LabPro®

Technical Reference Manual

Revision Date: 08/02/02

Contents

About This Manual

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

We have created and have available for download from our web site starter software for REALbasic (Macintosh), Visual Basic 6 for Windows and LabView for Windows, Macintosh and Linux/X-Window.

Most people who use LabPro do not need to refer to this manual. Instructions for using LabPro with the DataMate calculator program or app are given in ***Getting Started with LabPro***, which is included in LabPro package. Instructions for using LabPro with the Logger Pro computer program are in the Logger Pro manuals and help files. Again, this manual is only needed if you are writing your own programs.

LabPro can be used to collect data or to control digital or analog lines when connected to either computers or Texas Instruments calculators. The commands sent to LabPro and the results returned from LabPro are usually the same, no matter what kind of computer or TI calculator is used. In this manual we will use the term "host" to refer to either calculator or computer used to control LabPro. In a few cases, the commands are different on calculators, and we will use the term "calculator".

If you plan to use LabPro with Texas Instruments calculators, this manual assumes that you are somewhat familiar with the calculator, and the use of TI-GRAPH LINK™ for transferring programs from a computer to the calculator. If you are not, we encourage you to look over TI-GRAPH LINK, TI Connects, and calculator manuals for this information.

If you plan to use LabPro with your own computer software, this manual assumes that you are somewhat familiar with the computer, the programming environment, and how the serial or USB port of the computer is controlled. If you are not, we encourage you to look over other hardware and software manuals for this information.

Introduction

LabPro is a small handheld computer dedicated to the task of data collection and control of output lines. It contains a microprocessor that can communicate with a host calculator or computer. By using the command set documented in this manual, the host (computer or calculator) can customize the parameters of the data collection or control to suit specific applications.

LabPro contains different types of on-board memory; ROM and FLASH RAM. The ROM contains the most fundamental functions that allow LabPro to begin operation and load its operating system. The operating system is stored in the 8Mbits of FLASH memory. Having the operating system in FLASH memory provides the flexibility of future upgrades and feature enhancements. The FLASH memory is also used to store programs such as the DataMate calculator program. The FLASH memory has a user accessible portion that may be used for long term data storage or other programs.

LabPro has no ON/OFF switch. Instead, it uses an on-board power controller. When the LabPro goes into an IDLE state, it automatically enters a micro power mode. Any outside stimulus, such as activity on any of the communication ports or a button press will cause LabPro to "wake up" and return to a normal power state. When collecting data slowly, LabPro will power down unused elements in order to maintain a low power state between sample points.

The LabPro has three methods for communicating with a host; through the GraphLink port at the bottom of the device, through the RS-232 port or through the USB (version 1) port. Only one of these ports may

be used at a time. The GraphLink port is used almost exclusively with a TI Graphing calculator while the USB and RS-232 ports are used with a computer.

LabPro has six interface ports for data collection. The ports labeled CH1 through CH4 are used to collect analog data from sensors such as temperature, pH, force etc. The ports labeled DIG/SONIC1 and DIG/SONIC2 are used to collect digital data from such sensors as photogates, motion detectors, radiation monitors, and rotary motion sensors. LabPro may also be used to control 8 digital output lines and one analog output line (see connector information for pin assignments).

Programming LabPro

Programming of LabPro consists of sending a series of commands to configure the desired operation. There are a few dozen commands to control LabPro and request its status. Within a program, different commands are used to set up the number of active channels, rate of data collection, quantity of data collected, and how data is to be processed. Since the command set is rather extensive, this manual will detail some building blocks to illustrate how the commands are used within the context of a program.

Each command consists of a series of numbers that are sent to the LabPro. For example, the data rate for data collection is set with a Command 3, like this:

3,1,1,0

If you are using a TI calculator to write the programs, you typically store the data in a list and then send it to LabPro. If you are using a computer to control LabPro, you send these commands to LabPro using either the serial or USB port. Refer to the Calculator Programming and Computer Programming sections of this manual.

While error checking and command parsing are built into LabPro, it is preferred that the program use the commands as defined. That is to say, do not terminate commands in midstream. Complete requests for data by retrieving requested data prior to sending a new command. In general, attempts to keep a synchronous command/response sequence intact will add to the reliability of the design.

Program Structure

Programs for data collection with LabPro usually follow this basic pattern:

- Initialize LabPro
- Activate Channels from which data is to be collected.
- Define and Initiate data collection mode.
- Retrieve data from LabPro.

Initialization

Initialization takes place whenever the data collection settings need to be changed. The command used to search for an attached LabPro is Command 7 (status command). Besides indicating if a LabPro is attached, it provides valuable information regarding current status of the attached LabPro unit. Upon launch of the program it may be particularly important to search for LabPro by only using a Command 7. This is due to the fact that there may be data in the buffer from a previous experiment that needs to be accessed prior to reset and setup commands being sent.

In order to clear all settings, send a reset, 0 command. This command clears data collection RAM, channel assignments and data collection modes that are currently assigned in LabPro. This is a good first step to put LabPro into a known state before configuring the channels. However, this is not to say that a reset should always be sent to LabPro. In fact, since reset clears previous data, it is important to send reset only when you are sure the user is done with the current configuration and data.
Example:

```
7              //Ask for status from LabPro
Get response   //Evaluate response
0              //Reset LabPro to prepare for channel activation etc.
```

Channel Activation

In order to collect data from LabPro, the program must activate one or more channels. The channel setup commands (Command 1 and Command 12) provide a means by which the program configures LabPro to collect data from certain ports. This part of the program is where the channels are activated, calibration equations are loaded and post-processing options are set. Channel activation tells LabPro which ports are active and how to collect data from that port. Calibration equations are used to convert the raw voltage reading to units specific to the sensor connected to the port. Post processing options further process the data prior to returning the information to the host.

Data Collection Modes

Once LabPro has been initialized and the channels have been activated, the data collection details must be programmed. Data may be collected and returned in several different formats depending on the host. However, there are two basic modes of data collection, real time (RT) and non-real time (NRT). These terms are a little misleading in that data is always collected in real time. The modes differ in how data is stored in and retrieved from LabPro.

In RT data collection, data is collected at regular intervals and available to the host on a point by point basis. Data collection begins after LabPro has processed the command. Only the most recent point is stored in LabPro. If the program does not ask for the data often enough, data could be lost. In this mode, data collection is performed as part of the main processing loop. Therefore, other tasks and processing will determine when an opportunity for data collection occurs. LabPro attempts to take data as close as possible to the programmed time interval. The accurate time between samples is reported back for each data point. This is usually within 100 ms of the requested time. LabPro continues taking data until the host stops data collection or resets the unit. This mode is useful for relatively slow time-based data collection where an unlimited number of data points is necessary; such as a scrolling strip chart recorder.

In NRT data collection, data is collected at regular intervals. Data collection is interrupt-driven to achieve accurate sample periods. Using a wide variety of definable triggers, the program may control when data collection begins. LabPro stores the data in internal RAM until the requested number of data points have been collected. The unit will return the list of data only after receiving a ‘get request’ from the host. If the host sends the “get request” before data collection is complete, LabPro will begin data transmission after the last point is sampled. It is possible to monitor the data as it is being collected by using Command 8. This feature could be used to give the user a real-time view of data being collected in a NRT mode. Due to its flexibility, this is the most commonly used mode. A special case of the NRT mode is FastMode sampling. It is designed for use when a single channel must be sampled very quickly. This mode is used primarily when sampling sound with a microphone, or to approximate an oscilloscope. In general, FastMode is identical to non-realtime sampling with the following exceptions:

- The sampling is limited to a single analog channel.
- The selected channel must not be in operation mode 5, 6, or 7.

- The communications with the host are turned off during sampling.

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

Data Collection Mode Comparison Table

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

	Realtime Mode	Non-Realtime Mode	FastMode
Order of data returned when doing the GETs from the host computer (n = # of samples taken)	{ch1_1, ch2_1, … deltatime_1} {ch1_2, ch2_2, … deltatime_2} : : {ch1_n, ch2_n, … deltatime_n}	{ch1_1, ch1_2, … ch1_n} {ch2_1, ch2_2, … ch2_n} {ch3_1, ch3_2, … ch3_n} {ch4_1, ch4_2, … ch4_n} {time_1, time_2, … time_n}	Same as Non-Realtime
Number of samples limited?	Not limited by LabPro, but may be limited by the host computer	Yes, limited by available memory in LabPro	Same as Non-Realtime
Sample time limits (approximate)	This is determined by host communication speed. Sample Time > 0.002 second to ≤ 16000 seconds	Sample Time ≥ 1e-4 seconds to ≤ 16000 seconds	Sample Time ≥2e-5 seconds to ≤ 1e-4 seconds
Number of channels limited?	Yes, only CH1-4 and 11, 12	No	Yes, only a single channel from CH1 to CH4
Can use Triggering?	Not by LabPro, performed in host software	Yes	Yes, however, manual triggering is not available.
Communication maintained during sampling?	Yes	Yes	No

Notes:
1. Checksums are not returned when in ASCII mode communication with a computer, but they are returned when using binary data transfer.
2. In Non-Realtime Mode, any post-process data will follow the input data for the respective channel.

In addition to RT and NRT modes, there is a single point mode. Using Command 9, a single point of data may be read from an active channel. No time is associated with this reading. This command is extremely useful for monitoring inputs, checking status of channels, and for very long term collection that may be statistical or have the time base controlled by the host.

Timebase

Regardless of which type of data collection is used, the user must set the data collection rate based on the available rates offered by LabPro. The range of possible times between readings is from 16,000 seconds to 2×10^{-5} seconds for analog data collection with a single channel. With two analog channels read at the same time, the shortest sampling time is 2×10^{-4} seconds.

The data collection mode used affects the sample times allowed with LabPro. In normal mode, a system tick of 100µs is used to set the sample time. The sample time must be an integer multiple of 100µs. Many programmer designers choose to limit them to a finite number of rates, such as 10K, 5K, 2.5K, 2K, 1K, 500, 250, 200, 100, 50, 25, 20, 10, 5, 2.5, 2,and 1. At rates slower than 1 sample per second, the 100µs clock allows reasonable timing accuracy for any sample time requested.

In fast mode, a system tick of 400ns is used to set the sample rate. The sample time must be time period multiplied by 400ns resulting in an integer value. Many programmers limit the choices to rates of:

50K, 33K, 25K, 20K, 10K

Refer to the LabPro Command Summary section for further details.

Data Retrieval

Data may be retrieved from LabPro in a several different ways. The most common way to collect data is to send a get request. This will cause LabPro to return the next point in RT mode or to return the collected data in NRT mode. Command 9 will collect a single point outside active data collection. This is useful when wanting to monitor or test a channel. Command 8 can be used to return the most recent data point collected during an NRT mode. Commands 5 and 12 is used to select specific data to be returned from memory.

Miscellaneous Reference Information

LabPro Software Upgrades

LabPro uses *FLASH* technology, which allows you to easily upgrade to new software without buying a new LabPro. As new functionality becomes available, you can download the software from the Vernier web site to your computer and upgrade your LabPro.

Check the Vernier website (**http://www.vernier.com**) for upgrades, paying special attention to compatibility statements. Directions for downloading upgrades will be given on the web site.

Archiving in LabPro's FLASH Memory

LabPro has 24KB of *FLASH* memory that can be used for several purposes. In addition to allowing updates to the operating system and storing the DataMate and other calculator programs, the *FLASH* memory serves as an archive space for other programs and data.

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

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

on the calculator.

- Calculator user can use the DataMate program to Save, Load and Delete data sets in the *FLASH* archive. This can be very useful for performing and retaining multiple experimental trials in the field. Directions for using this feature are given in the ***DataMate Guidebook***.
- You can write a program to review the list of stored data sets and retrieve the desired one for further analysis. (See the sample archive program.)
- Calculator users can use the DATADIR program (available on the TI web site at http://education.ti.com/calc or the Vernier web site http://www.vernier.com/calc) to manage *FLASH* memory. Directions for using the DATADIR program are given in the ***DataMate Guidebook***.

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

Typical Program Implementations

Analog Data Collection

Analog data collection is the easiest to learn and will be introduced in the next two sections.

Here is pseudo-code for a very simple LabPro data-collection program. This program takes readings from a Vernier Barometer sensor. It will take 50 readings, 0.25 seconds apart. The general pattern is that you transfer lists of numbers (commands) to LabPro.

```
0
1,1,14,0,0,1
4,1,1,8.729,8.271
3,0.25,50,0,0,0,0,0,1
Get analog data
Get time data
```

We will go over the program one command at a time below:

The first command initializes the LabPro using a Command 0. (Remember that the first number in the command is the command type.) This is good practice prior to setting up data collection or when changes take place. This command clears data, channel assignments and data collection modes that are currently assigned in LabPro. However, this is not to say that a reset should always be sent to LabPro. In fact, since reset clears previous data, it is important to send reset only when you are sure the user is finished with the current configuration and data.

