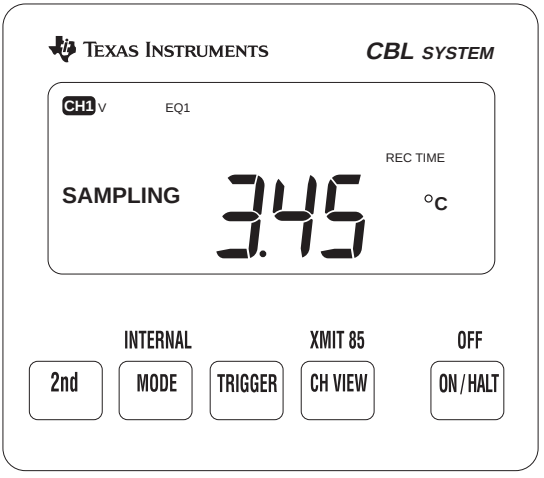


Display Layout

① Displays information for each of the six channels. When an *

⑤ Displays digital collected data values and error codes, the units of the collected data (meters, ohms, seconds, etc.), and a low-battery indicator.

Note: The displayed units in ① are the units being measured and not the final conversion units. If applicable, the final conversion units are displayed in ⑤. For example, the TI temperature probe measures the resistance of a thermistor when measuring temperature—the **Ω** indicator is lit in ① and the °C indicator is lit in ⑤. The resistance measured by the CBL is converted into temperature units.



Keypress Functions

Key	Description
[2nd]	Selects the function above [MODE], [CH VIEW], and [ON/HALT].
[MODE]	Toggles the CBL between Multimeter mode and Communications mode.
[2nd] [INTERNAL]	In Communications mode puts the CBL in Internal mode. [MODE] or [2nd] [INTERNAL] returns the CBL to Communications mode
[TRIGGER]	When the READY indicator is on, [TRIGGER] starts data collection if the Manual trigger option or Manual and Sample trigger option is selected in CMD3 (pages 39–40).
[2nd] + [TRIGGER]	When the READY indicator is on, overrides the trigger condition and begins data collection immediately.

Keypress Functions (Continued)

[CH VIEW]	**Communications Mode:** Rotates through all active channels in sequence and displays the data being collected on that channel. When a channel is selected, its indicator blinks every 0.25 seconds. **Multimeter Mode:** Rotates through CH1 and SONIC and the operations for those channels (three dashes appear momentarily between each key press). For example, CH1: 0–5 Volts, CH1: ±10 Volts, CH1: amps, CH1: ohms, CH1: seconds, CH1: Hz, SONIC: meters, SONIC: feet, CH1: 0–5 Volts, etc. (The same V indicator is used for both voltage ranges.) **Internal Mode:** Does not apply because only V (Volts) is active, which indicates the internal battery voltage.
[2nd] [XMIT 85]	During the DONE state sends collected data to a connected TI-85 graphing calculator when the TI-85 is in Receive mode. Manual data transmission is required on the standard TI-85 because programming commands to send and receive data are not provided.
[ON/HALT]	Turns the CBL on. If the CBL is on, aborts any pending operation and stops data sampling. Any data collected is saved in the CBL and is available to be retrieved into the calculator.
[2nd] [OFF]	Turns the CBL off. The state of the CBL is retained when the CBL is turned back on.

Note: Some CBL keys are sampled less frequently to minimize power use. The [2nd], [MODE], and [CH VIEW] keys should be pressed and held until the command is recognized.

Input and Output Channels

Three analog inputs, an ultrasonic motion detector input, a digital input, and a digital output let you connect various probes and sensors to the CBL. With the variety of probes, you can measure temperature, light, voltage, sound, force, motion, pH, and more.

Indicators in section ① of the display (page 14) show you when CH1, CH2, CH3, SONIC, DIG IN or DIG OUT have been set up. More than one probe may be connected and collecting data at the same time.

The connectors for analog, digital, and ultrasonic probes are different to make sure that you do not plug a probe into the wrong channel. For example, you cannot plug a motion detector (SONIC) into an analog or digital channel, or a voltage probe (analog) into a digital or ultrasonic channel.

Additionally, the labeling on CH1, CH2, and CH3 is green and matches the green band on the CBL DIN adapter and TI temperature, light, and voltage probes. The labeling for SONIC is red and matches the red band on the CBL RJ-11 adapter. The labeling for DIG IN and DIG OUT is blue and matches the blue band on the cable in the CBL digital probe kit (page 85).

Note: The included voltage probe (for ±10 Volts) can only be used on CH1 and CH2.

Analog Inputs

CHI, CH2, and CH3 are analog inputs for probes that produce a voltage output such as for sound or force. These channels also can measure resistance. Only CH1 has provisions for measuring period and frequency. CH1 and CH2 are on the top of the CBL; CH3 is on the left side of the unit.

IMPORTANT: It is very important that the ground connections of the analog inputs are not connected to different potentials. These ground connections are all in common. Connecting the grounds to different potentials may damage the CBL.

Ultrasonic Motion Detector Input

The ultrasonic motion detector input lets you connect a motion detector, such as the CBR™ (Calculator-Based Ranger™), to measure distance. The motion detector (SONIC) channel is on the left side of the unit next to CH3.

Digital Input and Digital Output

The digital input and digital output let you connect the CBL to 0–5 Volt binary signals. The digital input (DIG IN) and the digital output (DIG OUT) channels are on the right side of the CBL.

Chapter 3: Using the CBL System

This chapter describes how the CBL is set up and controlled by commands sent from a connected calculator. Parameter descriptions are provided for each of the commands.

Chapter Contents

About a Typical Program Format

Programs are created on a calculator to set up the CBL operations for the experiments that you want to perform.

A typical CBL program format might include the following basic tasks:

1. Clearing all channels of their previous settings with {1,0} (page 28).
2. Setting up one or more input channels to collect data with {1,1}, {1,2}, {1,3}, etc. (page 28).
3. Defining the sample time, how many samples to collect, and when to start collecting data with a CMD3 (page 39). This **must** be the last setup command sent to the CBL before data collection begins.
4. Retrieving the collected data from the CBL into a calculator (Refer to the *CBL™ Compatible Calculators Guidebook.*)

Below is a sample program for a TI-82 graphing calculator.

```
PROGRAM:TEMP
:PlotsOff:Func          Initialize graphing functions.
:FnOff:AxesOn
:1→Xmin:30→Xmax         Set up the window variables.
:10→Xscl:-20→Ymin
:60→Ymax:10→YScl
:ClrHome                Clear all channels; turn off CH and EQ
:{1,0}→L1               indicators; clear collected data.
                        Send command to CBL.
:Send(L1)               Set CH1 to AutoIDENT (page 21).
:{1,1,1}→L1             Send command to CBL.

:Send(L1)
:30→dim L3              Dimension list where data will be stored.
:{3,1,-1,0}→L1          Take a sample once every second; get next
                        sample immediately.
:Send(L1)               Send command to CBL.
:ClrDraw
:For(I,1,30,1)          Repeat 30 times.
:Get(L3(I))             Get a data point from the CBL.
:Pt-On(I,(L3(I))        Plot the next point.
:End
```

Automatic Setup Feature

AutoIDENT enables the CBL to identify the type of AutoIDENT probe connected to a channel and automatically set up the channel with predefined default values.

Specific resistance values contained in AutoIDENT probes are sensed by the CBL when connected to CH1, CH2, or CH3 (analog channels), or to the ultrasonic channel.

Each of the three TI probes provided with the CBL contain an AutoIDENT resistor. When an AutoIDENT probe is detected, the CBL sets the proper operation, loads a conversion equation into memory for the selected channel, and turns on the Conversion Equation for that channel. When the Channel Setup command ({1,*channel_number*,1}) is sent to the CBL, the channel is ready to collect data immediately.

Note: If an AutoIDENT probe is removed after the CBL receives a Channel Setup command {1,*channel_number*,1} and a different AutoIDENT probe is installed in the same channel, characteristics of the new probe are not recognized by the CBL.

Therefore, if you change probes, send another CMD1 ({1,*channel_number*,1}), or send a command to clear the specific channel ({1,*channel_number*,0}), a command to clear all channels ({1,0}), or an All Clear command ({0}).

Conversion equations set up by AutoIDENT overwrite any equation previously stored; likewise, a subsequent CMD4 (Conversion Equation Setup) will overwrite the AutoIDENT values, so you can input your own parameters if you wish.

The CBL contains provisions for other AutoIDENT resistor values. These values can be used for new probes with the AutoIDENT feature. (Refer to "AutoIDENT Probes" in Appendix A.)

Communications Mode and Operating Conditions

When the CBL is on, it is in one of three operating modes: Communications, Multimeter, or Internal. [MODE] or [2nd] [INTERNAL] controls the mode.

Communications mode is the default operating mode for collecting data. During Communications mode, the CBL is in one of three operating conditions: READY, SAMPLING, or DONE.

- **READY:** A setup command (CMD3) was received from a calculator. The unit is waiting for a trigger signal to start collecting data.
- **SAMPLING:** The CBL was previously in the READY state and the trigger condition has been met. SAMPLING flashes to indicate that the CBL is collecting data.
- **DONE:** The CBL was previously in the SAMPLING state. DONE indicates that data collection is complete. The data is now available for retrieval by a calculator.

In the display example to the right, the unit is in the Communications mode and is sampling data from a motion detector connected to the SONIC input.

Multimeter Mode

Important: Refer to "Safety Instructions" on page 4.

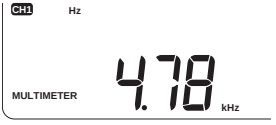
Note: Keys on the CBL are sensed differently from keys on a calculator. Press and hold [MODE] and/or [CH VIEW] until the command is recognized when performing the operations described below.

From the Communications mode, [MODE] changes the CBL to the Multimeter mode. [CH VIEW], while in Multimeter mode, cycles the CBL through the multimeter operations: (CH1) voltage (0–5 Volts), voltage (±10 Volts), current, resistance, period, frequency, (ultrasonic) meters, and feet.

Multimeter Mode (Continued)

Note: The CBL can be used in Multimeter mode as a stand-alone device (without a calculator connected) to measure voltage, resistance, current, period, frequency, meters, and feet without setup commands from the calculator.

For example, pressing MODE CH VIEW CH VIEW CH VIEW CH VIEW CH VIEW CH VIEW prepares the CBL to measure frequency as a stand-alone device. This is shown in the display example to the right.



If the CBL is connected to a calculator, commands in Multimeter Mode Setup (CMD6, page 52) also select multimeter operations.

When the CBL is in Multimeter mode, MODE returns the CBL to the Communications mode.

Note: The CBL does not automatically power down while it is in Multimeter mode.

Internal Mode

This mode lets you measure the internal system voltage of the CBL.

When the CBL is in Communications mode, 2nd [INTERNAL] puts the CBL into Internal mode.

For example, pressing 2nd [INTERNAL] sets up the CBL to measure the internal system voltage provided by four AA batteries inside the unit.

In the display example to the right, these batteries indicate a combined voltage level of 4.50 Volts.

Note: This is the point at which a low-battery condition is sensed. In this case, the batteries are low, and the low-battery indicator is on. The optimum level is about 5.0 Volts with new batteries.

MODE or 2nd [INTERNAL] when the CBL is in Internal mode returns the CBL to Communications mode.

What are CBL Commands?

Commands are sent to the CBL as a list. A command number is always the first integer in the list. CBL command numbers are single-digit integers that represent operations as shown in the table below. There are eight commands that are used to control the CBL.