The second command configures the channel for reading data. Command 1 tells LabPro a number of things about how data is to be collected. The official syntax for this command, when used with sensors, is:

1, channel, operation, post-processing, delta, conversion

You may not require all these features and you will rarely use some of them. (Use zeros, or leave them out so the default value is used.) Here are the commonly used parameters:

channel = The input channel is specified with the second number in the list. For analog sensors, you can use 1, 2, or 3, or 4 (for CH1, CH2, CH3, or CH4). For a motion detector you use 11 for a Motion Detector connected to DIG/SONIC1 or 12 for DIG/SONIC2.

operation = The third number in the list provides more specific information regarding the channel setup. This includes input selection (each analog port has two inputs) and use of internal conversion information. In this example, we use a 14 to indicate that for this port, LabPro should collect voltage data from the 0 to 5 V input. Most of Vernier analog sensors use this input. Many of Vernier sensors

now support an Auto-ID feature. By using a 1 for operation in this command, LabPro will automatically determine input configuration, conversion information as well as other sensor specific information. If no sensor is found during an Auto-ID process, it defaults to the 0 to 5V input. Using 14 is a more manual example. It is more common to exploit the AutoID feature.

post-processing = This option directs LabPro to process the collected data to calculate values such as first and second derivatives. Sometimes it is desirable for the host to calculate these values instead of LabPro. Here we use zero since it is not needed.

delta = not used often, use zero

conversion = The sixth number in the list is either 0 or 1. If it is a 1, the LabPro will use a user programmed conversion equation to convert voltages to readings which correspond to a sensor like a force sensor, pressure sensor, magnetic field sensor, etc. If it is 0, either an internal conversion or no conversion equation will be used. You should use a 0 in this position if you are using an AutoID sensor or want to read back raw voltage values. Use a 1 if you are using a Vernier analog sensor with a DIN (5-pin) plug or other sensors that don't support AutoID.

Let's take a closer look at the second line of our sample program:

```
1,1,14,0,0,1
```

Command 1 used here sets up channel 1 to use a Vernier sensor and (since the 6th value is 1) to use a conversion equation.

The third line of our sample program uses a Command 4. Command 4 is only used to set up the calibration equation for an analog sensor, such as one of the Vernier probes with a DIN connector. With the proper Command 4, LabPro will read correct values (newtons, degrees Celcius, % dissolved oxygen, etc). If you are using an AutoID sensor, or you just want to read the raw voltage from an analog sensor, do not use a Command 4. Skip this line. Another way of saying this is that if the sixth number in your Command 1 line is zero, do not use the Command 4.

If an equation is to be used to convert voltages to other measurement units, Command 4 is used to load a conversion equation to LabPro. Almost all Vernier probes use linear calibrations (1st order polynomial). The calibration is specified by entering k_0 (the y-intercept) and k_1 (the slope). For this kind of calibration, the form of the Command 4 line will always be:

```
4,channel number,1,1,k0,k1
```

In our sample program, the following line is used to load the conversion equation:

```
4,1,1,8.729,8.271
```

In this case, channel 1 is being used, with a intercept of 8.729 and a slope of 8.271. This is the proper calibration for a Vernier Barometer, calibrated in atmospheres. Information on the proper Command 4 line values for each Vernier sensor is included in the sensor documentation.

Command 3 controls the actual data collection. Here is Command 3 from the sample program we are studying. It specifies taking readings every 0.25 seconds for 50 readings, and specifies that we should record the time of each reading.

```
3,0.25,50,0,0,0,0,0,1
```

The syntax for this command is:

```
3, samptime, numsamp, trigtype, trigch, trigthres, prestore, extclock, rectime, filter, FastMode
```

Many of these features may not be needed and left in their default state or set to zero. Here are the commonly used parameters:

samptime = the time between samples (in seconds). The range is 0.00002 to 16000 seconds.

numsamp = the number of readings to be made. This can be any integer from 1 to 12,000. (Numsamp = -1 puts LabPro into RT data collection mode as explained below.)

trigtype = this specifies if the program should wait for a triggering event before starting the actual data collection. "0" instructs LabPro to begin data collection immediately without waiting for a trigger. "1" means wait for the Start/Stop button on Labpro to be pressed. Other numbers can be used to specify triggering on a certain signal level. The default is 1, which you usually do not want, so you should almost always have to put a zero here.

The last two commands of our sample program are used to retrieve data from LabPro.

Get Analog Data

Get Time Data

As the first four commands of our sample program are executed, LabPro will go about its business of collecting the data. The program should at some point send a command to LabPro requesting the data. The details of this are different depending on the computer or calculator being used. Each command will get a complete list of data from LabPro. The analog sensor readings will be retrieved first and then the times. If we had set rectime to 0 in Command 3, then we would not have had the times recorded, and we would have used only one retrieve command.

Analog RT Data Collection

The discussion above is about non-realtime data collection. That is, it assumes that you want to have a certain number of readings taken at specified intervals for later use by the host (e.g., making a graph). There is another variation of data collection that is sometimes used. We call this RealTime (RT) data collection. In this type of program, LabPro takes one reading, the computer retrieves the reading (and usually does something with it, such as put a point on a graph), and then the program loops and repeats.

Here is pseudo-code for a second sample program, similar to the first, but with RT data collection:

```
0
1,1,14,0,0,1
4,1,1,1, 8.729,8.271
3,1,-1,0
Label A
Get value of I
Display I
Goto A
```

This program is the same as the previous sample through the first three lines. After that, the data collection portion is very different. Here is what is going on:

3,1,-1,0	Note the Command 3 now has a -1 for the number of samples. This will tell LabPro to take one reading and continue on.
Label A	This is just a label, so the program can loop back here.
Get value of I	Get the one reading and store it in the variable I.
Display I	Display this reading.
Goto A	Loop back to Label A and repeat.

Note that in most real programs you need to provide a graceful way of breaking out of this loop.

This type of data collection works great for many programs where you just want to monitor the reading from a sensor as you collect data and take action if it exceeds a certain specified value; for example, a program that turns on a fan if a temperature gets too high.

Motion Detector Data Collection

Programs for using motion detectors (also known as ultrasonic rangers) are somewhat like programs for using an analog sensor. When using motion detectors, LabPro has the ability to return velocity and acceleration. Below is pseudo-code for a typical motion detector.

```
0
1,11,1,2
3,.05,50,0
Get distance data
Get velocity data
Get acceleration data
Get time data
```

The Command 1 line is changed to use channel 11 for DIG/SONIC1. The parameter following the channel number sets the units of distance the motion detector should read. In this case, LabPro will AutoID the motion detector and read distance in meters.

The next paramteter in the list assigns a post-processing setting of data. The value of 2 tells LabPro to calculate both velocities and accelerations (1^{st} and 2^{nd} derivative of the raw data with respect to time.)

In the sample program we requested that the velocity and acceleration be reported. Whenever either velocity or acceleration is reported, the time of data collection will also be reported. As a result, we need to get back four lists of numbers from LabPro.

```
Get distance data
Get velocity data
Get acceleration data
Get time data
```

Monitoring Inputs During NRT

Command 8 retrieves the most recent sample at request time and returns the value to the host. The limitation is each channel must be requested individually.

8,1 request data point from channel 1

Note Command 8 only works for channels 1,2,3,4,11,12 and only returns values in ASCII.

Monitoring Inputs without Data Collection

Command 9 allows the program to sample a single point from a channel. It returns the current value at request time to the host computer. The limitation is each channel must be requested individually.

9,1 request data point from channel 1

Note Command 9 only works for channels 1,2,3,4,11,12 and only returns values in ASCII.

Interrupting Data Collection

While in general it is best that commands and responses are kept synchronous and not interrupted, there are situations when the user will need to terminate data collection. Using a reset command may do this. However, if a reset is sent, all data is lost and the setup is erased. To gracefully terminate data collection,

send a Command 6:

```
6,0
```

This will terminate data collection while keeping intact the data buffer and the channel configuration.

Keeping Power on During Analog Data Collection

LabPro tries to minimize power consumption by turning power off to sensors when data is not being collected. There are some subtle issues involved with reading signals from sensors such as Vernier pH, Conductivity, Ion Selective Electrodes, Dissolved Oxygen, CO_2, and Flow Rate. These sensors all require power to be supplied for some time to stabilize before readings are accurate. The way to solve this problem is to send a Command 102 as shown the sample below. This command can be sent right after the channel is set up. Command 102 controls how many seconds prior to sampling that power is applied to the sensor. The –1 operation tells LabPro to keep power applied to the sensor at all times.

```
102,-1
```

Note that if you do this battery life will be reduced.

Digital Data Collection

Digital data collection using photogates, radiation monitors, and rotary motion probes are handled very differently from analog data. In all cases, Command 12 is also used for setup and to retrieve the data. Experiments can be performed using analog, sonic and digital channels simultaneously, but will require additional steps during their set up and data recovery phases.

Important Note: Currently, at least one analog channel must be active in order to collect digital data. The operating system does not collect data unless this is done. This is a known limitation and it may be eliminated in future operating system.

Photogate Timing

Photogates operate a little differently than the analog channel since the event occurrences are not predetermined in time. There are many different timing modes as well. In order to allow the greatest flexibility, the operating system commands are implemented in a rather generic way. It is up to the program to process the data as needed to report the desired timing.

Photogate operation is also unique in that the same command (12) is used to setup data collection as well as request gathered data. Use Command 12 prior to data collection to set up the timing modes. Use Command 12 during and/or after data collection to retrieve the requested data.

In general, you will need to follow this sequence:
Set up an analog channel (even if you will not use the data collected)
Set up timing mode using Command 12
Start data collection using Command 3
Data collection terminates either manually or automatically (time interval is up)
Retrieve data using Command 12 followed by a “get”
Process data for desired timing information

A word about Command 3 setup. In most of the timing modes (except counter mode) the sampling period is not a concern unless analog data is really needed. In most cases, this will be set for an arbitrarily long experiment that is terminated by the user.

LabPro handles multiple digital inputs as separate measurements. The user is allowed to set up a wide variety of combinations to get the timing they desire. However, it is up to the host program to use the

timing data from each of the LabPro channels and calculate the desired result.

The continuous pulse mode (time gate is blocked) is used for several modes of timing. The following examples detail some common timing tasks.

Timing how long a photogate connected to a DIG/SONIC port is blocked (Gate Timing)
This timing mode is used to time pulses through a single photogate. The times reported to the user represent the duration of the photogate being blocked. LabPro may be used in two modes; pulse width or continuous pulse width. The difference being that pulse width stops collection after a single value has been collected. Since Logger Pro currently supports multiple pulses under gate mode, it might be more useful to use the continuous pulse mode. The setup would be:

0	Clear all channels and reset the device
102,-1	Turn power on continuously. Not required, but a good idea.
1,1,14	Setup one dummy analog channel, if no other analog channels have been assigned
12,ch,3,1	Timing mode where ch is channel number 41 or 42 (DIG/SONIC1, DIG/SONIC2 respectively). The 3 parameter refers to continuous pulse mode and 1 refers to active low pulse.
3,60,1000,0	Send trigger information for arbitrarily long experiment unless real analog data is being collected. This example sets the experiment length for 1000 minutes (1000 readings, each of 60 seconds).

The experiment will terminate after this 1000 minutes; however, we do not need to wait until the experiment is over to retrieve data. The Command 12 is used to poll for and retrieve available data. The program must poll LabPro to find the number of available data points that have been collected.

12,ch,0	Requests the number of available data

The number returned will corresponds to the number of available events. The program may use this number to set up data retrieval as well as when to update data tables etc. LabPro reports two types of data, the pulse width and the time at which the pulse ended relative to the beginning of the experiment. (Note that the time the pulsed ended, not the time it started, is reported.) These times are reported back in units of seconds.

12,ch,-1,**n**,**m**	Requests the pulse width times beginning at event **n** and ending at event **m**. For instance, if 10 data points were collected and only points 8 to 10 were needed this would correspond to **n**=8 and **m**=10. If n and m are omitted, all events are returned.

The program may either “poll and retrieve” only new data or retrieve the entire data set each time. When the user clicks on stop, the program should terminate data collection with a Command 6.

6,0

Timing how long each of two photogates is blocked, independently (Gate Timing with 2 Gates)
As mentioned before, the ports operate independently of each other so that the times reported back are relative to each port. Simply setup and retrieve data as mentioned above using both ch 41 and ch 42.

0	Clear all channels and reset the device
102,-1	Turn power on continuously.
1,1,14	Set up one dummy analog channel, if no other analog channels have been assigned
12,41,3,1	Set continuous pulse mode for digital input 1
12,42,3,1	Set continuous pulse mode for digital input 2
3,60,1000,0	Send trigger information for arbitrarily long experiment unless real analog data is being collected. This example sets the experiment length for 1000 minutes.

Poll channel 1 for a new event. Once an event has occurred, poll for an event change on channel 2. Once this event occurs, retrieve the latest pulse widths from both these channels.

12,41,0	poll until you get a change in return value, store this in a variable, e.g., **j**
12,42,0	After channel one event change is detected, poll channel two until you get a change in return value, store this in a variable, e.g., **k**

12,41,-1,**j**,**j**	get pulse width from channel one
12,42,-1,**k**,**k**	get pulse width from channel two

Store these events and begin polling again until the user terminates the experiment.

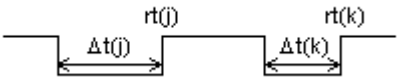
Timing from the time of blocking of one photogate until the blocking of the second photogate (Pulse Timing)

This may be done by requesting the times back rather than the pulse width for the photogates. Setup is the same as that for time with two photogates as mentioned above. However, now the times of interest are different. Polling is done in the same manner in that an event must occur on channel one prior to channel 2. However, now the time of interest is the time from edge to edge of the pulses. Using Gate Timing with two gates as the model, data retrieval now changes to:

12,41,-1,**j**,**j**	get pulse width from channel one. For equation below this is $\Delta t(j)$
12,42,-1,**k**,**k**	get pulse width from channel two. For equation below this is $\Delta t(k)$
12,41,-2,**j**,**j**	get pulse trailing edge time from channel one. For equation below this is rt(j)
12,42,-2,**k**,**k**	get pulse trailing edge time from channel two. For equation below this is rt(k)

Calculate the time from the blocking of photogate one to photogate two as follows:

$$T = (rt(k) - \Delta t(k))-(rt(j) - \Delta t(j))$$



The user terminates the experiment.

Motion Timing

This is used to measure a continuous stream of pulses. For example, if an object with clear and opaque sections (sometimes called a picket fence) is moved through a photogate. Many time measurements are made. Each represents the time between successive blockings of the photogate. This uses a slightly different mode than the previous examples, mode 4, for period measurement. For DIG/SONIC1, the setup is as follows:

0	Clear all channels and reset the device
102,-1	Turn power on continuously
1,1,14	Set up one dummy analog channel, if no other analog channels have been assigned
12,41,4,1	Set period - continuous pulse mode for DIG/SONIC1
3,60,1000,0	Send trigger information for arbitrarily long experiment unless real analog data is being collected. This example sets the experiment length for 1000 minutes.

Events retrieved are:

12,41,-1,n,m	Requests the a subset of the data beginning at event n and ending at event m. For instance, if 10 data points were collected and only points 8 to 10 were needed

this would correspond to n=8 and m=10. If n and m are omitted, all events are returned.

12,41,-2,n,m Requests the start times of each period measurement.

These two values are used to fill in the data table. Since the start times are referenced to the start of the experiment, the value for the first event should be subtracted from the times to get the first event starting at time t = 0.

Radiation Monitoring

Radiation counting is also set up using Command 12. It operates much like the photogate mode with the exception that the data rate set in Command 3 is used to set the counting period.

The following is an example of how to set up radiation counting on DIG/SONIC1:

0	Clear all channels and reset the device
102,-1	Turn power on continuously
1,1,14	Set up one dummy analog channel, if no other analog channels have been assigned
12,41,5	Set count mode for digital input 1
3,30,2000,0	Send trigger information for arbitrarily long experiment unless real analog data is being collected. This example sets the experiment length for 1000 minutes. The sample rate determines the count information that is returned as the number of counts per 30 seconds.

Data is polled using:

12,41,0	returns number of available data points. This also is the number of sampling cycles that have occurred since start.
12,41,-1,m,n	returns data points starting with point m and ending at point n. Data is number of counts that occurred during a sample period.

Rotary Motion Sensors

Reading data from a Vernier Software & Technology rotary motion sensor is also setup and monitored using Command 12. LabPro reports the position of the sensor as a number in either low or high resolution. The command to setup takes this form:

12, channel, 6, scale factor

where the scale factor should be 0 or 1 indicating whether you are in low or high resolution. If you use 0, the resolution will be 360 counts per rotation of the sensor. If you use 1, the revolution will be four times as many or 1440.

The following is an example of how to set up a rotary motion sensor on DIG/SONIC1.

0	Clear all channels and reset the device
102,-1	Turn power on continuously
1,1,14	Setup one dummy analog channel, if no other analog channels have been assigned
12,41,6,0	Set rotary motion mode for digital input 1 for low resolution measurements
3,30,2000,0	Send trigger information for arbitrarily long experiment unless real analog data is being collected. This example sets the experiment length for 1000 minutes. The sample rate determines the count information that is returned as the number of counts per 30 seconds.

Data is polled using:

12,41,0	returns number of available data points. This also is the number of sampling cycles that have occurred since start.

12,41,-1,m,n returns data points starting with point m and ending at point n. Data is position of the rotary motion sensor, relative to its position when the data collection began.

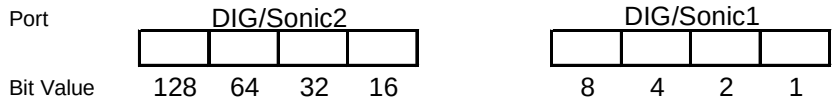
Digital Outputs

The electrical characteristics of the digital outputs are:

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

Using Command 2001

This is the simplest way to set the status of the digital output lines. Just send the following command to LabPro: 2001, X, where X is a number between 0 and 255, that matches the binary pattern you want on the 8 digital output lines. For example, sending 2001, 7 will set the first three digital output lines on DIG/SONIC1 to high and all the other digital output lines to low.



If you use a series of numbers after the 2001 in the command line, the data will be sent out at about 200-µsec intervals.

Using the Digital Output Buffer

A more complex method of controlling the digital output lines is to use the digital output buffer. This is especially useful when you want a pattern of outputs to be repeated. Examples include, flashing LEDs or stepper motors.

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

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

Digital Output Buffer Example

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

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

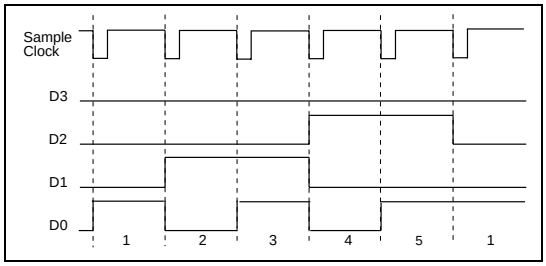


Figure 1. Digital Output Example

Analog Outputs

The analog output is present on line 1 of CH4. Once the channel has been setup, the output is enabled immediately regardless of data collection mode. It will remain active until the unit is reset or until it is disabled using Command 401

When the output is activated using Command 401, the driving voltage may be monitored by reading Vin on CH4.

The voltage out is limited to +/- 3 V and to +/- 100 mA. By changing the parameters you may change the output value. A variety of waveforms are supported. Command 401 allows the program to set a waveform, amplitude, offset and period and the analog output will generate the desired waveform. The official syntax for this command is:

401, waveform, amplitude, offset, period

The current Lab Pro operating system revision understands the following parameter:

waveform = DC voltage, ramp up, ramp down, triangle, sine

amplitude = the peak to peak voltage

offset = the voltage relative to ground

period = time (in milliseconds) to complete one cycle

The DC output voltage is set by the equation:

V_{out} = 2.4mV*amplitude – 1.2mV*offset

The command

```
401,1,1024,1024,0
```

will output a 1.25V signal. To turn off the analog output:

```
401,0,0,0,0
```

When the analog output is off, the Vin line (pin 1) of CH4 line may be used as a ± 5 volt analog input. Note that this is different from the other three analog input channels.

Computer Programming

Basic communications

Commands are sent using the following format:

s{**command number**, *parameter 1,…, parameter n*}

where the command number is required followed by one or more parameters that may or may not be required (see command reference section).

Data is returned either automatically or by requesting data by sending: the character "g".

Before you start programming, it is a healthy exercise to spend some time with a terminal program (Hyperterm for Windows or Zterm for Mac are two examples) sending commands and receiving data.

Data Formats

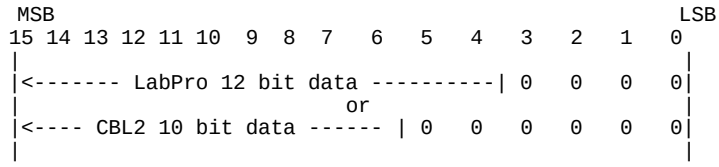
ASCII Data

Numbers are returned as ASCII representation of 32-bit floating point numbers in the format of

sm.dddddEsee (sign mantissa_digit . digit digit digit digit digit E sign exponent exponent)

Hex Data

Binary mode is requested by the command {4,0, -1} but is only supported on the active analog and motion channels. It reports the raw ADC output (i.e. calibration equations and derivatives are ignored). The data format is 16 bits of ADC output that is zero filled, left justified according to the interfaces ADC resolution.



The data is transferred most significant byte first. No carriage return or line feed is transmitted.

In real time sampling mode, all active channels plus the 32-bit time counter are returned.

Ch1_MSB Ch1_LSB ... ChN_MSB ChN_LSB T_MSB T_B2 T_B1 T_LSB Chk

Where CH1_MSB indicates the most significant byte of data from the lowest number channel that is active. After all the data has been transferred for a sample point, a checksum is included verifying the data integrity (serial port only, does not apply to USB communications). The checksum is a single byte computed by exclusive-ORing all bytes in the line and ones-complementing the result.

For example, assume you request a single data point with time. LabPro will transmit the following bit pattern for a data value 8CH, a time of 00e0H and the checksum of 93H:

0000-1000 1100-0000	0000-0000 0000-0000 0000-0000 1110-0000	1101-0111
16-bit data	32-bit time	ChkSum

In non-real-time sampling mode, all N data points for the current channel are returned. Less than N data points will be returned if windowing is turned on with Command 5. Each successive "Get" iterates through

the active channels, just as it does in the ASCII or calculator mode. For instance, with two channels active, the following would be returned:

g (sent by host)
Pt1_Ch1_MSB Pt1_Ch1_LSB Pt2_Ch1_MSB Pt2_Ch1_LSB ... PtN_Ch1_MSB PtN_Ch1_LSB Chk
g (sent by host)
Pt1_Ch2_MSB Pt1_Ch2_LSB Pt2_Ch2_MSB Pt2_Ch2_LSB ... PtN_Ch2_MSB PtN_Ch2_LSB Chk

As in the real time mode, each case, the checksum is a single byte computed by exclusive-ORing all bytes in the line and ones-complementing the result (serial port only, does not apply to USB communications). After the checksum, transmission stops, i.e., no carriage return, linefeed or other stop character is sent after the data.

Serial Port Communication Details

The serial port transmits commands and data requests in ASCII. Serial port setup is 38400,N,8,1. LabPro will return command/response information in ASCII but has the option of returning collected data in either ASCII or binary.

When communicating over the serial port, a carriage return character follows each command.

Since LabPro may be running from batteries, it may be in a low power state. In that case, if the host is communicating over the serial port, the first byte will be missed. For safety, if the time since the last communications is unknown, then the host should send an “s” followed by a carriage return to wake up the LabPro. If it is not asleep, the “s” will be ignored. As an example, a status request would look like:

s<CR>
s{7}<CR>

While a setup sequence would look like:

s<CR>
s{0}<CR>
s{1,1,14}<CR>
s{3,.1,-1,0}<CR>

USB Communication Details

If the host is connected with USB, each time the program requests data, LabPro will send the data as soon as the sampling occurs. If the program does not ask for the data often enough, data could be lost. If the host is a computer connected through the serial port, LabPro automatically sends a continuous stream to the host. This continues until the host stops data collection or resets the unit.

The LabPro enumerates with VID=08f7 and PID=0x0001.
There is 1 input bulk endpoint and 1 output bulk endpoint.
The USB packet size for bulk transfers is 64 bytes.
Transfers from LabPro to PC are always in multiples of 64 bytes.

The USB connection operates in much the same way as the serial port. It transmits commands and data requests in ASCII. LabPro will return information in ASCII but has the option of returning collected data in ASCII or binary. Some differences should be noted due to transport.

One significant difference is that trying to read from USB will not return 0 bytes of data, like an empty serial port call. Instead, the call blocks until data is available from the LabPro. This occurs because LabPro sends a NAK (Not Acknowledge) response until data is valid. The device driver will then wait, blocking on the read, until the data is there. This means that the software read function will not return until the data is ready. If this is an issue, the read request can be put in a separate thread so that the main thread can continue to run. Third party drivers are available to create the abstraction of an input buffer similar to the serial port operation.

The operating system in LabPro was written to make the USB interface as similar as possible to the RS232 serial interface. Getting data using USB works similar to getting data through the serial port, with some subtle differences.

There is no checksum character for binary data, since the USB protocol already includes error detection.

Since the data is transmitted in multiples of 64 bytes, it is possible that there will be extraneous data in the last 64-byte packet. The application software needs to know when to stop reading the buffer. In ASCII mode, looking for a carriage return character can do this. In binary mode, it is only necessary to keep track of the number of samples requested, and read the appropriate number of bytes.