Command	Function
0*	**All Clear:** CMD0 resets all channels to default conditions (page 27).
1*	**Channel Setup:** CMD1 sets up a channel for data collection (page 28).
2	**Data Type and Display Setup:** CMD2 lets you select the type of data, such as lists, matrices, and pictures that will be retrieved by a calculator (page 36).
3*	**Sample and Trigger Setup:** CMD3 sets up the timing and trigger parameters for an experiment (page 39).
4	**Conversion Equation Setup:** CMD4 sets up parameters to convert the physical unit measured by CBL into a more useful measurement unit such as Newtons or °C (page 47).
5	**Data Range Setup:** CMD5 selects the type of data to be retrieved as well as the starting and ending data points to be retrieved by a calculator (page 49).
6	**Multimeter Mode Setup:** CMD6 sets up the CH1 or SONIC channels to measure volts, ohms, meters, feet, and other multimeter operations (page 52).
7	**Request Status:** CMD7 creates a list of CBL status information for retrieval by a calculator (page 54).

***Note:** Clears all previously collected data from the CBL.

Command Examples

{1,*n*,*n*,*n*,*n*} and {3,*n*,*n*,*n*,*n*} are examples of a Command instruction. The first integer in the examples represents the Command number, and *n* represents other parameters within the Command instruction.

About CBL Channel Parameters

Physical channels are input or output connections on the CBL. The channel number parameter is the second element in the Channel Setup command (CMD1). Each CBL channel is identified by a specific number as shown in the table below.

Channel Number	Channel Name	Type	Label
1	Channel 1	Analog	CH1
2	Channel 2	Analog	CH2
3	Channel 3	Analog	CH3
11	Ultrasonic Motion Detector	Ultrasonic	SONIC
21	Digital Input	Digital	DIG IN
31	Digital Output	Digital	DIG OUT

Channel Setup Examples

{1,1,*n*,*n*,*n*}, {1,2,*n*,*n*,*n*}, and {1,11,*n*,*n*,*n*} are examples of a CMD instruction to set up a channel. The first example sets up CH1, the second sets up CH2, and the third sets up the SONIC channel for the ultrasonic motion detector.

Maximum Command Length

The maximum number of elements that can be in a command list is 25. If a list sent to the CBL contains more than 25 elements, the CBL ignores the entire list, and the calculator resumes operation at the next program instruction.

Predefined Default Settings

You control the CBL by sending commands from a calculator. To automate many setup operations, the CBL uses predefined (default) settings when:

- Specific parameters are omitted at the end of a command list.
- The AutoIDENT feature is active.

Example

Assume the CBL receives two one-parameter commands as successive lists as shown by the following:

```
:{1}→L1 :Send(L1)
:{3}→L2 :Send(L2)
```

The CBL interprets the first list ({1}) as a Channel Setup command and performs the following default operations:

1. Selects CH1 to collect data.
2. Uses AutoIDENT values if active, and voltage (0 to 5 Volts) if not active. All other CMD1 parameters default to 0 and are not active.

As previously noted, CMD3 must be the last setup command sent to the CBL before data collection begins.

The CBL interprets the second list ({3}) as a Sample and Trigger Setup command and performs the following default operations:

1. Sets Sample Time to 0.5 seconds, Number of Samples to 1, Trigger Type to Manual, and Trigger Channel to 1. All other CMD3 parameters default to 0 and are not active. (READY is lit in the display.)
2. Collects one sample when [TRIGGER] is pressed (the SAMPLING indicator blinks, and then DONE is lit in the display).

There are many more default parameters than those listed above. The predefined settings will become more clear as you read about each of the commands starting on the next page. On the following pages, default parameters are shown in boldface for each of the command descriptions.

List Syntax

{0}

CMD0 Operations

CMD0 clears the unit of all previous data and resets all channels to their default settings. The only element in the list is a zero.

When you send a CMD0 to the CBL:

- All channel indicators are turned off.
- All data is cleared.
- All conversion equations are cleared and EQ indicators turned off.
- Any error message is cleared.

Note: If any AutoIDENT probes are connected, the AutoIDENT default values reactivate for those probes.

CMD1 Operations

CMD1 allows you to set up parameters for the channel in which you have a probe connected for collecting data. This command clears all previously collected data from the CBL. The first element in the list must be a 1 to designate CMD1.

List Syntax

{1,*channel_number*,*operation*,*post_processing*,*statistics*, *conversion*}

Note: Refer to page 35 for Channel Setup instruction examples.

Channel

This parameter selects the channel on which to collect data. (Default: **1**)

0 Clears all channels (refer to last note on page 33)

1 Selects CH1 (analog channel)

2 Selects CH2 (analog channel)

3 Selects CH3 (analog channel)

11 Selects SONIC (motion detector channel)

21 Selects DIG IN (digital input channel)

31 Selects DIG OUT (digital output channel)

Note: The parameters for this command depend on the channel selected. The channels and their corresponding parameters are described on the following pages.

CH1, CH2, CH3: Analog

Operation

This parameter (the third element of the list) lets you select the type of data to collect for the selected analog channel. (Default: **1**)

0	Clears the channel (refer to last note on page 33)	
1	AutoIDENT (**Note:** If AutoIDENT is not active, the operation defaults to Voltage, 0 to 5 Volts)	
2	Voltage measurement	(±10 Volts; CH1, CH2)
3*	Current measurement	(±10 Amps; CH1, CH2)
4	Resistance measurement	(1 Kohms to 100 Kohms)
5**	Period	(0.000004 sec to 50 sec)
6**	Frequency	(0.02 Hz to 250 KHz)
10	Temperature measurement	(-20°C to 125°C)
11	Temperature measurement	(-4°F to 230°F)
12	Light measurement	(10µW/cm^2 to 1mW/cm^2)
14	Voltage measurement	(0 to 5 Volts)

* Based on voltage conversion on Vin of 1V = 1A.

**Refer to "Measuring Period and Frequency" in Appendix A for additional information.

Post-Processing

This parameter lets you select the type of processing that is performed after the data has been collected. (Default: **0**)

0	None (no processing to be done)
1	*d*/*dt* (first derivative, **only** d/dt indicator is lit on the display panel)
2	*d*/*dt* and d^2/dt^2 (first and second derivative, **only** d^2/dt^2 indicator is lit on the display panel)
3	Statistics (mean, standard deviation, minimum, maximum)

Derivatives and statistics are computed on values after the conversion equation has been applied. When derivatives are requested, Relative Record Time (CMD3) is automatically turned on.

CH1, CH2, CH3: Analog (continued)

The Statistics option creates four lists: mean, standard deviation, minimum, and maximum. The original data is not displayed and is discarded after the statistical summary is computed. (Refer to the example on page 34.) This option is valid only for lists and matrices. This option is not valid if period or frequency is selected and will produce an E.13 error message (page 56).

Note: Post-processing will not operate if the Number of Samples parameter in Sample and Trigger Setup (CMD3) is ¯1 (for real-time display of collected data). Additionally, only one channel can be active when Statistics post-processing is selected, or it will produce an E.07 error message (page 56).

Statistics Samples

This parameter lets you select the number of statistics samples to collect for each computed statistic point. It applies only when Post-processing is set to 3 (Statistics is selected). (Default: **10**)

2–512 (**10**) Number of samples

Conversion Equation

This parameter lets you select whether the Conversion Equation is on or off for the selected channel. 0 (zero) turns it off, and 1 turns it on. (Default: **0**)

Conversion Equation is a CBL feature that converts a measured physical unit such as volts or ohms into a more useful measurement unit such as Newtons or degrees Celsius. The equation types are defined in CMD4 (Conversion Equation Setup) on page 47.

CH11: SONIC

Operation

This parameter lets you select the kind of data to collect on the ultrasonic motion detector channel. (Default: **1**)

0 Clears the channel (refer to last note on page 33)

1 AutoIDENT (**Note:** If AutoIDENT is not active, the operation defaults to meters.)

2 Meters

3 Feet

Note: The CBL uses 343 meters/second, the speed of sound at a pressure of 760 millimeters of mercury at 20ºC, for ultrasonic motion computations.

Post-Processing

This parameter lets you select the type of processing that is performed after the data has been collected. (Default: **0**)

0 None (no processing to be done)

1 d/dt (first derivative, only d/dt indicator is lit on the display panel)

2 d/dt and d^2/dt^2 (first and second derivative, only d^2dt^2 indicator is lit on the display panel)

3 Statistics (mean, standard deviation, minimum, maximum)

Derivatives and statistics are computed on values after the conversion equation has been applied. When derivatives are requested, Relative Record Time (CMD3) is automatically turned on.

The Statistics option creates four lists: mean, standard deviation, minimum, and maximum. The original data is not displayed and is discarded after the statistic summary is computed. (Refer to the example on page 34.) This option is valid only for lists and matrices. This option is not valid if period or frequency is selected and will produce an E.13 error message (page 56).

Note: Post-processing will not operate if the Number of Samples parameter in Sample and Trigger Setup (CMD3) is ⁻1 (for real-time display of collected data). Additionally, only one channel can be active when Statistics post-processing is selected, or it will produce an E.07 error message (page 56).

CH11: SONIC (Continued)

Statistic Samples

This parameter lets you select the number of data samples to collect for each computed Statistic point. It applies only when Post-processing is set to 3 (Statistics is selected). (Default: **10**)

2–512 (**10**) Number of samples

Conversion Equation

This parameter lets you select whether the Conversion Equation is on or off for the ultrasonic channel. Zero (0) turns it off, and 1 turns it on. (Default: **0**)

Conversion Equation for the ultrasonic channel is a CBL feature that converts a measured distance in meters or feet to another measurement unit. The equation types are defined in CMD4 (Conversion Equation Setup) on page 47.

CH21: Digital In

Operation

This parameter applies only to the digital input channel. When this parameter is 1 (active), it lets you collect data from digital logic circuits. (Default: **1**)

0 Clears the channel (refer to last note on next page)

1 Active

Note: Refer to "Clock-In Line Operation" (page 68) for additional technical information about this parameter.

CH31: Digital Out

Number of Data Elements

This parameter applies only to CH31. It sets the number of data elements that will be in the list. (Default: **1**)

0 Clears the channel (refer last note below)

1–22 Selects the number of data elements to output

Data Elements

This parameter applies only to CH31. It selects the actual digital data elements to output from the DIG OUT channel when the trigger condition selected in Command 3 is met. The output is a 4-bit (TTL 0–5 Volts) digital *nibble* for each data element. For example, 0=0000, 1=0001, 2=0010, 10=1010, 15=1111. (Default: **0**)

0–15 Selects the values of the data elements to output

Notes:

1. Refer to "Clock-Out Line Operation" (page 68) and "Digital Output Buffer" (page 69) for additional technical information about this parameter.
2. Refer to "Digital Nibble" in the Glossary for a definition of this term.
3. The Operation parameter to clear channels for CH1, CH2, CH3, CH11, CH21 and CH31 does the following:
   - Turns off the channel indicator for that channel.
   - Turns off the conversion equation and the EQ indicator for that channel.
   - Clears data for that channel.
   - Conversion equation remains loaded, but is not active.
   - For Channel = 0, the above operations affect all channels. Additionally, Record Time is turned off.

Example: Statistics Post-Processing

Statistics post-processing is selected and you collect five data samples for each computed statistic point. In CMD1 (Channel Setup) you define five samples per statistic point, and in CMD3 (Sample and Trigger Setup) you define six statistic points to collect.

The CBL collects 30 data samples (6 statistic points × 5 data samples). The data that is returned to the CBL consists of four lists (mean, standard deviation, minimum, maximum) with each list containing six elements.

The original data is discarded, and the computed statistical data is available to be retrieved by a calculator.