In real time binary mode, each real-time sample is returned as 16 bits. The data is formatted as in the RS232 design, then 0-padded up to 16 bytes. Real-time binary data is normally returned with 1 real-time sample per USB packet. This allows roughly 1 sample/ms transfer rate, depending on loading conditions and host controller design. If real-time sampling occurs faster that USB packets are delivered to the host, there will be gaps in the real-time data. To allow deeper buffering of the sample data (and thus faster sampling rates), there is an option to pack more than one sample per USB packet. The binary mode command has an optional parameter to specify this packing. The command format is {4, 0, -1, X} where X is the number of samples to place into one USB packet. X must be a value from 1 to 4. If no value is specified, the default is 1. One consideration in applying this scheme is this: if USB packet delivery is sufficiently delayed in this case, each delayed packet results in a gap that is larger than a single sample time.

Communications Speed Limitations

LabPro may operate in two modes; real time (RT) and non-real time (NRT). In RT mode, LabPro returns each sample as it is collected. However, the serial port or USB port have limitations on how fast they may transfer data. The setup limitations depend on the data rate, the number of samples requested and the length of the experiment. The primary factor for decision making is the number of active channels. From that information, the determination of maximum rates etc. can be calculated.

When using LabPro in RT, the samples are not stored internally. Therefore, the max number of samples and, consequently, the experiment length is limited by the software.

When using LabPro in RT mode over the serial port, the number of bytes per data point is 2*# of active channels+4 (time bytes) + 1 (checksum) (see above information for details). This translates to 7,9,11,13,15,17 bytes per data point for 1 to six channels (four analog and two sonic) respectively. Therefore, at a transmission rate of 38400, we can assume 10 bits/byte for a throughput of 3840 bytes/second. Using the timebase options above, we have the following theoretical limits imposed on real time collect mode for serial port:

500 samples per second max.	1 channel active
250 samples per second max.	2 - 4 channels active
200 samples per second max.	4 - 6 channels active

When using LabPro in RT mode over USB, the number of bytes transmitted back is always 16 (see above information). For an unloaded USB bus (i.e. no other peripherals), we should have a limit of 1k samples per second for RT mode for 1 to 6 channels active.

If you try to use RT at higher data rates, loss and corruption of data can occur. When the RT mode limit is exceeded, the software must switch to utilize the NRT mode of LabPro. Data rate limitations change as follows:

50K samples per second max.	1 channel active
5k samples per second max.	2 channels active
2.5k samples per second max.	3-4 channels active
2k samples per second max.	5 channels active
1k samples per second max.	6 channels active

Since the data is stored internally to LabPro prior to sending it to the host computer, the number of data points being collected is limited to 12k samples/# of channels.

One implication of this is that the user may set up an experiment to take data from one channel at 1k samples/second for 12 seconds. LabPro would not complete the data transfer for 18.25 seconds (12 seconds for the experiment + 6.25 seconds to data transfer over the serial port for 24000 bytes at 3840 bytes/second). Having such a delay may give the impression something is wrong. The software and the user need to be aware of the times involved in such a situation.

Programming tips

Since the System Setup command (Command 6) must be processed while not disturbing data collection, it is possible for additional data points to be transmitted after the Command 6 has been sent. These points may be ignored but be aware that the receive buffer may not be empty immediately after sending this command.

We have found that commands delimited by a carriage return character can be stacked in LabPro's input buffer. The input buffer can hold up to 300 characters. The benefit of stacking commands is that the simple example

Calculator Programming

LabPro is designed to work with the TI-73, TI-82, TI-83 TI-83 Plus, TI-85, TI-86, TI-89, TI-92 and TI-92 Plus calculators. Programs are created on a TI calculator to set up specific LabPro operations, depending on the experiment or other function that you want to perform. LabPro operations are controlled by commands sent in the form of lists from a calculator. In the majority of cases, the data returned by LabPro is also in the form of a list. As a rule, when a TI calculator is the host, LabPro is a passive communicator, which must first receive a command list to provoke a response. Data is never automatically sent to the calculator from LabPro.

Basic Communication

Below is a general example of communication between any TI calculator and LabPro:
{**command number**, *parameter 1,…, parameter n*}→*listname*
Send(*listname*)
Get(*variable)*

where the first line stores the **command number** and parameters to the calculator list called *listname*, the second line actively sends the list called *listname* to LabPro and the third line retrieves the requested data from LabPro to *variable* on the calculator.

- In the command list the **command number** is required followed by one or more parameters that may or may not be required. See the section titled LabPro Command Summary for details on the commands and their parameters. We will use Command 7, the "Request System Status" command in the examples to follow. This command has no parameters and is thus is sent as a single element list.
- Any *listname* is acceptable when using "Send" to transfer the command list to LabPro. Refer to your calculator guide book for the restrictions on list names and their syntax requirements. In the following examples we will use the calculator list L6 for *listname.*
- There are a number of types of *variable* that can be used in the "Get" request. Most cases call for using a calculator list. It is even common to use the same list for both *listname* and *variable*. For clarity we will use the list called L1 to "Get" data from LabPro to the calculator.

Note: Only the TI-82 and TI-85 calculators need to store the command to a list in order to send it to LabPro. All of the other calculators can omit the first step and simply use

{**command number**, *parameter 1*,…,*parameter n*}

in the "Send" command.

Below is a working example which commands LabPro to generate and prepare to return a 17-element list of status information and then places the requested information into the list called L1on the calculator. It is shown in three ways to give the syntax for all of the supported calculators.

TI-73, TI-82, TI-83/83Plus, TI-86	TI-89, TI-92/92Plus	TI-85
{7}→L6 Send(L6)…or simply: Send({7}) Get(L1)	{7}→L6 Send L6…or simply:Send {7} Get L1	{7}→L6 Outpt("CBLSEND",L6) Input "CBLGET",L1

During the "Get", the list L1 is deleted from the calculator and reformed by the data coming in from LabPro. Regardless of the list's length and contents prior to the "Get" request in our example, L1 should look something like this:

{6.0112,0,0,888,0,0,0,0,0,0,0,0,1,0,0,0}

These steps can be executed from within a calculator program or line by line from the calculator home screen. The TI-82 can only send commands from within a program. On the TI-73, TI-82 and TI-83/83Plus calculators the lists called L1 and L6 are system-defined lists found on the keyboard or in the "List Names Menu". On the TI-85, TI-86, TI-89 and TI-92/92Plus calculators the lists called L1 and L6 are user-defined-lists which can be directly typed from the keyboard as the letter 'L' followed by the numbers '1' or '6'. In either case, it is always best to initialize all variables prior to their use.

Retrieving Data

In the vast majority of cases, LabPro will be prepared to return data in calculator list format. However, LabPro will return data in the format specified by the *variable* in the "Get(*variable*)" command. The choices are: lists (as we used L1 above); list elements; real numbers; and in some cases strings or categorical lists (TI-73 only). Below are examples and explanations of each of these (using the TI-83 syntax):

"Get" request with a list element:
Send({7})
Get(L1(2))
In this case, only the second element of the list called L1is specified in the "Get" request. Therefore only the second element of the list will be deleted and populated with the requested data. All other elements in

L1 will remain as they were prior to the “Get“ request. Since LabPro was prepared to return a 17-element status list on the next “Get“ request, and only a single list element was specified in that request, only the first in the status list was returned as data. If L1 was {1,2,3,4,5} prior to the “Get“; after the “Get“ it would be {1,6.0112,3,4,5}.

“Get“ request with a real number:
Send({7})
Get(A)
In this case real number variable A was specified in the “Get” request. Regardless of it’s contents prior to the “Get“ request, the real number variable A will be erased and populated by the first value in the commanded data. In this case A would be: 6.0112, the first element of the 17-element list requested by the status command.

“Get“ request with a string or categorical list:
When using some of the specialized archive commands (see section titled Archive Operation Commands) it is possible to retrieve text directly from LabPro FLASH memory. There is a 20-character limit to the length of each string and not all characters are supported. The format of this text depends on the data type specified in the “Get” request. See below for details on individual calculator types.
For the TI-83/83Plus, TI-85 and TI-86:

- If the data type specified is a string, LabPro will return a 20-character name of item.
- If the data type specified is a list , LabPro will return a 20-element list, each element representing an ASCII character code in the text string.

For the TI-73:

- If the data type specified is a categorical list, LabPro will return 4 elements of 5 characters each. Concatenate these 4 elements to form the complete text string.
- If the data type specified is a list , LabPro will return a 20-element list, each element representing an ASCII character code in the text string.

For the TI-89, TI92/92Plus:

- The only allowable data type is a list. LabPro will return a 20-element list, each element representing an ASCII character code in the text string.

Data Control

LabPro accepts over 20 different commands, each with a variety of parameters. Some of these, such as Command 0 and Command 102, are used for experimental setup, power control or other administrative purposes and do not generate data in response. While others, such as Command 7 and Command 201, will generate data and prepare the LabPro to respond only to the next “Get” request. Data gathered from experiments will remain in the LabPro data buffer, available for multiple retrieval, until the buffer is cleared either by a loss of power or a command of type 0, 1 or 3. Be aware that pressing the Quick Setup button will also clear the data buffer and reset any existing LabPro setup. If there is data in the buffer that has been gathered from an experiment, successive “Get” requests will retrieve the data in an orderly fashion. Each successive "Get" iterates through the active channel and time data, beginning with the lowest active channel.
For Example:
CH1*a*, CH1*b*, CH1*c*, CH2*a*, CH2*b*,…,CHn*c*, Record Time, CH1*a*,…etc.
(Channel 1 is assumed to be the lowest active channel, *a* is raw data, *b* is d/dt, and *c* is d^2/dt^2)

Refer to Command 5 for further information on data control.

Calculator Limitations

Calculator memory is an important factor to consider when collecting data with LabPro. Even though LabPro can store up to 12,000 points, if a calculator has insufficient memory when using a "Get" request, no data will be retrieved. Each element of a list, and therefore each data value takes up about 10 Bytes of calculator memory (regardless of the calculator) and calculator programs also occupy memory. Each calculator supported by LabPro has unique limitations on memory availability for program and data storage and other limitations that may need to be considered while programming for LabPro. The table below highlights some calculator features.

Calculator	User available memory (in Bytes)	# of available lists	Maximum list length	Maximum # of data points**
TI-73	**25 K**	**No limit***	**999***	**2500**
TI-82	**28 K**	**6**	**99**	**594**
TI-83	**27 K**	**No limit***	**999***	**2700**
TI-83 Plus	**24 K**	**No limit***	**999***	**2400**
TI-85	**28 K**	**No limit***	**2800***	**2800**
TI-86	**96 K**	**No limit***	**6000***	**9600**
TI-89	**188 K**	**No limit***	**No limit***	**18800**
TI-92	**68 K**	**No limit***	**No limit***	**6800**
TI-92 Plus	**188 K**	**No limit***	**No limit***	**18800**

*Number will vary depending on available memory.

**These numbers are approximate, are based on a free memory, using 10 Byte/data point standard. The TI-82 is limited to 6 lists of 99 points/list.

LabPro Command Summary

The table below lists the commands you can use in writing programs for LabPro.

Command Number	Command Description
0	**Reset:** Resets all channels to default conditions.
1	**Channel Setup:** sets up a channel for data collection.
3	**Data Collection Setup:** Sets up the collection parameters for an experiment.
4	**Conversion Equation Setup (Analog):** Sets up parameters to convert physical units measured by LabPro into a more useful measurement unit such as newtons or °C.
5	**Data Control:** Selects the type and range of data to be retrieved.
6	**System Setup:** Turns sound on or off; sets an ID number for LabPro; selects a filter to be applied to data.
7	**Request System Status:** Generates and prepares to return status information.
8	**Request Channel Status:** Generates and prepares to return sensor type, last valid data, and last valid data position for the requested channel.
9	**Request Channel Data:** Generates and prepares to return one data point before sampling starts. Used to verify that setup is correct.
10	**Advanced Data Reduction:** Sets up LabPro to process certain time-intensive algorithms instead of processing them in the calculator.
12	**Digital Data Capture:** Sets up the capture or measurement of data from the digital input channel.
102	**Port Power Control Command:** Sets the power to always on; power-saving; or designated power up.
105	**Baud Rate Selection:** Sets
106	**Motion Detector Undersample Rate:** Sets
107	**Oversampling Burst:** Sets
115	**Request Set-up Information:** Returns status information for the designated channel.
116	**Request Long Sensor Name:** Returns long sensor name.
117	**Request Short Sensor Name:** Returns short sensor name.
119	**Request Alternate Calibration:** Selects an alternate calibration for the smart sensor.

201	**Archive Operations Command:** Allows the calculator to determine the contents of LabPro's *FLASH* memory.
401	**Analog Output Setup:** This command sets up parameters to control the analog output driver in LabPro.
1998	**Set LED Command:** Turns LEDs on and off on command.
1999	**Sound Command:** Specifies length and frequency of LabPro sounds.
2001	**Direct Output to Digital-Out Port:** Outputs data to the digital output port.

Detailed information about each command is given below. Functionality is continually being added to each command and the feature is denoted by a firmware version where it first appears.