		CBL Post-processing computations on statistics samples			
Statistic Point	Raw Data Samples	$\bar{x}$	σx	minX	maxX
1	1, 1.2, 1.1, 1.3, 1.2	1.16	.10	1.0	1.3
2	2, 2.2, 2.3, 2.1, 2.3	2.18	.12	2.0	2.3
3	4, 4.2, 4.3, 4.2, 4.5	4.24	.16	4.0	4.5
4	4.7, 4.6, 5, 4.9, 4.5	4.74	.19	4.5	5.0
5	5.1, 4.9, 5, 5.2, 5	5.04	.10	4.9	5.2
6	5.7, 5.9, 6.1, 6, 5.8	5.90	.14	5.7	6.1
	↓ Discarded	↓ L1	↓ L2	↓ L3	↓ L4
		↘	↓	↓	↙
			Calculator		

Examples: Channel Setup Instruction

These two examples apply to the analog channels.

`{1,2,3}`	1=	Channel Setup command.
	2=	Select CH2.
	3=	Measure current.
`{1,1,2,3,50}`	1=	Channel Setup command.
	1=	Select CH1.
	2=	Measure voltage (±10 Volts).
	3=	Set up Statistics post-processing.
	50=	Collect 50 samples for each statistics point.

These two examples apply to the digital output channel.

`{1,31,1,15}`	1=	Channel Setup command.
	31=	Select CH31.
	1=	Number of data elements.
	15=	Select output data element to be digital pattern corresponding to 1111.
`{1,31,4,0,1,2,3}`	1=	Channel Setup command.
	31=	Set up CH31.
	4=	Number of data elements.
	0,1,2,3=	Output 0,1,2,3 where: 0=0000, 1=0001, 2=0010, 3=0011.

CMD2 Operations

CMD2 sets up the data type to which data will be stored on the calculator, and the channel whose data is displayed during sampling. The first element in the list must be a 2 to designate CMD2.

List Syntax

{2,*data*,*display*,*picY*,*Ymin*,*Ymax*,*picX*,*Xmin*,*Xmax*}

Note: This command should always come after the last CMD1; otherwise, your selections may be cleared.

Data Type

With the exception of picture data, all data is stored in the CBL as a sequence of real numbers. This parameter lets you determine if the data will be stored as on the calculator as a list, matrix, or picture.

Note: This command parameter is primarily for use with the standard TI-85 calculator. On other calculators, the data type is determined by the variable used in the **GET(**, **GET**, or **Input "CBLGET"** instruction. (Default: **1**)

1 Collected data is stored as a list (on the calculator).

2 Collected data is stored as a matrix.

3 Collected data is stored as a pixel image for a picture.

List data: Collected and stored in the CBL as a set of real values. List data is retrieved by a calculator into a predefined list variable.

Matrix data: Collected and stored in the CBL as a set of real values. matrix data is retrieved by a calculator into a predefined matrix variable.

Picture data: Collected and stored in the CBL as a pixel image. Picture data is collected on two channels that you specify. The first channel collects data to represent the Y values, and the second channel collects data to represent the X values. The data is scaled by the CBL for the appropriate calculator. Picture data is retrieved by a calculator into a predefined picture variable.

Data Display Channel

This parameter selects the channel whose data will be displayed. The rate at which data is displayed during data collection depends on the sample rate you select in CMD3 (refer to the Sample Time parameter on page 39). (Default: **0** lowest active channel.)

Note: This feature works only when the sample time is greater than or equal to 0.25 seconds.

0 Displays data of lowest active channel

1 Displays data of CH1

2 Displays data of CH2

3 Displays data of CH3

11 Displays data of CH11 (SONIC)

21 Displays data of CH21 (DIG IN)

Note: If you select Data Type 1 (list) or 2 (matrix), everything after this parameter is ignored. The following parameters only apply when the Data Type parameter is a 3 (picture).

Pic (Picture) Y Channel

This picture-only parameter lets you select the channel on which to collect the Y values for picture data. (Default: **1**)

1 Collects Y values on CH1

2 Collects Y values on CH2

3 Collects Y values on CH3

11 Collects Y values on CH11 (SONIC)

21 Collects Y values on CH21 (DIG IN)

Ymin

This picture-only parameter sets the minimum Y value for picture data. Enter a real number. (Default: **-10**)

Ymax

This picture-only parameter sets the maximum Y value for picture data. Enter a real number greater than Ymin. (Default: **10**)

Note: Ymin and Ymax, and Xmin and Xmax (on next page), are Window variables on a calculator, except on the TI-85 where they are Range variables.

Pic (Picture) X Channel

This picture-only parameter lets you select the channel on which to collect the X values for picture data. (Default: **0**)

0	Collect X data (X data is a number from 1 to the number of samples defined in CMD3)
1	Collect X values on CH1
2	Collect X values on CH2
3	Collect X values on CH3
-1	Collect X data as the recorded time selected in CMD3

Note: If Pic X Channel is -1, Record Time must be selected in CMD3, or a blank pic will be returned.

Xmin

This picture-only parameter sets the minimum X value for picture data. Enter a real number. (Default: **1**)

Xmax

This picture-only parameter sets the maximum X value for picture data. Enter a real number greater than Xmin. (Default: **512**)

Examples: Data Type Setup Instruction

`{2,1}`	2= Data Type and Display Setup command. 1= Select list data type using the default to display lowest active channel data on the CBL.
`{2,2,3}`	2= Data Type and Display Setup command. 2= Select matrix data type. 3= Display CH3 data on the CBL. (This assumes that CH3 was previously set up.)
`{2,3,0,2,-5,5,0,0,96}`	2= Data Type and Display Setup command. 3= Select picture data type. 0= Display channel is lowest channel number set up. 2= Pic Y channel is CH2. -5= Ymin. 5= Ymax. 0= Pic X channel, collect X data from 1 to the number of samples. 0= Xmin. 96= Xmax.

CMD3 Operations

CMD3 sets up the sampling rate, when to start collecting data, the recording time option, and more. It is this command that puts the CBL into the READY state to start data acquisition. This command clears all previously collected data from the CBL. The first element in the list must be a 3 to designate CMD3.

List Syntax

{3,*sample_time*,*number_samples*,*trigger_type*,*trigger_channel*,*trigger_threshold*,*prestore*, *external_clock*,*record_time*,*filter*}

Note: The last list sent to the CBL **must** be a Sample and Trigger Setup command (CMD3). This list should be sent by itself and **must** be the last setup command sent to the CBL before data collection begins.

You should precede send instructions that follow a CMD3 with a **Pause** instruction. When a **Pause** instruction is used, the program should not be resumed until sampling is complete (DONE indicator is on). (Refer to "Improving Data Collection Accuracy Using Pause" on page 68.)

If another send instruction is sent while SAMPLING is active, data collection is halted and the command's function is not performed.

Sample Time

This parameter lets you select how often to collect data (in seconds). For example, entering .00010 for this parameter tells the CBL to collect a sample every 100 microseconds (minimum allowed). (Default: **0.5**)

0	Selects external clock for sample-time generation using the source specified by the External Clock Source (page 44).
0.00010 to 0.2 0.25 to 16000	Selects the sample time in seconds. Values greater than 0.2 and less than 0.25 are not valid (E.32 error message). Values greater than 0.25 must be in multiples of 0.25; otherwise, you will also get an E.32 error message (page 57).

Note: Refer to "Determining the Minimum Sample Time" for detailed information about allowable sample times on page 70. For real-time data collection, refer to "Maximum Sample Rate for Real-Time Data Collection" on page 67.

Number of Samples

This parameter lets you select the number of samples to collect. (Default: **1**)

1–512 Number of samples to collect. If Statistics is selected in CMD1, the upper limit is 256.

-1 Causes continuous data collection following each **Get(**, **GET** or **Input "CBLGET"** instruction from a calculator. This value is necessary for real-time data collection.

Note: When Number of Samples is -1 for real-time display of collected data:

- Only one channel can be active.
- Post-processing will not operate (pages 29, 31).
- Record Time will not operate (page 44).
- Filter will not operate (page 46).

Trigger Type

This parameter lets you select a specific point at which to start collecting data. You can trigger CBL to start collecting data at a specific point on the actual data, or on an external clock. The function performed by Trigger Types 2 to 5 depends on whether or not period or frequency is selected in CMD1. (Default: **1**)

0 None.

The following triggering information applies when the Number of Samples is -1 and Trigger Type is 0:

- If Sample Time is less than or equal to 0.20 seconds, then a sample will be taken immediately after receiving the Sample and Trigger Setup command (CMD3). Subsequent samples will be taken immediately after a **Get(** or **Input "CBLGET"** instruction is received from the calculator.
- If Sample Time is greater than or equal to 0.25 seconds, then the first sample will be taken at the sample time after the Sample and Trigger Setup command is received.

1 Manual. Lets you manually start data collection by pressing TRIGGER.

Manual triggering (Trigger Type 1 or 6) is useful when you want to set up the CBL and then disconnect it from the calculator to collect the data. The CBL waits for you to press TRIGGER before starting data collection.

Trigger Type (Continued)

For Trigger Types 2 through 5, data collection begins when the input signal changes with respect to Trigger Threshold values—from below to above the value for Trigger Types 2 or 4, and from above to below the value for Trigger Types 3 or 5.

The selected Trigger Type also specifies the edge polarity that is used during period and frequency measurements. Trigger Types 4 and 5 are used for measuring the waveform pulse-width between rising and falling edges (see page 72).

2 Rising edge to rising edge (+ +).

3 Falling edge to falling edge (− −).

4 Rising edge to falling edge (+ −).

5 Falling edge to rising edge (− +).

Note: For Trigger Types 2 through 5, see also "Software Triggering" on page 71 or "Measuring Period and Frequency" on page 72.

6 Manual and Sample.
Lets you collect one sample at a time each time TRIGGER is pressed. (Note that when Trigger Type is 6, the Sample Time parameter is ignored.)

1*nnnn* Digital *nibble* on Channel 21 (DIG IN), where n=0 or n=1 is the desired data value, and n=2–9 indicates a "do not care" for that bit. (Refer to Digitial Nibble in the Glossary, if necessary.)

Note: This selection for Trigger Type automatically selects CH21 as the trigger channel regardless of the value entered for Trigger Channel (see below).

Trigger Channel

This parameter lets you select the active channel that detects the selected trigger type (Trigger Type must be 2–5). This channel must have been selected in CMD1. (Default: **1**)

0 n/a

1 Triggers on CH1

2 Triggers on CH2

3 Triggers on CH3

21 Triggers on an external clock signal. This trigger can be one of two physical signals that is determined by the External Clock Source parameter (page 44).

Trigger Threshold

This parameter defines the voltage level required from the input signal to begin triggering. It is also used to set the threshold for counting signal transitions when measuring period and frequency.

This parameter does not apply when:

- Operation 5 (Period) or 6 (Frequency) is not selected in CMD1, and Trigger Type is 0, 1, 6, or 1*nnnn*.
- External Clock is 0.

The table below shows valid Trigger Threshold values and other parameters required to use Trigger Threshold. (Default: see boldface text below.)

Trigger Threshold Values	(CMD1) Operation	Trigger Type	Trigger Channel
1 (Volt) **1 (Amp)** **1 (Kohms)**	2, 14[2] 3 4	2, 3, 4, 5	1, 2, 3, 21
-10 to 10 (Volts)[1]	2, 14[2]	2, 3, 4, 5	1, 2, 3
-10 to 10 (Volts)[1]	5, 6	0, 1, 2, 3, 4, 5, 1*nnnn*	n/a
-10 to 10 (Amps)[1]	3	2, 3, 4, 5	1, 2, 3
1 to 100 (Kohms)	4	2, 3, 4, 5	1, 2, 3

[1]Applies to CH1 and CH2 only.

[2]Operation 14 (0–5 Volts) applies only to software triggering.

Note: If there is a conflict between the value entered in Trigger Threshold and the operation selected in CMD1, you will get an E.36 error message (page 57).

There are two types of thresholds that can be set—hardware triggering and software triggering. (Refer to page 71 for additional information.)

Trigger Threshold (Continued)

Hardware Trigger Threshold: Hardware triggering is selected by either of the following:

- Trigger Channel in CMD3 is set to 21 (DIG IN), and External Clock Source in CMD3 is set to 1.
- Operation 5 (Period) or 6 (Frequency) is selected in CMD1 and Trigger Type selected in CMD3 is 0, 1, 2, 3, 4, 5, or 1*nnnn* (Digital *nibble*). (Refer to pages 71–72.)

Note: Rising-edge polarity is selected automatically when Trigger Type is 0, 1, or 1*nnnn*.

Software Trigger Threshold: The threshold is a "software" value that is converted to an analog-to-digital converter value for determining the trigger event. Software triggering is selected by the following (all are required):

- Trigger Channel is set to 1, 2, or 3.
- Trigger Type is set to 2, 3, 4, or 5.
- Period or Frequency operation is not selected.

Note: If an external clock is used with a software trigger, the hardware threshold for External Clock Source = 1 is set to 1 Volt.

Prestore Data Percentage (%)

This parameter selects the percentage of the number of samples to collect before the trigger condition is met. (Default: **0**) (Refer to "Triggering with Prestore Reference Information" in Appendix A.)

0–100 Percentage (integer value) of samples to collect.

For example, a prestore data value of 10 results in 10% of the data being collected before triggering and 90% of the data being collected after triggering.

Note: This parameter is ignored if Post-Processing is 3 (Statistics) in CMD1.

External Clock Source

This parameter lets you select one of two physical sources to be used as a clock or trigger signal. It is used only when an external clock is specified when you set the Sample Time parameter to zero (see page 39), or when you set the Trigger Channel to 21 (see page 41). (Default: **0**)

0 Selects the signal on the External Clock-In line of Channel 21 (DIG IN). This input is a 0–5 Volt logic input with a threshold near one-half battery voltage. The polarity of the clock edge or trigger transition is established by the Trigger Type parameter that you select.

1 Selects the signal on the Vin line of CH1. This input is a ±10 Volt analog input. The threshold can be set to one of seven levels in this range by the value of the Trigger Threshold parameter (see page 71). The polarity of the clock edge or trigger transition is established by the Trigger Type parameter that you select.

Note: To ensure that samples are only taken at external clock events, Trigger Channel 21 (CH21) should normally be selected when using an external clock source.

Record Time

This parameter lets you specify whether CBL records absolute or relative time during data collection. (Default: **0**)

0 None. No time value is recorded.

1 Absolute. Records the actual time in seconds from the start of data collection.

2 Relative. Records the time in seconds between samples.

If any derivatives are requested (Post-processing set to 1 or 2 in CMD1), relative record time is automatically turned on.

Note: Record Time will not operate when the Number of Samples parameter in Sample and Trigger Setup (CMD3) is ⁻1 (for real-time display of collected data).

When the Sample Time parameter specified in CMD3 is greater than or equal to 0.25 seconds, the absolute record time for the first sample will be about 0.013 seconds longer than the Sample Time that you specify for points stored after the trigger point.

Record Time (Continued)

The absolute record time for the first sample is zero for manual triggered nonprestore samples. It is approximately equal to the sample time for most other conditions. If an external clock is used, it will be the time between the CMD3 (Sample and Trigger) and the first external clock.

The resolution for Record Time is shown by the table below.

Clock Condition	Record Time Resolution
Sample Time ≤ 0.2 sec Sample Time ≥ 0.25 sec	3.2 μsec 3.906 msec
External Clock < 0.1289 sec External Clock > 0.1289 sec	3.2 μsec 3.906 msec

Filter

This parameter lets you select one of six numeric filtering algorithms to remove noise from collected data and derivatives. 1 to 4 selects among Savitzky-Golay fourth-order filters with varying numbers of points. 5 and 6 select median pruning filters designed to remove outlying values. (Default: **0**)

0 Selects no noise filtering

1–6 Selects one of six filtering algorithms:

- 1 5-point Savitzky-Golay (S-G) smoothing (applies only to derivatives)
- 2 9-point (S-G) smoothing
- 3 17-point (S-G) smoothing
- 4 29-point (S-G) smoothing
- 5 3-point median pruning filter
- 6 5-point median pruning filter

Collected data before and after the range of data that is filtered is assumed to be equal to the first and last data point, respectively. This "end effect" affects the filtered data at the beginning and end of the data range for $(n-1)/2$ points, where n is the number of points in the filter.

Filter (Continued)

Note: If CH31 or Statistics is requested, or when the Number of Samples parameter in Sample and Trigger Setup (CMD3) is ⁻1 (for real-time display of collected data), the default (no filtering) is used.

Examples: Sample and Trigger Setup Instruction

{3,.25,100}	3=	Sample and Trigger Setup command.
	.25=	Take a sample every 0.25 seconds.
	100=	Collect 100 samples.
		Default values used for trigger and remaining parameters.
{3,.0002,99, 2,1,2.9}	3=	Sample and Trigger Setup command.
	.0002=	Take a sample every 200 µsec.
	99=	Collect 99 samples.
	2=	Software triggering on rising edge.
	1=	Trigger on CH1.
	2.9=	Trigger when voltage exceeds 2.9 Volts.

CMD4 Operations

CMD4 sets up parameters to convert collected data to specific units such as Newtons or degrees Celsius by specifying equation type, equation order, and constants. The first element in the list must be a 4 to designate CMD4.

List Syntax

{4,*equation_number*,*equation_type*,*equation_order*,*constant*, *units_display*}

Equation Number

This parameter selects the equation number in which to load the conversion equation. Equations have a fixed relationship to the channels. EQ1 corresponds to CH1, EQ2 corresponds to CH2, etc. (Default: **0**)

0 Clears all equations*
1 Selects EQ1 (for CH1)
2 Selects EQ2 (for CH2)
3 Selects EQ3 (for CH3)
4 Selects EQ4 (for SONIC)

* Conversion Equation is still enabled if selected in CMD1 and the EQ indicator in the display remains on.

Note: To use equations defined by this command, the Conversion Equation parameter in CMD1 must be set to 1.

Equation Type

This parameter specifies the type of equation to use for the conversion. (Default: **0**)

0 Clears the above selected equation*
1 Polynomial
2 Mixed Polynomial
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

* Conversion Equation is still enabled if selected in CMD1 and the EQ indicator in the display remains on.

Note: Refer to “Conversion Equation Reference Information” in Appendix A.

Equation Order

This parameter lets you specify the equation order (m,n) for equation types 1 and 2 to use in the conversion equation. There will be 0, 1, or 2 integers required here depending on the presence of m and/or n in the equation.

1 Use one integer when $n>0$, $m=0$ as in Equation Type 1 (n=1–9).

2 Use two integers when $m>0$, $n>0$ as in Equation Type 2. The first integer is m (0–4), the second integer is n (0–4), and $m+n>0$ (m and n cannot both be 0).

Note: For Equation Types 3–12, there is no Equation Order field. The next field after Equation Type is Constants.

Constants

This parameter lets you specify the constant values to use in the conversion equation. The number of constants is determined by the Equation Order parameter for Equation Types 1 and 2.

$K_0...K_n$ Real numbers (Equation Type 1)

$K_{-m}...K_n$ $K_{-m}...K_n$ Real numbers (Equation Type 2)

Units Display

This parameter lets you specify the type of units to show in Section 5 of the display (page 14) following the conversion. (Default: **0**)

0 None

1 Display °F to show units in degrees Fahrenheit

2 Display °C to show units in degrees Celsius

3 Display K to show units in Kelvin

Example: Conversion Equation Setup Instruction

Assume your experiment is measuring the resistance of a Cadmium Sulfide (CdS) photoresistor in which the relationship between I (illuminance in Lux) and R (resistance in Kohms) is approximated by the equation $I = 2750R^{-1.3}$.

This equation is a Type 3 equation, power, $K_0X^{(K1)}$, where $K_0 = 2750$ and $K_1 = -1.3$.

```
{4,1,3,2750,
-1.3}
```

4= Conversion Equation Setup command.
1= Set up equation 1 (for CH1).
3= Set equation type to Power.
2750, -1.3= Set constants.
Set K_0=2750
Set K_1= -1.3

CMD5 Operations

CMD5 lets you select the channel number, and raw collected or processed data retrieved by a calculator. It also lets you select the number of elements for list and matrix samples retrieved by the calculator. The first element in the list must be a 5 to designate CMD5.

List Syntax

{5,*channel*,*data_select*,*data_begin*,*data_end*}

Note: CMD5 parameters are ignored if the Data Type parameter is 3 (picture) in CMD2.

Channel Select

This parameter lets you select the channel from which to retrieve data into the calculator. (Default: **0**)

0 Selects the lowest active channel

1 CH1 (analog channel)

2 CH2 (analog channel)

3 CH3 (analog channel)

11 SONIC (ultrasonic channel)

21 DIG IN (digital input channel)

-1 Selects the recorded time selected in CMD3

Note: If this parameter is -1, you must have also selected Record Time (absolute or relative) in CMD3; otherwise, you will get an E.52 error message (page 57).

If absolute record time is selected in CMD3, the time returned to a calculator is relative to the sample collected just prior to the first sample. For example, if the Data Begin parameter is set to 100, the recorded time retrieved will be relative to the recorded time of the 99th sample.

The CBL only stores the relative record time and computes the absolute time as each list or matrix is requested. If you need absolute time with respect to some other point for your application (such as the first collected sample), you can retrieve the relative time and compute the absolute time on the calculator.

Data Select

This parameter lets you select which data to return to the calculator. (Default: **0**)

0 Retrieve raw collected data (filtered if filter is on)

1 *d*/*dt* (filtered if filter is on)

2 d^2/dt^2 (filtered if filter is on)

3 Raw collected data (ignore filter setting)

4 d/dt (ignore filter setting)

5 d^2/dt^2 (ignore filter setting)

If filtering is selected in CMD3, options 3, 4, and 5 allow you to retrieve unfiltered data, if desired. When one of these options is selected, subsequent **GET(**, **GET**, or **Input "CBLGET"** instructions continue to retrieve unfiltered data until Data Select is set to a value (0–2), which retrieves filtered data.

Likewise, when Data Select is 0, 1, or 2, successive **GET(**, **GET**, or **Input "CBLGET"** instructions cycle through raw collected data, *d*/*dt*, and d^2/dt^2 to retrieve filtered data to the calculator.

Note: To retrieve *d*/*dt*, d^2/dt^2, or Statistics you must have also selected *d*/*dt*, d^2/dt^2, or Statistics post-processing in CMD1; otherwise, you will get an E.53 error message (page 57).

Data Begin

This parameter lets you select the first sample number to return in a list or matrix to a calculator. (Default: **1**)

1–512 Starting sample number

Data End

This parameter selects the last sample number to return in a list or matrix to a calculator. It must be greater than or equal to the parameter selected for Data Begin. (If Data End is zero, the last sample is selected.) (Default: **0**)

0–512 Ending sample number

If no Data End is specified and the data set has more than 99 samples, Data End is set to 99 for a list or 255 for a matrix.

If the number of elements is greater than 99 for a list or 255 for a matrix, Data End is set to Data Begin plus 99 or 255.

Examples: Data Range Setup Instruction

`{5,2,1}`	5=	Data Range Setup command.
	2=	Retrieve data from CH2 .
	1=	Retrieve filtered *d/dt* (if filter is on)*.
`{5,1,0,100,150}`	5=	Data Range Setup command.
	1=	Retrieve data from CH1.
	0=	Retrieve filtered raw collected data (if filter is on).
	100=	Set Data Begin to 100.
	150=	Set Data End to 150.
`{5,11,3}`	5=	Data Range Setup command.
	11=	Retrieve data from SONIC channel.
	3=	Retrieve unfiltered raw collected data (ignore filter setting)*.
`{5,-1}`	5=	Data Range Setup command.
	-1=	Retrieve recorded time*.