A table listing valid values follows the syntax of each command. Default values appear in **boldface** type. The syntax of each command is presented in terms of what is required and what is optional. Every command must be enclosed in curly brackets, "{" and "}". The command # and the option parameters are comma delimited.

Syntax: { *command #*, [option [,option…]] }

The *command #* represents the command to be issued to LabPro. The reset command has the simplest syntax: s{0}.

[option] indicates an optional parameter. In many instances, using one optional parameter requires additional optional parameters be specified. The channel setup command is a good example. It can take one, two or five optional parameters.

Command 0 Reset LabPro

This command clears the data memory, error information, channel setup, and data collection information. Only the RAM is reset; *FLASH* memory is not cleared.

Syntax: {0}

Return values: No information is returned.

Example: Clear LabPro

Computer	Calculator
s{0}<CR>	:Send({0})

Command 1 Channel Setup

This command sets up a channel for data collection.

Syntax: {1, *channel[, operation[, post-proc, delta, equ]]* }

Parameter List:

Channel – indicates channel on which this command operates. The possible values are

Channel number	Description
0	All channels
1 – 4	Analog channels 1 through 4
11, 12	Sonic Channel 1, Sonic Channel 2
21, 22	Digital Input 1, Digital Input 2
31, 32	Digital Output 1, Digital Output 2

Operation – indicates the units of measure the channel should return.

Operation Value	Analog Channel (1 –4)	Sonic Channel (11, 12)
0	Turn channel off	Resets channel
1	Auto-ID the sensor (default to 0-5V if no sensor found)	Meters – Returns distance and Δtime (RT and NON-RT)
2	Voltage ±10V	Meters – Returns distance and Δtime (RT and NON-RT)
3	Current ±10A	Feet – Returns distance and Δtime (RT and NON-RT)
4	Measures resistance between ground (pin-2) and the junction of V_{ref} (pin-3) and $V_{in\text{-}low}$ (pin-6).	Meters – Returns distance, velocity, and Δtime (RT) or distance and Δtime (NON-RT)
5	Period in seconds of signal on ±10V input line (CH 1 only)	Feet – Returns distance, velocity, and Δtime (RT) or distance and Δtime (NON-RT)
6	Frequency in Hertz of signal on ±10V input line (CH 1 only)	Meters – Returns distance, velocity, acceleration, Δtime (RT) or distance and Δtime (NON-RT)
7	Count of transitions on ±10V input line (CH 1 only)	Feet – Returns distance, velocity, acceleration, Δtime (RT) or distance and Δtime (NON-RT)
10	Temperature (Centigrade) from TI Temperature or Stainless Steel	Unused
11	Temperature (Fahrenheit) from TI Temperature or Stainless Steel	Unused
12	TI Light sensor	Unused
14	Voltage, 0-5V	Unused

Post-Proc – enables post processing to take place on data collected. Since data is not stored in RT mode, no post processing is allowed.

Post-Proc Value	Description
0	None (RT and NON-RT)
1	d/dt (NON-RT)
2	d/dt and d^2/dt^2 (NON-RT)

Delta – used for internal debugging purposes and should always be set to zero (0).

Post-Proc Value	Description
0	Not used but required as a place holder if EQU is specified

Equ – indicates whether or not a conversion equation is applied to the data before it is returned. If Equ set to 1, Command 4 must be sent prior to data collection to specify the equation.

Equ Value	Analog Channel (1 –4)	Sonic Channel (11, 12)
0	No conversion equation applied	No temperature compensation
1	Apply equation specified in Command 4.	Compensate for temperature as set in Command 4.

Return values: No information is returned.

Example 1: Clear all LabPro channels.

Computer	Calculator
s{1,0}<CR>	:Send({1,0})

Example 2: Clear Analog channel 3.

Computer	Calculator
s{1,3,0}<CR>	:Send({1,3,0})

Example 3: Set analog channel 2 to read 0 to 5V with all other channels off.

Computer	Calculator
s{1,0}<CR> s{1,2,14,0}<CR> …collect the data… get time and channel 2 data	:Send({1,0}) :Send({1,2,14,0})

Example 4: Set analog channel 1 to read voltages in the range of –10 to +10 Volts, analog channel 2 to read current and calculate the first order derivative of current.

Computer	Calculator
s{1,0}<CR> s{1,1,2,0}<CR> s{1,2,3,1}<CR> …collect the data… get time, channel 1data, channel 2 data and the derivative column	:Send({1,0}) :Send({1,1,2,0}) :Send({1,2,3,1})

Alternate Command 1 Syntax:

One variation on Command 1 is used for setting the output value on the Digital Output channels. LabPro outputs one element for each sample. Between samples, the output returns to 0 unless the user has commanded the power to remain on (using Command 102, -1).

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

Channel	Operation	List of Values
31 = Digital Output 1 32 = Digital Output 2	0 = Clears the channel 1-32 = Count (number of data elements in list)	Values may be from 0 to 15.

The list of values must have one value for each count.

Example 5: Count down from 5. Note we set Channel 1 active. We don't have to retrieve the data.

Computer	Calculator
s{102,-1}<CR> s{1,31,0}<CR> s{1,31,6,5,4,3,2,1,0}<CR> Set the period Start counter	:Send({102,-1}) :Send({1,31,0}) :Send({1,31,6,5,4,3,2,1,0})

Measuring Period and Frequency

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

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

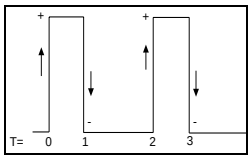


Figure 2. Period and Frequency Measurement

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

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

If LabPro is set up using Command 3 to make multiple measurements at a particular sample time, LabPro waits for the sample time that you specified after it completes the current measurement. It then initiates the next cycle of period/frequency measurement. The minimum sampling time for period and frequency is 0.25 seconds.
Note: Period and frequency measurements using Trigger Type 4 or 5 are only possible on non-repetitive signals or on repetitive signals that are less then 600 Hz. This is because at 600 Hz, the edge counts will prevail.

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

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

Measuring Frequency

Assume a frequency measurement is requested on CH 1, and 20 measurements are desired at a .5 second sample time.

The following commands would set up LabPro for this example:

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

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

Assume a ±10 Volt, 20 Hz sine wave is the input signal on pin 1. LabPro 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, LabPro takes approximately 15 seconds to complete all the sampling.

Command 3 Data Collection Setup

This command sets up the data collection parameters for an experiment.

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

Parameter List:

samptime – sets time between samples in seconds. The default sampling time is 0.5 second. The possible values are 0.00002 to 16,000 seconds. Samptime may also be –1 if the previous sampling needs to be repeated. Each probe has a minimum sample time, which is listed in the table below:

Probe Type	Minimum Sample Time
Analog probes	100µsec per probe 20µsec per probe in FastMode
Sonic probes	8 milliseconds
Digital In/Out	200µsec per channel

numpoints – indicates the number of data points per input should be recorded. The possible values are 1 to 12,287. A value of zero is invalid. Setting this value to –1 puts LabPro into real-time data collection mode.

trigtype – indicates what events must occur on the Trigger Channel (trigchan) to start sampling. Pressing the START/STOP button will circumvent triggered data collection. The possible values are

trigtype Value	Trigger Type	Exceptions
0	Immediate	May not be used with frequency measurements or with period measurements.
1	Manual (default)	May not be used with frequency measurements, with period measurements or with FASTMODE sampling.
2	Rising edge / Rising edge	May not be used with transition counting.
3	Falling edge / Falling edge	May not be used with transition counting.
4	Rising edge / Falling edge	May not be used with transition counting.
5	Falling edge / Rising edge	May not be used with transition counting.
6	Single sample	May not be used with frequency measurements, with period measurements, with FASTMODE sampling or with transition counting.

trigchan – indicates on which active channel the trigger conditions occur. Possible values are - zero (0) for no triggering; one (1) for hardware triggering on analog channel 1; two (2), three (3) or four (4) for software triggering on analog channels 2, 3 or 4; and 11 or 12 for DIG/SONIC1 or 2.

trigthresh – indicates the trigger threshold of the channel measured by the sensor attached to the trigger channel. The type of the value used here is a float and must be within the measurable limits of the channel.

pre-store – indicates how much data (as a percentage of all measurements to be made) prior to the triggering event should be stored. This value can be an integer between zero (0) and one hundred (100). For example, if pre-store is set to 10 with 1000 total measurements to be made, 100 data points made before the trigger event will be reported.

extclock – used for internal debugging purposes and should always be set to zero (0).

rectime – indicates the how time should be recorded for each data point. The possible values are zero (0) which disables time recording; one (1) which time-stamps data relative to the start of data collection; and two (2) which time-stamps data relative to the time of the previous sample. In the last case, the data taken before the trigger event will have negative times.

filter – indicates what type of smoothing should be applied to the collected data. The possible values are

Filter Value	Description	Used with collection mode
0	No filter	realtime or non-realtime
1	Savitzsky-Golay 5-point filter	non-realtime
2	Savitzsky-Golay 9-point filter	non-realtime
3	Savitzsky-Golay 17-point filter	non-realtime
4	Savitzsky-Golay 29-point filter	non-realtime
5	Median Pruning 3-point filter	non-realtime
6	Median Pruning 5-point filter	non-realtime
7	Light Realtime tracking filter	realtime
8	Medium Realtime tracking filter	realtime
9	Heavy Realtime tracking filter	realtime

fastmode – indicates whether or not data will be collected at the maximum sample rate allowed LabPro. In FASTMODE, only one channel can be active, and it must be an analog channel. Sampling can be as fast as 20µs/sample in this mode. FASTMODE is operational only for sample rates from 50,000 sample/second to 5,000 samples/second. The possible values are zero (0) for normal operation and one (1) for FASTMODE operation.

Return values: No information is returned.

Example 1: Start reading samples and displaying them every 0.5 second.

Computer	Calculator
s{3,0.5,-1}<CR>	:Send({3,0.5,-1})

Example 2: Repeat last data collection.

Computer	Calculator
s{3,-1}<CR>	:Send({3,-1})

Example 3: Collect data every 10 seconds for 600 seconds and apply a Savitzsky-Golay 9-point filter.

Computer	Calculator
s{3,10,61,0,0,0,0,0,0,2}<CR>	:Send({3,10,61,0,0,0,0,0,0,2})

Triggering Details

Two types of triggering thresholds can be set in LabPro:

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

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

- If the operation in Command 1 is frequency, period, or count (operation = 5, 6, or 7 on Channel 1 only), then the threshold parameter in Command 3 sets a voltage level in LabPro hardware. The signal on the Vin pin of CH 1 must pass through this voltage for LabPro to see the signal change states.

- If the operation in Command 1 is anything other than 5, 6, or 7, then the threshold parameter in Command 3 specifies a trigger level and is measured in the units of the sensor selected.

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

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

Asynchronous / Synchronous Triggering versus Record Time

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

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

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

When Trigger Type is set to 6 (Manual and Sample Trigger) in Command 3 and rectime = 1 or 2, the recorded sample times are not the actual relative times when START/STOP is pressed. They are the same times that would be returned during an NRT data collection. Thus, set the sample interval to 1 second and rectime = 1 to get a list of sample numbers returned.

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 LabPro is always sampling on the internal clock interval that you selected and is storing points (if you selected prestore) until the trigger event occurs.

Example

Assume the following:

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

LabPro 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,...}.

Command 4 Conversion Equation Setup (Analog)

This command sets up parameters to convert physical units measured by LabPro into a more useful measurement unit such as newtons or °C.

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

Parameter List:

channel – *indicates channel on which this command operates. The possible values are*

Channel	Description
0	All channels
1 – 4	Analog channels 1 through 4
11, 12	Sonic Channel 1, Sonic Channel 2

equtype – *indicates what conversion equation is to be applied to the desired channel. Equation types 1 and 2 use a modified syntax. All equtype values except 13 apply only to analog channels 1 through 4. The possible values are:*

equtype	Equation Type	Equation	Restrictions
-1	Unary. Hex value representing 5V/16bits.		Data is returned in hexadecimal format. May only be used with channel value of 0.
1	Polynomial	$K_0 + K_1X + K_2X^2 + ... + K_nX^n$	$1 \le N \le 9$
2	Mixed Polynomial	$K_{-m}X^{-m} + ... + K_{-1}X^{-1} + K_0 + K_1X + ... + K_nX^n$	$0 \le N \le 4$ $0 \le M \le 4$ $M + N > 0$ $X \ne 0$
3	Power	$K_0X^{(K_1)}$	$X>0$
4	Modified power	$K_0K_1^{(X)}$	$K_1>0$
5	Logarithmic	$K_0 + K_1\ln(X)$	$X>0$
6	Modified logarithmic	$K_0 + K_1\ln(1/X)$	$X>0$
7	Exponential	$K_0\, e^{(K_1X)}$	No restrictions other than overflow.
8	Modified exponential	$K_0\, e^{(K_1/X)}$	$X\ne0$
9	Geometric	$K_0X^{(K_1X)}$	$X\ge0$
10	Modified geometric	$K_0X^{(K_1/X)}$	$X>0$
11	Reciprocal logarithmic	$[K_0 + K_1\ln(K_2X)]^{-1}$	$K_2X>0$
12	Steinhart-Hart Model	$[K_0 + K_1 (\ln 1000X) + K_2(\ln 1000X)^3\ldots]^1$	$X>0$
13		K_0 in units of K_1	Only applies to channels 11 and 12.