* Retrieves data from the first to the last sample.

CMD6 Operations

CMD6 sets up the CBL to use CH1 or the SONIC channel as a multimeter. Multimeter mode only works on one of these two channels at a time. The first element in the list must be a 6 to designate CMD6.

List Syntax

{6,*set_reset*,*operation*}

Note: Pressing [MODE] lets you use the CBL in Multimeter mode as a stand-alone device without requiring setup commands from the calculator.

Set/Reset

This parameter lets you set or reset the Multimeter mode. (Default: **1**)

0 Restore to Communications mode

1 Set to Multimeter mode

When the CBL is in the Multimeter mode:

- CMD6 is the only supported command.
- Active channel defaults to CH1.
- Sample time defaults to 0.5 seconds.
- Trigger defaults to 1 Volt on the rising (+ +) edge with the corresponding default trigger threshold for period and frequency.
- Result of the sample is displayed, but is not available for retrieval by a calculator. This prevents overwriting collected data from Communications mode.

Operation

This parameter selects the multimeter operation to measure. (Default: **1**)

1	AutoIDENT **Note:** If AutoIDENT is not active, the operation defaults to Voltage, 0 to 5 Volts	
2	Voltage measurement	(±10 Volts)
3*	Current measurement	(±10 Amps)
4	Resistance measurement	(1 Kohms to 100 Kohms)
5	Period	(0.000004 sec to 50 sec)
6	Frequency	(0.02 Hz to 250 KHz)
7**	Meters	
8**	Feet	

* Based on voltage conversion on Vin of 1V = 1A.

**Meters or feet apply only to the ultrasonic channel.

Multimeter Mode Setup Instruction Examples

This example collects one data sample on CH1. Voltage is measured and displayed on the CBL.

```
{6,1,2}
```

6= Multimeter Mode Setup command.
1= Set to Multimeter mode.
2= Measure voltage (±10 Volts) from CH1.

This example sets up the CBL according to the AutoIDENT resistance sensed. With the TI temperature probe connected to CH1, resistance is measured and converted to temperature in °C.

```
{6,1,1}
```

6= Multimeter Mode Setup command.
1= Set to Multimeter mode.
1= AutoIDENT.

CMD7 Operations

CMD7 creates a data list of CBL status information, which can then be sent to a calculator. The only element in the list is a 7.

List Syntax

{7}

Request Status

This command creates a list showing system status and sets up the CBL to clear any displayed error messages. The following items are created in the list:

- Device code: 1 (device code identifier)
- Last error code: 0–99 (0=no errors)
- AutoIDENT resistance values for CH1, CH2, CH3, and CH11 in Kohms (999 Kohms = open)
- List of all active channels

To create a list showing the system status of the CBL and to clear any error messages, send a CMD7, and then retrieve the list. Any error condition except POS (Power-on Short, page 57) is cleared, when the list is retrieved.

Note: If an error condition exists, the CBL will not respond to calculator commands (except CMD0 or CMD7) until the error condition is cleared. Pressing [ON/HALT] or sending an All Clear command (CMD0) also clears any error condition and displayed error message.

Request Status Example

`{7}→L1` `Send(L1)`	Send CMD7 to the CBL to create a system status list and set up the CBL to clear any displayed error messages.
`Get(L1)`	Retrieve the list created by CMD7 and store it to L1 in the calculator. Clear any active error messages from the CBL display.

Note: The list created by CMD7 is available for retrieving into a calculator until the next command invalidates the list. Therefore, you should retrieve this list immediately following a Request Status command.

Appendix A: Reference Information

This appendix contains reference information about displayed error codes, TI probes and connectors, conversion equations, and other reference information.

Contents

Error and Status Messages

When the CBL detects an error, it displays a coded error message from E.05 to E.63. In most cases, the first digit denotes the command in which the error occurred; the second digit denotes the parameter number where the error occurred.

Pressing ON/HALT or sending a CMD0 clears any error condition and displayed error message on the CBL. The error condition must be cleared before the CBL will respond to calculator commands.

Error Code	Error Description
E.05	Number is out-of-range for the CBL. The CBL detected an exponent greater than 31 (exponent > E31).
E.06	Command list contains a noninteger value in an integer-only position. For example, {1,1.5} causes an error, but {1,1} does not. (Must be an integer from ⁻32768 to 32767.)
E.07	Multiple channels are selected and trying to compute Statistics, period, or frequency; or multiple active channels and number of samples is ⁻1.
E.08	Command list exceeds maximum number of valid parameters for the selected command.
E.09	Command number parameter is out-of-range. (It must be an integer from 0 to 7.)
E.12	Invalid channel selected in Channel Setup command. (Only 0, 1, 2, 3, 11, 21, and 31 are valid.)
E.13	Invalid operation selected for specified channel in Channel Setup command (see pages 28–35).
E.14	Invalid post-processing option selected. (Must be 1, 2, or 3 and the number of samples cannot be ⁻1.)
E.15	Statistics samples count is out of range. (Must be from 2–512.)
E.16	Invalid Conversion Equation on/off parameter. (If present, it must be 0 or 1.)
E.22	Defined data type is not a list, matrix, or picture. (Must be 1, 2, or 3.)
E.23	Invalid data display channel selected. (Must be 0, 1, 2, 3, 11, or 21.)
E.24	Invalid Pic Y channel specified. (Must be 1, 2, 3, 11, or 21.)
E.25	Ymax ≤ Ymin for Picture setup in CMD2 (see page 37).
E.27	Invalid Pic X channel specified. (Must be ⁻1, 0, 1, 2, or 3.)
E.28	Xmax ≤ Xmin for Picture setup in CMD2 (see page 38).

Error Code	Error Description
E.30	Invalid filter selected. (Must be an integer from 0–6.)
E.32	Sample time out-of-range (see pages 39, 70).
E.33	Invalid number of samples selected. (Must be ⁻1, an integer from 1–256 if Statistics is on in CMD1, or an integer from 1–512 if Statistics is off.)
E.34	Invalid trigger type option. (Must be an integer from 0–6, or an integer from 10000–19999.)
E.35	Invalid trigger channel. (Must be 0, 1, 2, 3, or 21.)
E.36	Invalid or out of range trigger threshold (see page 42).
E.37	Invalid prestore value. (Must be an integer from 0–100.)
E.38	Invalid external clock selection. (Must be 0 or 1.)
E.39	Invalid record time option. (Must be 0, 1 or 2, and the number of samples cannot be ⁻1.)
E.40	Insufficient coefficients entered for specified equation.
E.42	Invalid equation number. (Must be an integer from 0–4.)
E.43	Invalid equation type selected. (Must be an integer from 0–12.)
E.44	Equation order is out-of-range for model (see page 48).
E.49	Invalid units display option. (Must be an integer from 0–3.)
E.52	Invalid or out-of-range Channel Select value. (Must be 0, 1, 2, 3, 11, 21, or ⁻1. If ⁻1, Record Time must be selected in CMD3.)
E.53	Invalid or out-of-range Data Select value. (Must be an integer from 0–5. If 1, 2, 4, or 5, Post-processing = 1 or 2 in Cmd 1 must also be selected.)
E.54	Invalid or out-of-range Data Begin value. (Must be an integer 1 to ≤ requested number of samples.)
E.55	Invalid or out-of-range Data End value. (Must be an integer 0 to ≤ requested number of samples, and ≥ Data Begin value unless Data End = 0.)
E.62	Invalid Set/Reset parameter. (Must be 0 or 1.)
E.63	Invalid Multimeter mode operation. (Must be an integer from 1–8.)
POS	Power-on Short. The CBL detected a short on one or more of the +5 Volt DC supply pins, or a total current drain greater than 120 mA.

About the Light Probe

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

The AutoIDENT resistor in the probe causes the CBL software to automatically convert the measured voltage to mW/cm^2 units. The probe is direction dependent and achieves the highest output when the end of the probe is pointed directly at the light source.

The light probe 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 probe is designed to work in air only—it is not waterproof.

Light Probe Specifications

Channels	Connects to CH1, CH2, CH3 (analog channels)
Current drain	5 mA max.
Voltage range	0–5 Volts
Irradiance range	10μW/cm^2 to 1mW/cm^2
Spectral response range	300nm to 1100nm (nanometers) (non-flat response)
Chemical tolerance	None (air only)
Conversion equation Coefficients (units = mW/cm^2)	Irradiance = (K_0 * voltage) + K_1 K_0 = 0.198795 K_1 = 0.00602410
Accuracy	±20% (Calibrated to a tungsten lamp. Using other light sources will return irradiance < actual.)
Pins used	2 ground 4 AutoIDENT resistor 5 +5 Volts DC 6 Signal

About the Temperature Probe

The TI temperature probe uses a thermistor to measure temperature. The units are in degrees Celsius. 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 (refer to the table below).

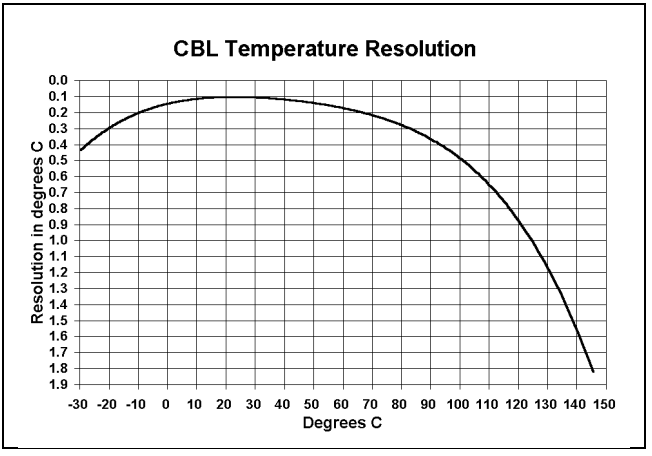
At 25°C, the resistance is 20 Kohms and the sensitivity is approximately 4.3% per °C. The CBL measures the thermistor as a resistance. The AutoIDENT resistor contained in the probe causes the CBL software to automatically convert the measured resistance to °C. The temperature probe is sensitive between ⁻20°C to +125°C. It is water resistant, but do not leave it in water for more than 24 hours.

Temperature Probe Specifications

Channels	Connects to CH1, CH2, CH3 (analog channels)
Current drain	0.5 mA max.
Temperature range	⁻20 to 125°C
Chemical tolerance	Tap water, salt water, and some chemicals. (Refer to "Temperature Probe and Chemical Tolerance" on the next page.)
Conversion equation (Steinhart-Hart model)	$T = [K_0 + K_1(\ln 1000R) + K_2(\ln 1000R)^3]^{-1} - 273.15$ where T is temperature in °C and R is the measured resistance in KΩ.
Coefficients	$K_0 = 1.02119E\text{-}3$ $K_1 = 2.22468E\text{-}4$ $K_2 = 1.33342E\text{-}7$
Accuracy	±2.50°C from ⁻20°C to 0°C ±1.25°C from 1°C to 85°C ±2.50°C from 86°C to 125°C
Pins used	2 Ground 3 Vres 4 AutoIDENT resistor 6 Signal

Temperature Resolution

Temperature resolution on the CBL is represented by the chart shown below. For example, the resolution at ⁻20ºC is about 0.29, at 0ºC about 0.15, at 20ºC about 0.1, and at 70ºC about 0.2.



Temperature Probe and Chemical Tolerance

The TI temperature probe was tested with chemicals at room temperature and at the chemical's boiling temperature. The probe was tested with each chemical for 12 hours.

The chemicals listed below did not have any adverse affect on the temperature probe during the testing period and are approved for use with this probe.

- Bleach (5.25% NaHClO)
- Calcium Chloride, $CaCl_2$ (10 g in 100 ml of water)
- Calcium Oxide, CaO (10 g in 100 ml of water)
- Cyclohexane, C_6H_{12} (100%)
- De-ionized Water (100%)
- Hydrochloric Acid, HCl (1M)
- Hydrofluoric Acid, HF (49%)
- Isopropanol, (100%)
- Magnesium Oxide, MgO (1g in 100 ml of 1M HCl)
- Potassium Iodide, KI (10 g in 100 ml of water)
- Sodium Hydroxide, NaOH (2M)

Note: Texas Instruments does not assume any responsibility for damage, alteration, or any other defect caused to temperature probes subjected to chemicals that are not on this list.

About the Voltage Probe

The TI voltage probe is a generic probe that you can use to read any voltage between ±10 Volts. The AutoIDENT resistor contained in the probe causes the CBL 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 (analog channels)
Voltage range	±10 Volts
Chemical tolerance	None (air only)
Pins used	1 Signal 2 Ground 4 AutoIDENT 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.

AutoIDENT Probes

The CBL contains provisions for the AutoIDENT probe resistor values listed below. A Conversion Equation is loaded automatically for some of the AutoIDENT values.

CH1, CH2, and CH3			
IDENT Value1	**Probe Type**	**Operation Default**	
33K	TI Voltage probe	**2**	±10 Volts (CH1 or CH2)
6.8K	Current probe[2]	**3**	±10 Amps (CH1 or CH2)
3.3K	Resistance probe	**4**	1K to 100KΩ
10K	TI Temperature probe[3] for °C	**10**	-20°C to 125°C
15K	Temperature probe for °F	**11**	-4°F to 230°F
4.7K	TI Light probe	**12**	10µW/cm^2 to 1mW/cm^2
47K	Voltage probe	**14**	0 to 5 Volts

[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 to convert current to voltage; this must be done in the external probe.

[3] Default value for the TI Temperature probe is °C.

AutoIDENT Probes (Continued)

CH11 (SONIC)		
IDENT Value1	**Probe Type**	**Operation Default**
15K	Motion detector, meters	**2**
10K	Motion detector, feet	**3**
22K	Motion detector, meters	**2**

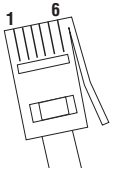
[1] IDENT values are resistance values in ohms (tolerance ±5%).

Designing Custom Probes

To connect custom-designed probes or other circuits to the analog input channels, the digital input channel, or the digital output channel on the CBL, you can purchase an analog probe kit, or a digital probe kit from TI or its Instructional Dealers. (Refer to page 87 for ordering information.)

Each probe kit includes a four-foot length of telephone cable and a connector attached to one end. The other end of the cable is not terminated.

Be very careful when designing a custom probe 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 on the figure at the right.



If you design a resistance-type probe, connect pin 3 (Vres) to pin 6 (Vin-low) (refer to “Connector Pinouts” on the next page). 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 CMD1 (page 28) is set to 2, 3, 5 or 6, the data is measured on the Vin pin (pin 1). The data for Operations 1, 4, 10, 11, 12, and 14 is measured on the Vin-low pin (pin 6).

Note: The most current that can be drained from all three analog channels is 120 mA. Power to the channels is shut off when the total current drain out of the channels reaches 120 mA. A POS (power-on short) error message is displayed (page 57).

Connector Pinouts

The connectors on the probes used on the CBL are 6-pin, British Telecom-style connectors.

Pin	CH1, CH2, CH3	SONIC	DIG IN	DIG OUT
1	Vin (CH1, CH2 only)	Echo	Clock-In	Clock-Out
2	Gnd	Init	Gnd	Gnd
3	Vres	AutoIDENT	D0 In	D0 Out
4	AutoIDENT	+5 Volts DC	D1 In	D1 Out
5	+5 Volts DC	Gnd	D2 In	D2 Out
6	Vin-low	n/a	D3 In	D3 Out

	Vin	Vin-low
Channels:	CH1 and CH2 only	CH1, CH2, CH3
Input signal:	Analog data	Analog data
Input range:	±10 Volts	0 to 5 Volts
Resolution (using CBL's 10-bit A/D converter):	19.6 mV	5.6 mV
Input impedance:	740KΩ to 2.0 Volts	748KΩ to 0.03 Volts

Note: Due to a floating internal reference voltage, it is normal for the CBL to measure about 30 mV (Vin-low) or 2.0 Volts (Vin) when no input is connected.

- **Vres:** Output reference voltage from the CBL 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).
- **AutoIDENT:** AutoIDENT probe detection data input. (AutoIDENT resistor connected from pin 4 to ground.)
- **Echo:** Ultrasonic motion detector input.
- **Init:** Distance initialization signal
- **Clock-In:** External digital input clock.
- **D0 In** to **D3 In:** Input pins for digital input pulses.
- **Clock-Out:** Digital output clock.
- **D0 Out** to **D3 Out:** Output pins for digital output pulses (refer to the example on page 69).

CMD4 Type, Form, and Restrictions

The conversion equations listed in CMD4 (page 47) have certain computational limitations. In particular, some operations are not defined for negative arguments.

The overall accuracy of the CBL does not guarantee that a precisely zero volt input will not be read as a slightly negative number. Therefore, if you are using a conversion equation that has this limitation, use input voltages with minimum values above zero.

If an equation encounters an error, e.g., division by zero or a power of a negative number, that operation causes an overflow value (9.9E31) to be carried in the computation. The end result will likely be a very large value. This allows the sampling process to continue without interruption, but extremely large results (9.9E99) should be interpreted as an indication that the restrictions listed below have been violated.

Equation Type		Equation Form	Restrictions
1	Polynomial (order: n=1–9)	$K_0 + K_1X + K_2X^2 + ... + K_nX^n$	*
2	Mixed polynomial (order: m=0–4, n=0–4, m+n>0)	$K_{-m}X^{-m} + ... + K_{-1}X^{-1} + K_0 + K_1X + ... + K_nX^n$	X≠0
3	Power	$K_0X^{(K1)}$	X>0
4	Modified power	$K_0K_1^{(X)}$	$K_1 \geq 0$
5	Logarithmic	$K_0 + K_1\ln(X)$	X>0
6	Modified logarithmic	$K_0 + K_1\ln(1/X)$	X>0
7	Exponential	$K_0\, e^{(K1X)}$	*
8	Modified exponential	$K_0\, e^{(K1/X)}$	X≠0
9	Geometric	$K_0\, X^{(K1X)}$	X≥0
10	Modified geometric	$K_0\, X^{(K1/X)}$	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

*No restrictions other than overflow.

Trigger Location Point

When a trigger and a nonzero prestore percentage are used, it may not be obvious where the trigger point occurred. The following will help you determine the precise location of the trigger point.

Prestore %	Trigger Point
0	The first sample in the list will always be the first sample after the trigger point.
100	The last sample collected by the CBL will always be the first sample after the trigger point.
1 to 99	The first sample after the trigger point is identified by the following equation: $$T = L - N + int\left(\frac{PN}{100}\right) - B + 2$$ where: T = The location in the list retrieved from the CBL of the first sample after the trigger event. L = The actual length of the list returned by the CBL (see next page). N = The number of samples requested in CMD3 (an integer from 1 to 512, but only 1 to 99 is recommended for the TI-82). P = The prestore percent requested in CMD3 (an integer from 1 to 99). B = The Data Begin specified in CMD5 (usually this is 1, but can be changed by CMD5 to be an integer from 1 to 512). int(*PN/100*) means the integer portion of the number in the parenthesis.

How It Works

Due to sampling times and the input signal, the first sample after the trigger point may not occur at the exact trigger point. The sample taken could be up to one sample time after the trigger point.

If a nonzero prestore is requested, the length of the list returned by the CBL may not equal the number of samples requested. The CBL guarantees that the number of poststore points derived from the prestore parameter will always be taken; however, the number of prestore points varies depending on the timing of CMD3 and the occurrence of the trigger event. There may not be enough time between these two events to collect all the prestore samples requested.

Because the some calculators, such as the TI-82, only returns lists up to 99 elements, determining the actual length of the list collected by the CBL is difficult unless the number of samples requested is 99 or less. If CMD5 is used to change the data range, the *T* computed on the previous page could be outside the list retrieved from the CBL.

Resistance and Temperature Measurement Accuracy

To obtain accurate resistance measurements, when data is collected for several minutes, use an external power adapter.

The CBL uses the battery voltage as a reference when you are measuring resistance to take temperature readings. The voltage is measured at the beginning of sampling and used until sampling is complete (DONE indicator is lit on the display).

The accuracy of your collected data will be affected if there is any change in the battery voltage during data collection. The external power adapter will maintain a constant voltage level for the CBL.

Note: Do not connect an external power adapter to the CBL when the SAMPLING indicator is lit on the CBL display. This would change the operating voltage during the measurement and affect the accuracy of the collected data.

Maximum Sample Rate for Real-Time Data Collection

For real-time display of collected data, the Number of Samples parameter is set to $^{-}1$ (see "Number of Samples" on page 40). The maximum sample rate is then, in part, determined by the speed of execution of the calculator program. The maximum rate using various calculators will be about 10–14 points per second (0.1–0.07 seconds between samples).

Refer to the *CBL™-Compatible Calculators Guidebook* or the TI web site at **www.ti.com/calc/docs/sgraph** for information specific to your calculator.

Note: In the case of real-time data collection, any value entered for the Sample Time parameter that is less than or equal to 0.20 causes the CBL to collect data at this maximum rate.

Improving Data Collection Accuracy Using Pause

When the sample time specified in CMD3 is faster than 0.003 seconds, sample events can be affected by the CBL having to respond to a **Get(**, **GET** or **Input "CBLGET"** instruction from a calculator.

If Record Time is on, discrepancies will be found in the collected data. This is because the CBL is actively communicating with the calculator when a **Get(**, **GET**, or **Input "CBLGET"** instruction is executed immediately after receiving a **Send(**, **Send {**, or **Outpt("CBLSEND"** instruction that contains a CMD3.

To ensure that valid sampling and triggering occurs, you should put a **Pause** instruction immediately after a **Send(**, **Send {** or **Outpt("CBLSEND"** instruction when the **Send(**, **Send {** or **Outpt("CBLSEND"** instruction contains a CMD3. When sampling is complete (DONE indicator is on), press [ENTER] on the calculator to execute the next instruction of the program.

Clock-In Line Operation

A low-going pulse (5–0 Volts) on the External Clock-In line (part of the DIG IN channel) is used for an external clock. This signal is only recognized as a sample clock when the Sample Time and External Clock Source parameters in CMD3 are both set to zero.

Data from the DIG IN channel may be read based on the internal sampling clock, and does not require the use of the External Clock-In line. Conversely, the External Clock-In line can be used to control the sampling time for signals on the other channels.

Clock-Out Line Operation

At each sample time, the External Clock-Out line (part of the DIG OUT channel) goes low for about 3 microseconds. The digital output lines change to the next value and are valid when the External Clock-Out line returns high.

The Clock-Out line provides the low-going 3-microsecond pulse on all sample events (not just the events associated with DIG OUT operation), except for certain conditions when the sample time is less than 0.00020 seconds. This allows the signal to be used to "slave" additional CBLs by connecting to their external Clock-In lines. However, care should be taken to make sure circuits connected to the DIG OUT channel are not confused by these clock pulses if other channels are actively sampled.

Digital Output Buffer

The Digital Output Buffer (DOB) is a circular buffer that contains up to 22 data elements. The output from the DOB is a 4-bit (TTL 0–5 Volts) digital *nibble* (refer to "Digitial Nibble" in the Glossary, if necessary) for each data element. For example, 0 = 0000, 1=0001, 2=0010, 10=1010, 15=1111. One digital nibble appears at DIG OUT on the D0–D3 lines at each sample time. (Refer to the diagram below.)