K0 & K1 – *Except when equtype =13, these are the coefficients for the equation defined by* equtype *and are type float. When equtype=13, K0 is the ambient temperature in units defined by K1, and K1 may have the following values:*

K1	Temperature Units
0	°Celsius
1	°Fahrenheit
2	°Celsius
3	Kelvin
4	Rankin

Return values: No information is returned.

Example 1: Compensate motion detector for air temperature of 29°C.

Computer	Calculator	Note
s{4,11,13,84.2,1}<CR> s{4,11,13,29,2}<CR>	:Send({4,11,13,84.2,1}) :Send({4,11,13,29,2})	For °Fahrenheit temps. For °Celsius temps.

Example 2: Take 500 samples from Analog Channel 1 at 50,000/s in NRT mode and return the values in hexadecimal values.

Computer	Calculator	Note
s{0}<CR> s{1,14,1}<CR> s{4,0,-1}<CR> s{3,0.00002,500,0}<CR> g<CR>	:Send({4,11,13,84.2,1}) :Send({4,11,13,29,2})	Reset the LabPro. Enable 0 to +5V range input on Channel 1. Set data to return in Hex Start sampling Get the samples from the LabPro

Example 3: Apply a logarithmic conversion equation to analog channel 2 data.

Computer	Calculator
s{4,2,5,0,1}<CR>	:Send({4,2,5,0,1})

Alternate Command 4 Syntaxes:

When the polynomial conversion equation (equtype = 1) is used, the syntax for Command 4 is

{4, channel, 1, N, K0, . . .Kn}

When the mixed polynomial conversion equation (equtype = 2) is used, the syntax for Command 4 is

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

Example 3: Occasionally, data needs to be weighted by a polynomial function such as 4th order polynomial as a crude frequency filter. This example demonstrates applying the polynomial function,
Y = -X^4 + 3.25X^2 – 2.25, to input data from analog channel 1.

Computer	Calculator
s{4,1,1,4,-2.25,0,3.25,0,-1.0}<CR>	:Send({4,1,1,4,-2.25,0,3.25,0,-1.0})

Command 5 Data Control

This command selects the type of data to be retrieved, as well as the starting and ending data points to be retrieved. This is the only command that requires "Get" statement to follow each Command 5 regardless of the host. Sampling must be completed before sending Command 5 to control the data. Before sending Command 5, do a Get statement to ensure that sampling is completed or send Command 7 to check the status and verify that sampling is completed. Data End must be greater than or equal to Data Begin (unless Data End = 0). Both DataBegin and DataEnd must be less than or equal to the number of samples reported in the status command.

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

Parameter List:

channel – *indicates which channel on which this command operates. The possible values are*

Channel number	Description
-1	Recorded time
0	Lowest active channel
1 – 4	Analog channels 1 through 4
11, 12	Sonic Channel 1, Sonic Channel 2
21, 22	Digital Input 1, Digital Input 2

Dataselect – indicates what conversion equation is to be applied to the desired channel. If Data Select = 0, 1, or 2 and Command 3 Filter = 1-6, data will be filtered according to the filter selected in Command 3. If Data Select = 3, 4,or 5; the filter setting in Command 3 will be ignored. Dataselect may have the following values

dataselect	Filter
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)

databegin – indicates which data point (or row) the data block should start. Any integer value from zero to the last data point collected may be used. If this value is zero (0), the first data point collected will be used to mark the beginning of the data. This parameter persists until LabPro receives a Command 0 (Reset), Command 3 (Data Collection Setup), or another Command 5 (Data Control). Hence subsequent Get statements will return data with this *databegin* as the starting point.

dataend – indicates which data point (or row) the data block should end at. Any integer value from zero to the last data point collected may be used. If this value is zero (0), the last data point collected will be used to mark the ending of the data. This parameter persists until LabPro receives a Command 0 (Reset), Command 3 (Data Collection Setup), or another Command 5 (Data Control). Hence subsequent Get statements will return data with this *dataend* as the ending point.

step – every nth point starting with first point in window. This first occurred in firmware 6.06227. If your LabPro firmware is pre 6.06227, do not include this parameter. This parameter persists until LabPro receives a Command 0 (Reset) or another Command 5 (Data Control). Hence subsequent Get statements will return data every *n* points. A new Command 3 (Data Collection Setup) will not reset this parameter as it does with the two former parameters.

Return values: No information is returned until the next get command.

Example 1: Get all filtered, raw unfiltered data collected on analog channel 1. In the case of the calculator, store the data in list L1. Then, look at the data in rows 1 through 7.

Computer	Calculator
s{5,1,3,0,0}<CR>	:Send({5,1,3,0,0})
g<CR>	:Get(L1)
s{5,1,3,1,7}<CR>	:Send({5,1,3,1,7})
g<CR>	:Get(L1)

In a terminal session, the host-LabPro conversation appears as follows:

Host	LabPro
s{0}	
s{1,1,14,0}	
s{3,0.02,11,0}	
g	{ +2.31502E+00, +2.31868E+00, +2.32234E+00, +2.32479E+00, +2.32723E+00, +2.21734E+00, +1.81319E+00, +1.48230E+00, +1.21368E+00, +9.92674E-01, +8.11966E-01 }
s{5,1,3,0,0}	
g	{ +2.31502E+00, +2.31868E+00, +2.32234E+00, +2.32479E+00, +2.32723E+00, +2.21734E+00, +1.81319E+00, +1.48230E+00, +1.21368E+00, +9.92674E-01, +8.11966E-01 }
s{5,1,3,1,7}	
g	{ +2.31502E+00, +2.31868E+00, +2.32234E+00, +2.32479E+00, +2.32723E+00, +2.21734E+00, +1.81319E+00 }

Command 6 System Setup

This command can be used to turn sound on or off, set an ID number for LabPro, and select a filter to be applied to data.

Syntax: {6,*syssetup[, parm]*}

Parameter List:

syssetup – indicates which channel on which this command operates. The possible values are

syssetup	Description
0	Abort Sampling
1	* Undefined *
2	Abort Sampling
3	Turn sound off
4	Turn sound on
5	Sets an ID number for LabPro
6	Selects a filter to be applied to data

parm – If syssetup has the value of 5, parm may be any floating point number between -10^{38} to $+10^{38}$which sets the ID number for LabPro. This ID is used to identify a specific LabPro when multiple units are linked together or attached to a single computer. If syssetup has the value of 6, parm may have any value from zero (0) to six (6). Parm is the number of the filter to be applied as specified by Command 3.

Return values: No information is returned.

Example 1: Turn off LabPro sound.

Computer	Calculator
S{6,3}	:Send({6,3})

Command 7 Request System Status

This command returns LabPro's 17 status registers.

Syntax: {7}

Return values: The following information is returned.

Register	Description
softwareID	Current software ID in format: X.MMmms where X=product code number, MM=major ID number, mm=minor ID number, and s=step ID number.
error	If non-zero, LabPro should be reset and the cause of the error corrected.
battery	Battery status. Can return the following values: 0 Battery is OK for use 1 Battery is low during sampling 2 Battery is low all the time
8888	Constant value. If the correct list location is set to zero prior to requesting and getting the list, this value can be used to ensure that the status message was received correctly.
Sample time	Sample time that was commanded by the host during the last sample run.
trigger condition	Triggering condition that was commanded by the host during the last sample run.
channel function	Triggering channel that was commanded by the host during the last sample run.
channel post	Post-processing setting that was commanded by the host during the last sample run.
channel filter	Filter that was commanded by the host during the last sample run.
num samples	Number of samples that was commanded by the host during the last sample run. If sampling was aborted, this parameter reflects the actual number of samples taken.
record time	This can have the following values: 0 No time was recorded in the last run 1 Absolute time was recorded in the last run 2 Relative time was recorded in the last run
temperature	Temperature used for the temperature correction of the sonic data during the last run if a sonic sensor was selected.
piezo flag	This is the buzz/no-buzz value that was last commanded. Values are: 0 Sound is disabled (OFF) 1 Sound is enabled (ON)
system state	The following values are used for the system state: 1 Idle 2 Armed 3 Busy 4 Done 5 Self-test 99 Initializing code Add 16 to the value if the last mode was QuickSetup. Add 32 to the value if the last data collected has not yet been retrieved.
datastart	First point of data available for transmission to the host unless the host has sent Command 5 to override this value.
dataend	Last point of data available for transmission to the host unless the host has sent Command 5 to override this value.
System ID	The System ID that was set using Command 6.

Example 1: Request LabPro's system status registers.

Computer	Calculator
s{7}	:Send({7}) :Get(L1)

In a terminal session, the host-LabPro conversation appears as follows:

Host	LabPro
s{0}	
s{7}	{ +6.01120E+00, +0.00000E+00, +0.00000E+00, +8.88800E+03, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +1.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00}
s{4,2,5,0,1}	
s{7}	{ +6.01120E+00, +0.00000E+00, +0.00000E+00, +8.88800E+03, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +1.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00}
s{3,10,61,0,0,0,0,0,2}	
s{7}	{ +6.01120E+00, +3.10000E+01, +0.00000E+00, +8.88800E+03, +1.00000E+01, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +6.10000E+01, +2.00000E+00, +0.00000E+00, +0.00000E+00, +1.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00}

After the Command 3 was issued, the computer indicated an error by beeping 3 times. Command 7 is used to see the error value, in this case, error 31. Looking the Error code appendix, error 31 means that Command 3 was sent prior to performing any channel setups. However, the command was accepted and LabPro can collect data every 10 seconds for 600 seconds and apply a Savitzsky-Golay 9-point filter.

Command 8 Request Channel Status

This command is used during data collection to read the operation or sensor type, the last valid data point and the number of samples collected. Calculators must use the "Get" command to retreive this information. Using this does not interfere with the active data collection.

Syntax: {8,*channel, reqtype*}

Parameter List:

channel – *indicates which channel on which this command operates. The possible values are*

Channel number	Description
1 – 4	Analog channels 1 through 4
11, 12	Sonic Channel 1, Sonic Channel 2

reqtype – *determines whether the current sampled data is returned (reqtype = 0) or the data stored when channel was last setup (reqtype = 1.)*

Reqtype value	Description
0	current sampled data is returned
1	previously sampled data is returned

Return values: Three values are returned – *operation*, *lastdata* and *lastposn*. Calculators must send a Get to retrieve these values.!!!Need to add info about –999.

operation = same *operation* used in Command 1

lastdata = last valid data read from sensor, if any. This is not applicable to CH1 with operations 5, 6, 7; CH21 Digital In; or CH31 Digital Out.

lastposn = last valid data position or the sample number where stored in the resulting list.

Example 1: Get the last sampled data collected. In the case of the calculator, store the data in list L1.

Computer	Calculator
s{8,1,0}<CR> g<CR>	:Send({8,1,0}) :Get(L1)

In a terminal session, the host-LabPro conversation appears as follows:

Host	LabPro
s{1,14,1}	
s{3,0.5,21,0}	
s{8,1,0} *sent after the 6th data point was collected*	{ +0.00000E+00, ***+2.24176E+00***, +6.00000E+00 }
g	{ +2.14530E+00, +3.32112E-01, +2.30891E+00, +1.70085E+00, +1.10256E+00, ***+2.24176E+00***, +2.44200E-01, +2.32357E+00, +2.02076E+00, +5.44567E-01, +2.29060E+00, +1.29670E+00, +1.81441E+00, +2.18071E+00, +2.69841E-01, +2.31502E+00, +1.81929E+00, +8.96215E-01, +2.26007E+00, +6.28816E-01, +2.32723E+00 }

The values returned from the Command 8 line show that during data collection, point 6 was the last valid measured row.

Command 9 Request Channel Data

This command requests one data point before sampling starts. Used to verify that setup is correct.

Syntax: {9,*channel, mode*}

Parameter List:

channel – *indicates the channel on which this command operates. The possible values are*

Channel number	Description
1 – 4	Analog channels 1 through 4
11, 12	Sonic Channel 1, Sonic Channel 2

mode – *chooses between present setup or setup for previously collected run. This allows sensors to be disconnected after run is completed but still able to retrieve auto ID value.*

Reqtype value	Description
0	Re-tests the channel for AutoID value
1	returns the stored AutoID value

Return values: one value is returned – current sensor value (curval). Calculators must send a Get to retrieve these values.

curval = immediate value of sensor which was setup in requested channel.

Example 1: Retest the analog channel 1 for a smart sensor. In the case of the calculator, store the data in list L1.