The drive (output current) capability for *nibble* data and the clock is shown by the following:

- $V_{output\text{-}high} > 3.98$ Volts @ $I_{output\text{-}high} > {}^{-}6$ma (negative current flow out of the CBL)
- $V_{output\text{-}low} < 0.26$ Volts @ $I_{output\text{-}low} < 6$ma (positive current flow into the CBL port)

The number of times that the DOB outputs the contents of the buffer depends on the number of data elements defined in CMD1 and the number of samples defined in CMD3.

Digital Output Buffer Example

CMD1 list is {1,31,5,1,2,3,4,5}, where:

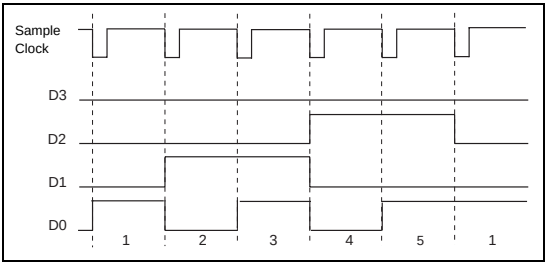
1=Channel Setup.
31=DIG OUT.
5=Five data elements.
1=0001 (digital nibble).
2=0010 (digital nibble).
3=0011 (digital nibble).
4=0100 (digital nibble).
5=0101 (digital nibble).

CMD3 list is {3,1,100}, where:

3=Sample and Trigger Setup.
1=One second sample time.
100=One hundred samples.

(Trigger Type defaults to manual triggering.)

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.



Determining the Minimum Sample Time

Different minimum sample times apply depending on what is currently active on the CBL. Several conditions that affect minimum sample times are: number of active channels, what is being measured, status of record time, Statistics post-processing, etc.

For the table below, the following rules apply:

- For conditions 1–4, the largest sample time applies regardless of how many other conditions are active.
- For conditions 5–7, and no condition 1 through 4 active, add the minimum sample time for each active item.

Condition	Minimum Sample Time (in Seconds)
1. Period/Frequency measurement	0.25
2. SONIC channel	0.008 (see note below)
3. Statistics post-processing = on	0.0030
4. Manual Trigger or Manual and Sample Trigger = on	0.0006
5. Number of active channels	add 0.00010 for each channel (100 µsec)
6. Record Time = on	add 0.000064 (64 µsec)
7. DIG IN or DIG OUT = on	add 0.000080 (80 µsec)

Minimum Sample Time Examples

Active Elements	Minimum Sample Time
CH1 active, everything else is off	0.00010 (Condition 5.)
CH1, Frequency	0.25 + 0.00010 = **0.25** (Conditions 1 and 5, but 1 is largest value.)
CH1, CH2, Manual Trigger	0.00010*2 + 0.0006 = **0.0006** (Conditions 4 and 5, but 4 is largest value.)
CH1, CH3, Record Time, DIG IN	0.00010*3 + 0.000064 + 0.000080= **0.000444** (Add Conditions 5, 6, and 7.)

Note: The actual minimum sample time for the SONIC channel is dependent on the motion detector that you use. Consult your motion detector documentation for actual minimum sample time allowed.

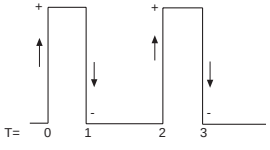
Hardware Triggering

When you set hardware triggering to trigger on a specific voltage, the CBL selects one of seven voltage levels as the trigger point. These voltage levels are established by the Trigger Threshold parameter and are shown in the table below.

Trigger Level	Threshold Parameter
-5.0 Volts	-10.0 ≤ Vthresh < -2.45
-1.0 Volts	-2.45 ≤ Vthresh < -0.35
-0.2 Volts	-0.35 ≤ Vthresh < -0.05
0.0 Volts	-0.05 ≤ Vthresh < 0.05
0.2 Volts	-0.05 ≤ Vthresh < 0.35
1.0 Volts	-0.35 ≤ Vthresh < 2.45
5.0 Volts	-2.45 ≤ Vthresh ≤ 10.0

Software Triggering

When you select software triggering, data collection begins on either the rising edge or falling edge of the signal (see figure below) depending on the Trigger Type and Trigger Threshold selected. Note that Trigger Types 2 and 4, and 3 and 5 start triggering on the same edge.

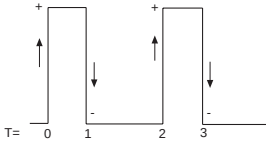


Trigger Type	Triggering Point
2 or 4	+ + or + − (T=0, 2,...)
3 or 5	− − or − + (T=1, 3,...)

Measuring Period and Frequency

Period and frequency apply only to CH1 and only CH1 can be active if 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 measures period and frequency by counting edges for 0.25 seconds, or 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.



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 is set up using CMD3 to make multiple measurements at a particular sample time, the CBL 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 nonrepetitive signals or on repetitive signals that are less then 600 Hz. This is because at 600 Hz, the edge counts will prevail.

Measuring Period and Frequency (continued)

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	Trigger Threshold parameter	Trigger Threshold parameter
6	Not allowed (E.34 error).	
1*nnnn*	Rising (+)	n/a

Example: Measuring Frequency

Assume a frequency measurement is requested on CH1, and 20 measurements are desired at a 500-millisecond sample time. The following commands would set up the CBL for this example:

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

where: 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 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 takes approximately 15 seconds to complete all the sampling and turn on the DONE indicator in the display.

Asynchronous/ Synchronous Triggering vs. Record Time

Actual triggering is asynchronous from the internal sampling clock for either of the following:

- Trigger Type in CMD3 is set to 1 or 6 (manual triggering).
- Trigger Channel in CMD3 is set to 21 (external clocking using 1 of 7 hardware trigger values) and Sample Time is not 0.

The actual sample time for the trigger point depends on whether or not prestore is selected in CMD3.

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 TRIGGER or the hardware threshold trigger event).

When Trigger Type is set to 6 (Manual and Sample Trigger) in CMD3, the recorded sample times are the actual relative times when TRIGGER 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 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 21 (hardware threshold triggering).
- Trigger Threshold is set to 1.0 and Trigger Type is set to 2 (trigger on rising edge).

The CBL 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,...}.

Appendix B: Command Tables

The tables in this section provide a quick reference to CBL commands. Default values appear in boldface type.

Contents

CMD1 Syntax and Parameters

{1,*channel_number*,*operation*,*post_processing*,*statistics*, *conversion*}

Channel	Operation	Post-Processing	Statistic Samples	Conversion Equation
1–3 = Analog (0 = Clear all channels)	0 = Clear channel **1= AutoIDENT or Voltage (0–5V)** 2= Voltage (±10V)[1] 3= Current (±10A)[1] 4= Resistance (1K–100KΩ) 5= Period (0.000004 sec to 50 sec)[2] 6= Frequency (0.02Hz–250KHz)[2] 10= Temperature (⁻20°C–125°C) 11= Temperature (⁻4°F–230°F) 12= Light (10µW/cm^2 to 1mW/cm^2) 14= Voltage (0–5V)	**0 = None** 1= d/dt 2= d/dt and d^2/dt^2 3= Stats (mean, standard deviation, minimum, maximum)	**0= n/a** 1 = error 2–512 (**10**) Applies only when post-processing = 3 (Statistics)	**0 = Off** 1= On
11= Sonic	0 = Clear channel **1= AutoIDENT or Meters** 2= Meters 3 = Feet	**0 = None** 1= d/dt 2= d/dt and d^2/dt^2 3= Stats (mean, standard deviation, minimum, maximum)		

[1] Applies only to CH1 and CH2.

[2] Period and Frequency apply only to CH1, and only CH1 can be active if Operation = 5 or 6.

CMD1 Syntax and Parameters (Continued)

Channel	Operation
21 = Digital In	0 = Clear channel **1 = Active**

Channel	Number of Data Elements	Data Elements
31 = Digital Out	0 = Clear channel **1**–22	**0**–15[3]

[3] Data Elements is a 4-bit *nibble*: 0=0000, 1=0001, 2=0010, ..., 15=1111

CMD2—Data Type and Display Setup

CMD2 Syntax and Parameters

{2,*data*,*display*,*picY*,*Ymin*,*Ymax*,*picX*,*Xmin*,*Xmax*}

Data Type	Data Display Channel	PicY Channel[1]	Ymin[1]	Ymax[1]	PicX Channel[1]	Xmin[1]	Xmax[1]
1 = List 2 = Matrix 3 = Picture	**0**, 1–3, 11, 21 (default is lowest channel number setup)	**1**–3, 11, 21	**-10** Real	**10** Real	**0** = 1 to # samples[2] 1–3 = Channel # -1 = Record time[3]	**1** Real	**512** Real

[1] PicY and PicX parameters only apply when Data Type is 3 (Picture).

[2] Collect X data from 1 to the number of samples defined in CMD3 from the specified Y channel.

[3] Collect X data as the recorded time selected in CMD3.

CMD3 Syntax and Parameters

{3,*sample_time*,*number_samples*,*trigger_type*,*trigger_channel*, *trigger_threshold*,*prestore*, *external_clock*,*record_time*,*filter*}

Sample Time (sec)	Number of Samples[2]	Trigger Type[3]	Trigger Channel
0.5 0 = External clock Range[1] .00010–.2 .25–16000	**1**–512 ⁻1 causes continuous data collection following each Get(or Input "CBLGET" instruction.	0= None **1= Manual** 2= + + 3= – – 4= + – 5= – + 6= Manual trigger and sample 1*nnnn* = digital nibble, where: *n*= 0,1 is data, *n*= 2–9 is don't care.	0= n/a **1**–3, 21 1–3= Analog Input 21= External Clock[3]

Trigger Threshold[4]	Prestore Data %	External Clock Source	Record Time	Filter[5]
0 = N/A if trigger = 0, 1, 6, or digital *nibble*. **1V, 1A, 1KΩ** if Trig. Type = 2, 3, 4, 5, and Trig. Channel = 1, 2, 3, 21. ⁻10 to 10 Volts if volts selected. ⁻10 to 10 Amps if current selected. 1 to 100 Kohms if resistance sel.	**0**–100%	**0= External clock** 1= Analog input, CH1	**0= None** 1= Absolute 2= Relative	**0**–6

[1] Range restrictions apply. (See "Sample Time" on page 51, and Appendix A, "Determining the Minimum Sample Time.")

[2] Limit is 256 if Stats is selected in CMD1.

[3] If the trigger type is a digital nibble, CH21 is automatically selected as the trigger channel regardless of value enter for Trigger Channel.

[4] The trigger threshold for period and frequency is limited to 7 levels (5.0, 1.0, 0.2, 0, ⁻0.2, ⁻1.0, ⁻5.0 for voltage and corresponding values for current and resistance). The trigger threshold in the setup string is rounded to the nearest value.

[5] If CH31 or Stats is requested, or number of samples is ⁻1, the default (no filtering) is used.

CMD4 Syntax and Parameters

{4,*equation_number*,*equation_type*,*equation_order*,*constant*, *units_display*}

Equation #	Equation Type	Equation Order	Constants	Units Display
0 = Clear all equations 1–4 = Equation number	**0= Clear specific equation** 1= polynomial 2= mixed polynomial 3= power 4= mod. power 5= logarithmic 6= mod. logarithmic 7= exponential 8= mod. exponential 9= geometric 10= mod. geometric 11= reciprocal logarithmic 12= Steinhart-Hart model	integers (*m,n*): 0,1, or 2 integers per model *Only applies to equation types 1 and 2; this field omitted for equation types 3–12.	real $K_0 ... K_n$ (type 1) $K_{-m} ... K_n$ (type 2)	**0= None** 1= °F 2= °C 3= K

Equation Type		Equation Form	Restrictions
1	Polynomial (order: n=1–9)	$K_0 + K_1X + K_2X^2 + ... + K_nX^n$	*
2	Mixed polynomial (order: m=0–4, n=0–4, m+n>0)	$K_{-m}X^{-m} + ... + K_{-1}X^{-1} + K_0 + K_1X + ... + K_nX^n$	X≠0
3	Power	$K_0X^{(K_1)}$	X>0
4	Modified power	$K_0K_1^{(X)}$	$K_1 \geq 0$
5	Logarithmic	$K_0 + K_1\ln(X)$	X>0
6	Modified logarithmic	$K_0 + K_1\ln(1/X)$	X>0
7	Exponential	$K_0\, e^{(K_1X)}$	*
8	Modified exponential	$K_0\, e^{(K_1/X)}$	X≠0
9	Geometric	$K_0\, X^{(K_1X)}$	X≥0
10	Modified geometric	$K_0\, X^{(K_1/X)}$	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

* No restrictions other than overflow.

CMD5—Data Range Setup

CMD5 Syntax and Parameters

{5,*channel*,*data_select*,*data_begin*,*data_end*}

Channel Select	Data Select	Data Begin	Data End
0 = lowest active channel 1–3, 11, 21 ⁻1 = record time	**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)	**1**–512	**0**–512 (0 = get last sample)

Notes: Data Select = 0, 1, 2; filtered if Filter = 1–6 in CMD3.
Data Select = 3, 4, 5; ignore filter setting in CMD3.
Data End must be *greater* than or equal to Data Begin (unless Data End = 0), and both must be *less* than or equal to the number of samples sent to the CBL in the last CMD3.

CMD6—Multimeter Mode Setup

CMD6 Syntax and Parameters

{6,*set_reset*,*operation*}

Set/Reset	Operation
1= Set to multimeter mode 0 = Restore to communications mode	**1 = AutoIDENT** or **voltage (0–5 volts)** 2= Voltage (±10V) 3= Current (±10A) 4= Resistance (1K–100KΩ) 5= Period (0.000004 sec to 50 sec) 6= Frequency (0.02 to250KHz) 7= Meters 8= Feet

Note: Operations Meters and Feet apply only to CH11 (SONIC).

CMD7—Request Status

(Refer to page 53.)

Appendix C: Service and Warranty Information

This appendix contains information about batteries, and service and warranty information.

Contents

Operating Power Requirements

The CBL is designed to operate with four AA alkaline batteries.

Factors that affect battery life are the actual time that the CBL is on and the amount of current used by connected probes during your experiments. The display contains a low-battery icon (LOW) to let you know when these batteries should be replaced.

To extend battery life in the classroom we recommend that you use the approved power adapter.

For extended experiments out of the classroom, when more battery power is needed, you can connect an external 6-Volt lantern battery to the CBL .

When to Replace Batteries

The four AA batteries should be replaced at least once each year to prevent damage from leaking batteries, or when the low-battery icon (LOW) is displayed—whichever comes first. The low-battery icon is displayed when the internal battery voltage drops to 4.5 Volts. (Refer to "Installing the AA Batteries" on page 11.)

Note: Save any collected data before removing batteries. All CBL setup information and all collected data is lost if the batteries are removed and the optional AC adapter is not connected to the CBL.

Recommended Batteries

- Four 1.5-Volt size AA alkaline batteries.
- One 6-Volt lantern type. Recommended for experiments performed outside the classroom that draw large amounts of current (e.g., when using a motion detector).

Installing the AA Batteries

1. Holding the CBL upright, push the latch on the battery cover down with your finger and pull the cover out.
2. Replace all four AA alkaline batteries. Be sure to position them according to the diagram inside the battery compartment.
3. Replace the cover, and then press [ON/HALT] to turn the CBL on.

Connecting an Optional AC adapter

1. Press [2nd] [OFF] to turn the CBL off.
2. Connect one end of the approved adapter to the external power input connection located on the right bottom edge of the CBL.
3. Plug the other end of the adapter into an electrical wall outlet.
4. Press [ON/HALT] to turn the CBL on.

Approved AC Power Adapter

The CBL is designed to accept voltage input from an external AC-to-DC power adapter that provides a regulated 6 Volts DC output when plugged into an electrical wall outlet.

The Texas Instruments model AC-9201 power supply is the only AC-to-DC power adapter approved for use with the CBL. The use of other power adapters is strongly discouraged.

AC9201 AC9201E AC9201/UK

To order the adapter, call Customer Support at:

1-800-TI-CARES (1-800-842-2737)

Building an External Battery Adapter Cable

To build an external battery adapter cable, you will need a connector, 16-gauge wire (about 6 feet), and two alligator clips.

Note: At the time of this printing, the Radio Shack Coaxial DC Power Plug #274-1569 (5.5mm O.D., 2.1mm I.D.) or equivalent is an acceptable connector.

1. Identify one 3-foot length of the wire as black (ground) and solder it to the insulated pin of the connector.
2. Identify the other 3-foot length of wire as red and solder it to the outside of the connector.
3. Connect an alligator clip to the open end of each wire.

Connecting an External 6-Volt Battery

1. Press [2nd] [OFF] to turn the CBL off.
2. Connect one end of the external battery adapter to the external power input connection located on the right bottom edge of the CBL.
3. Connect the red lead to the positive (+) terminal of the battery. Connect the black lead to the negative (–) terminal of the battery.
4. Press [ON/HALT] to turn the CBL on.

Problem	Possible Cause/Recommended Solution
CBL does not turn on, display is blank.	Inspect battery compartment. Ensure batteries are correctly installed (page 84). Replace batteries. Press [ON/HALT] to turn the CBL on. If available, connect an optional AC adapter.
CBL not communicating with a calculator.	Ensure CBL is turned on and the connecting cable is firmly seated (page 11). Press [ON/HALT] to abort any pending operation. Check calculator program for correct instructions and syntax used to send commands to the CBL and to retrieve data from the CBL. Make sure CBL is not in Multimeter mode (MULTIMETER indicator on) or in Internal mode (INTERNAL indicator on). CBL must be in Communications mode to receive commands from the calculator (page 22).
Calculator plotting previous collected data instead of new data.	The CBL and the calculator are not communicating. They may not be properly connected. Refer to the previous item above.
Nothing happens when [TRIGGER] is pressed.	Manual trigger or Manual and Sample trigger option not selected. Check Trigger Type parameter (4th field) in the CMD3 setup list (page 40). CBL not in the READY state (page 22). CMD3 not received by CBL.
Measured temperatures exceed the stated temperature range (–20ºC to 125ºC).	Temperature probe is not operating correctly. A shorted thermistor or broken Vres wire causes a very high reading (e.g., 300ºC) or an overflow. An open circuit at the thermistor can also cause an overflow in addition to very low (e.g., ⁻273ºC) and inconsistent temperature readings.

For Service and General Information

If you have questions about service or about the general use of your CBL, please call Customer Support toll-free at:

1-800-TI-CARES (1-800-842-2737)

Hours: 8:00 AM–4:30 PM CST on Monday–Thursday
10:00 AM–4:30 PM CST on Friday

Please contact Customer Support:

- Before returning the product for service.
- For information on our express service option for fast return delivery.
- For information about available documentation
- For information about purchasing related products.

For Technical Information

If you have technical questions about the installation or use of the CBL, you can call the Technical Support Group of Customer Support at:

1-972-917-8324

Hours: 8:00 AM–4:30 PM CST on Monday–Thursday
10:00 AM–4:30 PM CST on Friday

Please note that this is a toll number, and collect calls are not accepted.

You may also use E-mail.

ti-cares@ti.com

Online Information

Texas Instruments offers online assistance via the Internet—a World Wide Web site for product information and service assistance, and an anonymous FTP site for downloading files.

http://www.ti.com/calc

ftp://archive.ppp.ti.com/pub/graph-ti

Probe Kit Part Numbers

To order probe kits from TI, refer to the TI part numbers in the table below, and call:

1-800-TI-CARES (1-800-842-2737)

Probe Kit	TI Part Number
Analog probe kit	9791694-0001
Digital probe kit	9791698-0001

This Texas Instruments warranty extends to the original consumer purchaser of the product.

Warranty Duration

The hardware (cable and adapters) provided with this product is warranted to the original consumer purchaser for a period of one (1) year from the original purchase date.

Warranty Coverage

Such hardware is warranted against defective materials or workmanship. **This warranty is void if the product has been damaged by accident, unreasonable use, neglect, improper service, or other causes not arising out of defects in material or workmanship.**

Software Warranty

Software programs are not warranted. For information regarding the software media warranty, please refer to the program license agreement.

Warranty Disclaimers

Any implied warranties arising out of this sale, including but not limited to the implied warranties of merchantability and fitness for a particular purpose, are limited in duration to the above one-year period. Texas Instruments shall not be liable for loss of use of the product or other incidental or consequential costs, expenses, or damages incurred by the consumer or any other user.

Some states do not allow the exclusion or limitations of implied warranties or consequential damages, so the above limitations or exclusions may not apply to you.

Legal Remedies

This warranty gives you specific legal rights, and you may also have other rights that vary from state to state.

Warranty Performance

During the above one-year warranty period, a defective TI product will be either repaired or replaced with a reconditioned comparable product (at TI's option) when the product is returned, postage prepaid, to a Texas Instruments Service Facility.

The repaired or replacement product will be in warranty for the remainder of the original warranty period or for six months, whichever is longer. Other than the postage requirement, no charge will be made for such repair or replacement. Texas Instruments strongly recommends that you insure the product for value prior to mailing.

Active Channel

One or more channels that have a connected probe and have been initialized by CMD1.

AutoIDENT

Identifies the type of probe connected to a channel and automatically sets up the channel with predefined default values.

Channel (physical)

An input or output connection on CBL.

Channel (parameter)

An integer value in the Channel Setup command that defines the channel to initialize.

Command

An instruction sent from a calculator that controls the CBL.

Conversion Equation

A parameter in the Channel Setup command that converts the physical unit measured by the CBL into a more useful measurement unit.

Data Begin

A parameter in the Data Type and Display Setup command that specifies the starting sample number to be returned to the calculator.

Data End

A parameter in the Data Range Setup command that specifies the ending sample number to be returned to the calculator.

Data Display Channel

A parameter in the Data Range Setup command that determines which channel's data to display on the CBL.

Default Values

Preset values in an input setup string that take effect in the absence of user-defined parameters.

Digital Nibble

A nibble is a 4-bit digital binary group. There are two nibbles to an 8-bit digital byte, and two bytes to a 16-bit digital word.

Done

The state of the CBL in which data collecting has ceased and data is ready to be sent to the calculator.

Filter

A parameter in the Sample and Trigger Setup command that defines the kind of noise filtering to perform during data collection.

Mode

One of three operating modes of the CBL communications, multimeter, or internal.

Operation

A parameter in the Channel Setup command that defines what the channel is to measure, e.g., voltage, resistance, frequency, etc.

Post-Processing

A parameter in the Channel Setup command that defines the type of processing to perform on the data after it is collected.

Prestore Sample

A parameter in the Sample and Trigger Setup command that specifies the percentage of data samples to collect before the trigger event occurs.

Ready

The state of the CBL immediately after a Sample and Trigger Setup command is sent from the calculator. The CBL is ready to collect data.

Record Time

A parameter in the Sample and Trigger Setup command that specifies whether CBL records absolute or relative time during data collection.

Statistic Samples

A parameter in the Channel Setup command that defines the number of samples to collect per computed Statistic point when Statistics Post-Processing is selected.

Trigger Channel

The channel that is initialized to sense the trigger event or condition.

Trigger Threshold

A parameter in the Sample and Trigger Setup command that defines the required input level where triggering begins.

Trigger Type

A parameter in the Sample and Trigger Setup command that defines the event or condition that causes data collection to begin.

Index