Computer	Calculator
s{9,1,0}<CR>	:Send({9,1,0}) :Get(L1)

In a terminal session, the host-LabPro conversation appears as follows:

Host	LabPro
s{9,1,0}	{ +1.94383E+00 }
s{9,1,0}	{ +1.70452E+00 }
s{9,1,1}	{ +1.84005E+00 }
** Change to Barometer sensor **	
s{9,1,0}	{ +2.19536E+00 }
s{9,1,0}	{ +2.19536E+00 }
s{9,1,0}	{ +2.19536E+00 }

Command 10 Advanced Data Reduction

This command sets up LabPro to process certain time-intensive algorithms instead of processing them in the host. This allows large data sets to be processed much more quickly.

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

Parameter List:

channel – *indicates the channel on which this command operates. The possible values are*

Channel number	Description
1 – 4	Analog channels 1 through 4

alg – *algorithm to process..*

Alg value	Description
1	At the time this document was written, only the HeartBeat algorithm which works as follows: 1. LabPro starts by finding the maximum and minimum points of the data set. The lower threshold is set at P1 percent of the maximum point, and the upper threshold is set at P2 percent of the minimum point. 2. LabPro checks the difference between the maximum point and minimum point against P3. If the difference is less than P3, the algorithm is aborted and a 0.0 is returned. (This is the case where the user expected the input data to have a certain variation but, for some reason, the variation was not found.) 3. LabPro then finds the number of "rising edges" where the data in the data set is increasing from below the upper threshold and the number of "falling edges" where the data is decreasing to below the lower threshold. The total number of rising edges and falling edges is stored. 4. Next LabPro determines how many samples are between the first edge and the last edge. The frequency is then determined as the number of edges divided by the number of samples and is returned to the host. 5. The user program is responsible for taking the result from LabPro and dividing it by the sample time to get the true frequency in Hz.

P1 – *value determines when data transitions from "high" to "low." This value can be an integer between zero (0) and one hundred (100) corresponding to 0 to 100 percent of the lower threshold.*

P2 – *value determines when data transitions from "low" to "high." This value can be an integer between zero (0) and one hundred (100) corresponding to 0 to 100 percent of the lower threshold. P2 must be greater than P1.*

P3 – *value determines the minimum difference in data between UpperThld and LowerThld. This value can be a real value in the units of the channel selected.*

Return values: The value returned is result of the algorithm's calculation.

Example 1: Determine the frequency of a periodic signal on analog channel 1 from a 5000 point block of data collected at 50 points per second. P1 is set to 10% of the lower threshold, P2 is set to 10% of upper threshold and P3 is set to 0.5 volts.

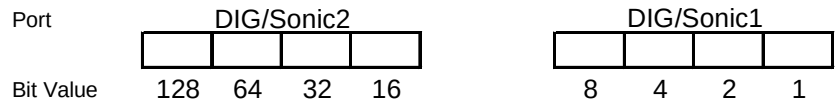
Computer	Calculator
s{1,1,14,0,0,0}<CR> s{3,0.02,5000,0,0,0,0,0,0,0}<CR> s{10,1,1,10,20,0.05}<CR>	:Send({1,1,14,0,0,0}) :Send({3,0.02,5000,0,0,0,0,0,0,0}) :Send({10,1,1,10,20,0.05}) :Get(Rate)

Freq = Rate / SampleInterval = Rate / 0.02

Command 12 Digital Data Capture

This command sets up the capture of data from the digital input channels. The digital lines are electrically "pulled" high so that the LabPro digital lines have a default state. Each DIG/SONIC port consists of four digital lines. Command 12 reads a single line of each DIG/SONIC port. Figure 1 illustrates how the digital lines are physical mapping. When Command 12 is used, the power generally stays on during sampling. As a result, this mode tends to deplete the batteries very quickly. The number of data samples taken is limited only by the available memory after memory is reserved for the Command 1 channels that are set up. LabPro has about 12,000 available memory locations. If X channels are setup and Y samples are selected using Command 3, the number of samples on CH 41 is limited to (12,000 – X*Y)/3.You absolutely must have at least one analog channel activated before sending the Command 3 to start sampling.

Syntax:{12, channel, mode[, P1[, P2]]}



Parameter List:

channel – indicates which channel to work with. The possible values are

Channel number	Description
41	DIG/SONIC Channel 1
42	DIG/SONIC Channel 2

mode – indicates what type of digital data collection to perform. The possible values are

mode	Use
-2	Returns a list of numbers based on collection mode (>0), {see individual collection modes for definition of list} *P1* and *P2* are the data row indices, or *Start* and *Stop* position for a block of data (see below).
-1	Returns a list of numbers based on collection mode (>0), {see individual collection modes for definition of list} *P1* and *P2* are the data row indices, or *Start* and *Stop* position for a block of data (see below).
0	return number of points collected on next get statement; *send after "getting" the analog channels*
1	Sample Mode This mode is used when none of the other modes (below) are useful. In this mode, each time the data changes, it is recorded in LabPro. This allows for any new digital probes to be used if the user is willing to write the program to process the data. Mode –2 will return a list of times and Mode –1 will return a list of final line states.
2, 3	Measures pulse width of the data on the DIG/SONIC channel. This mode is used with a photogate to get very accurate measurement of the time a photogate is blocked. Generally, this measurement is used to determine the speed of an object (must know object's length). Mode –2 will return a list of times and Mode –1 will return a list of pulse widths based on the Direction indicated by parameter P1 (see below).
4	Measures period of the data on the DIG/SONIC channel. This mode is used with a photogate to get very accurate measurement of the times between when the photogate becomes blocked. Generally, this measurement is used to determine the speed of a wheel or a picket fence or the period of a pendulum. Mode –2 will return a list of times and Mode –1 will return a list of cycle widths.

5	Counts transitions on the D0 input line of the Digital input port. This mode is used when the frequency of a source with a TTL (or CMOS compatible) output must be measured. Mode –1 will return a list of counts. Mode –2 is invalid in this context.
6	Vernier Rotary Motion sensor. Generally this indicates the position of a wheel on the sensor. Mode –1 will return the position of the rotary motion sensor, scaled as indicated by P1 (see below). Mode –2 is invalid in this context.

P1 –During the setup of a mode this parameter can indicate the desired direction of the digital signal or the scale factor of a rotary motion sensor. During the request of a block of data this indicates which row is to be the start of the data block.

Direction	Use (only with mode 2 or 3)
0	Low Active Pulse width is the time between a high-low transition and the next low-high transition, or the time a photogate is un-blocked.
1	High Active Pulse width is the time between a low-high transition and the next high-low transition, or the time a photogate is blocked.
Scale Factor	Use (only with mode 6)
0	Low Resolution rotary motion.
1	High Resolution rotary motion (4 x Low Resolution).
Data Start	Use (only with mode –2 or –1)
0 or integer N.	Start indicates which data point (or row) the data block should start at. Any integer value from zero to the last data point collected may be used. If this value is zero (0), the first data point collected will be used to mark the beginning of the data.

P2 – Only used when requesting a block of data (mode of –2 or –1). This parameter indicates which data point (or row) the data block should start at. Any integer value from zero to the last data point collected may be used. If the default value of zero (0) is used, the last data point collected will be used to mark the end of the data.

When used with mode 6, P2 is a Reset Inhibit (0 = count is reset to 0 on each new data collection, 1 = count is not reset.) Valid first on firmware version 6.06228.

Return values: The value returned is result of the algorithms calculation.

Example 1: Determine how many transitions have occurred on the D0 line.

Computer	Calculator
s{12,41,0}<CR>	:Send({12,41,0}) :Get(CNT)

Host	LabPro
s{12,41,0}	{ +1.71000E+02 }

Example 2: Sample Digital Inputs

To illustrate digital input sampling, LabPro will be told to monitor both digital inputs for 10 seconds.

Host	LabPro
s{0}<CR> s{1,1,14,0}<CR> s{12,41,1}<CR>	

s{12,42,1}<CR>	
s{3,10,2,0}<CR>	
s{12,41,0}<CR>	{ +2.00000E+00 }
s{12,42,0}<CR>	{ +2.00000E+00 }
s{12,41,-2}<CR>	{ +2.40160E+00, +5.04500E+00, }
s{12,42,-2}<CR>	{ +3.80320E+00, +5.92310E+00, }
s{12,41,-1}<CR>	{ +0.00000E+00, +1.00000E+00, }
s{12,42,-1}<CR>	{ +0.00000E+00, +1.60000E+01, }

At each transition of the digital inputs, the absolute time and state of the inputs is reported (See Figure 3.) This command can be run at the same time as analog sampling. The digital inputs are sampled 10,000 times/second. Each time a change in the input bits is found, the time and the new value are written to a data buffer area. When the data buffer area overflows, data collection is halted and an error message is sent.

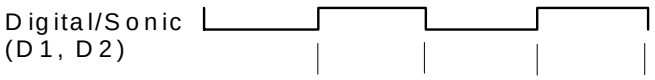


Figure 3. Digital Input Measurement

The input lines can only have a value of zero or one. DIG/SONIC1, the return values will be 0 or 1. DIG/SONIC2 being part of the upper 4-bits of the digital port will produce a 0 or 16. Each transition stored takes two data point locations – one for final state and one for time.

Example 3: Pulse Measurement

To illustrate its use, both ports will be used to monitor the time each time the photogates are blocked by the opaque bars on a Vernier Picket Fence.

Host	LabPro
s{0}	
s{7}	{ +6.01510E+00, +0.00000E+00, +0.00000E+00, +8.88800E+03, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +0.00000E+00, +3.30000E+01, +0.00000E+00, +0.00000E+00, +0.00000E+00}
s{1,1,14}	
s{12,41,2,1}	
s{12,42,2,1}	
s{3,10,2,0}	
s{12,41,0}	{ +8.00000E+00 }
s{12,42,0}	{ +8.00000E+00 }
s{12,41,-1}	{ +8.00000E+00 }
s{12,41,-1,0}	{ +2.90216E-02, +1.86400E-02, +1.48272E-02, +1.27016E-02, +1.13012E-02, +1.02400E-02, +9.50120E-03, +8.80680E-03, }
s{12,42,-1,0}	{ +1.42016E-02, +1.23008E-02, +1.09260E-02, +1.00016E-02, +9.30120E-03, +8.69040E-03, +8.13120E-03, +7.73720E-03, }
s{12,41, 2,0}	{ +2.80860E+00, +2.85100E+00, +2.88340E+00, +2.91070E+00, +2.93470E+00, +2.95630E+00, +2.97630E+00, +2.99480E+00, }
s{12,42, 2,0}	{ +2.88840E+00, +2.91500E+00, +2.93850E+00, +2.95990E+00, +2.97960E+00, +2.99790E+00, +3.01510E+00, +3.03140E+00, }

This mode is designed to measure the widths of pulses in a continuous stream of pulses. The Sonic Timer is used to record the time of the rising and falling edges. The resolution is 1.6 µsec. At the start of the pulse the time is recorded and again at the end of the pulse. The difference (properly scaled) is returned to the host. Continuous Pulse Mode may be used to measure either pulses in the high state as shown in Figure 4 or pulse in the low state. This is chosen by setting the *start* parameter to 1 or 0, respectively.

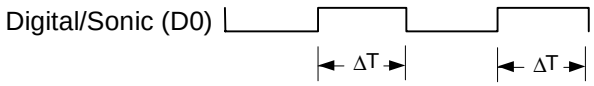


Figure 4. Continuous Pulse Period Measurement

Example 4: Period measurement

Host	LabPro
s{1,1,14}	
s{12,41,4}	
s{3,10,2,0}	
s{12,41,0}	{ +0.00000E+00 }
s{3,-1}	
s{12,41,0}	{ +2.00000E+00 }
s{12,41,-2,0}	{ +2.20510E+00, +5.36730E+00, }
s{12,41,-1,0}	{ +2.20506E+00, +3.16224E+00, }

This mode is designed to measure the periods of pulses in a continuous stream of pulses. The period of the pulse stream is measured beginning with either a high to low transition as shown in Figure 5 or a low to high transition. This is chosen by setting the *P1* parameter to 1 or 0, respectively. The Sonic Timer is used to record the time of the rising and falling edges. The resolution is 1.6 µsec. At the start of the pulse the time is recorded and again at the end of the pulses. The difference (properly scaled) is returned to the host.

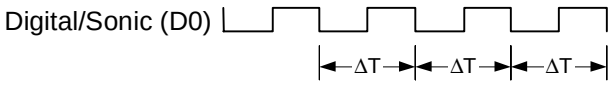


Figure 5. Continuous Pulse Period Measurement

To illustrate the point, LabPro will be set to measure period of the pulses on the photogate connected to DIG/SONIC1 port. On the first pass, the photogate will transition from unblocked to blocked during the ten second sample period which should produce no samples because no complete cycles were completed. The second pass shows two periods were measured when the photogate was twice blocked and unblocked and finally blocked. Finally, the times that all the transitions began are retrieved with the {12, 41,-2,0} command and the all the period lengths are returned with the {12,41,-1,0} command.

Example 5: Counter Mode using the command {12,41,5}

This mode is designed to count the transitions on the DIGITAL input line. The D0 line must be used for the input. The Sonic Timer is re-configured as a counter and will count the input transitions. The transitions count is limited to 65535 transitions per cycle. The cycle time is the same as the sample time. In other words, one count will be returned for each analog sample returned.

To illustrate it's use, LabPro will be programmed to count pulses for five, one-second intervals while a super pulley spins down (the spokes block the photogate beam.)

Host	LabPro
s{1,1,14}	
s{12,41,5}	
s{3,1,6,0}	
s{12,41,0}	{ +5.00000E+00 }
s{12,41,-1,0}	{ +5.90000E+01, +4.80000E+01, +3.70000E+01, +2.70000E+01, +1.90000E+01, }

Example 6: Rotary Motion Mode using the command {12,41,6,scalefactor}

Host	LabPro
s{1,1,14}	
s{12,41,6,1}	
s{3,1,10,0}	
s{12,41,0}	{ +1.00000E+01 }
s{12,41,-1,0}	{ -3.36000E+02, -3.31500E+03, -5.63200E+03, -7.38700E+03, -8.67000E+03, -9.57900E+03, -1.01930E+04, -1.05800E+04, -1.07980E+04, -1.08850E+04, }
s{3,-1}	
s{12,41,-1,0}	{ +1.10000E+01, +1.14000E+02, +2.06000E+02, +2.92000E+02, +3.72000E+02, +4.42000E+02, +5.00000E+02, +5.47000E+02, +5.87000E+02, +6.24000E+02, }
s{12,42,6,0}	
s{3,-1}	
s{12,42,-1,0}	{ -2.10000E+01, -2.09000E+02, -3.89000E+02, -5.58000E+02, -7.21000E+02, -8.72000E+02, -1.01700E+03, -1.15100E+03, -1.27600E+03, -1.39500E+03, }

This mode is designed to measure the position of a rotary motion sensor. Rotational motion information is determined by counting clockwise and counterclockwise signals from the Vernier Rotary Motion Sensor as shown in Figure 6. The resolution of the rotary motion sensor can be set to high or low where low resolution is one-fourth that of high resolution. This is chosen by setting the *P1* parameter to 1 or 0, respectively.

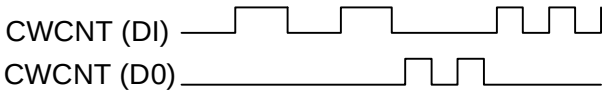


Figure 6. Rotary Motion Mode

Each rising edge of the CWCNT (D1) line will cause the position to be incremented by 1. Each rising edge of the CCWCNT (D0) line will cause the position to be decremented by 1. Only a 32-bit counter will be used, giving a count range from –(2^31) to (2^31)-1.

Unlike the previous modes, one data point will be saved for each sample. Sampling will be commanded by the normal Command 3.

The following illustrates the counterclockwise (increasing negative values) and clockwise motions (increasing positive values). The rotary motion detector will then be connected to DIG/SONIC2 and the pulley spun counterclockwise.

Command 102 Port Power Control Command

This command controls how the LabPro powers the analog and DIG/SONIC ports.

Syntax: {102,pwrctl}

Parameter List:
pwrctl – *determines how power is used in LabPro*

pwrctl value	Description
-2	Always ON; will automatically power down if running on batteries. Leaves power to the sensor ports on at all times. This is valid for LabPro version 6.06210 and newer.
0 1 - 999	Normal mode; "power save mode" Specifies when power comes on relative to the time a data point is to be taken. This number specifies the number of seconds before the reading when power is turned on.

Return values: No information is returned.

Example 1: Turn the LabPro on and leave it on as you might before controlling the digital lines or outputting a voltage.

Computer	Calculator
s{102,-2}	:Send({102,-2})

Command 105 Baud Rate Selection

New in firmware version 6.06200, this command controls the baud rate of the RS-232 serial port. Only hard reset or {105,38} returns the baud rate to 38400. This command has no effect on calculators.

Syntax: {105,baudrate}

Parameter List:
pwrctl – determines how power is used in LabPro

baudrate value	Description
38	38,400 baud
115	115,200 baud.

Return values: An “OK” is returned when this command is received and just before changing timers.

Example 1: Set the baud rate for the LabPro first to 115,200 baud then back to 38400 baud.

Host	LabPro
s{105,115}	OK
s{105,38}	OK

Command 106 Motion Detector Undersample Rate

New in firmware version 6.06227, this command controls the rate at which motion detector data is collected while not effecting the rate at which analog data is collecting. This is also known as "Collision Mode" as an accelerometer can be read at a rate of 1000 per second and a motion detector at a rate of 10 per second. When collecting data this way, data at times between motion samples will have a value of 0.0000. The first motion detector reading is taken after *rate* points.

Syntax: {106,channel,rate}

Parameter List:

channel – determines how power is used in LabPro

channel value	Description
11, 12	Channel to which the motion detector is attached.

rate – divisor for analog rate set in command 3

rate value	Description
<=0	Invalid
1	Resets the command
2 - 1024	Number of analog samples minus one between motion detector samples

Return values: No information is returned.

Example 1: Record one motion detector sample every 100 analog points. Collect analog samples for 3 seconds at 1000/second. Put the analog data in list L1, distance data in list L2 and time in list L3.

Computer	Calculator
s{0}	:Send({0})
s{1,1,1}	:Send({1,1,1})
s{1,11,1}	:Send({1,11,1})
s{106,11,100}	:Send({106,11,100})
s{3,0.001,300)	:Send({3,0.001,300})
g	:Get({L1})
g	:Get({L2})
g	:Get({L3})

Command 107 Oversampling Burst

New in firmware version 6.06227, this command controls the oversampling of data for slower rates of data collection. Currently it works with all available analog channels and will not work if a sonic channel is enabled. For best results, the minimum allowed sample interval sent in Command 3 is 0.2 seconds per sample. Also, the duration of an oversampling burst should not exceed ½ of the sample interval sent in Command 3.

Syntax: {107,rate,samples}

Parameter List:

rate – *sample interval for oversampling bursts*

rate value	Description
0.0001 – 16,000	Interval between samples in each burst.

samples – *number of samples to take at high rate. These samples are averaged to produce a valid data point*

Samples value	Description
0	Turn off the oversampling burst. Oversampling burst is also turned off if a Command 0 (Reset) is sent.
1 – 12,000	Number of samples to be taken in each burst.

Return values: No information is returned. Data is retrieved as normal after data collection is completed.

Example 1: Collect data twice a second for one minute, where each recorded sample is the average of an oversampling burst consisting of 100 samples at 1000 sample/second (0.001 seconds/sample).

Computer	Calculator
s{0}	:Send({0})
s{1,1,1}	:Send({1,1,1})
s{107,0.001,100}	:Send({107,0.01,100})
s{3,0.5,120,0)	:Send({3,0.5,120,0})
g	:Get({L1})
g	:Get({L2})

Command 115 Request Set-up Information

This command is only used to request the setup information for the Auto-ID sensor on a desired channel.

Syntax: {115,*channel*}

Parameter List:

channel – *indicates which channel on which this command operates. The possible values are*

Channel number	Description
1 – 4	Analog channels 1 through 4
11, 12	Sonic Channel 1, Sonic Channel 2

Return values: The following information is returned.

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

Example 1: Request LabPro's system status registers. In the case of the calculator, store the data in list L1.

Computer	Calculator
s{115,1}	:Send({115,1}) :Get(L1)

In a terminal session, the host-LabPro conversation appears as follows (changing probes after every Command 116):

Host	LabPro
s{1,1,1,0}	
s{116,1}	"BAROMETER(KPA) "
s{115,1}	{ +4.00000E+00, +4.00000E+00, +8.00000E+01, +1.10000E+02, +5.00000E+00, +6.00000E+02, +1.80000E+02, +1.40000E+01, +1.00000E+00, +0.00000E+00, +8.19520E+01, +7.80000E+00, +0.00000E+00, +2.00000E+00, +0.00000E+00 }

Command 116 Request Long Sensor Name

This command returns the long sensor name in a format the calculator can handle. This command requires the channels of interest be initialized first with Command 1 (e.g., s{1,1,1}). This command is only used with an Auto-ID sensor on a desired channel.

Syntax: {116,*channel*}

Parameter List:
channel – *indicates which channel on which this command operates. The possible values are*

Channel number	Description
1 – 4	Analog channels 1 through 4
11, 12	Sonic Channel 1, Sonic Channel 2

Return values: This command returns a 20 character string that can be read by a calculator.

Example 1: Request the sensor name (long form) of the Auto-ID sensor on analog channel 1. In the case of the calculator, store the data in variable LN.

Computer	Calculator
s{116,1}	:Send({116,1}) :Get(LN)

In a terminal session, the host-LabPro conversation appears as follows (changing probes after every Command 116):

Host	LabPro
s{116,1}	"VOLTAGE 0 TO 5(V) "
s{1,1,1,0}	
s{116,1}	"PH "
s{1,1,1,0}	
s{116,1}	"MICROPHONE "
s{1,1,1,0}	
s{116,1}	"BAROMETER(KPA) "

Command 117 Request Short Sensor Name

This command returns the short sensor name in a format the calculator can handle. This command requires the channels of interest be initialized first with Command 1 (e.g., s{1,1,1}). This command is only used with an Auto-ID sensor on a desired channel.

Syntax: **{117,*channel*}**

Parameter List:
channel – indicates which channel on which this command operates. The possible values are

Channel number	Description
1 – 4	Analog channels 1 through 4
11, 12	Sonic Channel 1, Sonic Channel 2

Return values: This command returns a 12 character string that can be read by a calculator.

Example 1: Request the sensor name (short form) of the Auto-ID sensor on analog channel 1. In the case of the calculator, store the data in variable SN.

Computer	Calculator
s{117,1}	:Send({117,1}) :Get(SN)

In a terminal session, the host-LabPro conversation appears as follows (changing probes after every Command 117):

Host	LabPro
s{1,1,1,0}	
s{117,1}	"VOLTAGE(V) "
s{1,1,1,0}	
s{117,1}	"PH "
s{1,1,1,0}	
s{117,1}	"MICROPHONE "
s{1,1,1,0}	
s{117,1}	"BARO(KPA) "

Command 119 Request Alternate Calibration

This command returns the short sensor name in a format the calculator can handle. This command requires the channels of interest be initialized first with Command 1 (e.g., s{1,1,1}). This command is only used with an Auto-ID sensor on a desired channel.

Syntax: {119,*channel,altcalib*}

Parameter List:
channel – *indicates which channel on which this command operates. The possible values are*

Channel number	Description
1 – 4	Analog channels 1 through 4
11, 12	Sonic Channel 1, Sonic Channel 2

Return values: This command returns

Example 1: Request LabPro's system status registers. In the case of the calculator, store the data in list L1. If the number of calibrations is not zero, one of the alternate calibrations can be selected.

Computer	Calculator
s{115,1}	:Send({115,1})
	:Get(L1)
s{119,1,1}	

In a terminal session, the host-LabPro conversation appears as follows (changed parameters are **bold**):

Host	LabPro
s{1,1,1,0}	
s{116,1}	"FORCE PLATE 250(N) "
s{115,1}	{ +6.00000E+00, +6.00000E+00, -2.50000E+02, +8.00000E+02, +2.62500E+02, +2.00000E-02, +1.80000E+02, +1.40000E+01, +1.00000E+00, +0.00000E+00, **-2.50000E+02, +2. 50000E+02**, +0.00000E+00, +2.00000E+00, **+0.00000E+00** }
s{119,1,1}	
s{116,1}	"FORCE PLATE 250(LB) "
s{115,1}	{ +6.00000E+00, +6.00000E+00, -2.50000E+02, +8.00000E+02, +2.62500E+02, +2.00000E-02, +1.80000E+02, +1.40000E+01, +1.00000E+00, +0.00000E+00, **-5.62020E+01, +5.62020E+01**, +0.00000E+00, +2.00000E+00, **+1.00000E+00** }

Command 201 Archive Operations Command

This command allows the host to manage the contents of *FLASH* memory. The content of FLASH memory is semi-permanent in that it will not be altered unless the user chooses to do so. *FLASH* memory will remain in tact even if power to LabPro is lost. With this command one can store, retrieve or erase calculator programs, lists of data or entire data sets to and from the *FLASH* memory. The DataMate program can already manage saved experiments (lists and data sets in the *FLASH* memory), and the DataDir program can be used to manage calculator programs stored in *FLASH* memory and allow you to perform a memory cleanup or Garbage Collection.

Syntax: {201, *operation[, operand1, operand2[, relinfolist]]*}

operation	Description	operand 1[1]	operand 2[1]	relinfolist[2]
0	Delete/Write Enable	Not used, set to zero (0)	Not used, set to zero (0)	2.46802 = enable writing data to FLASH 1.35791 = enable deletion of data from FLASH
1*	Get	Not used, set to zero (0)	Not used, set to zero (0)	Calculator type[3]
2*	Get directory information	Directory type[4] (except Saved Program)	n	N/A
3*	Get directory Label (n) [5]	Directory type[4]	n	Calculator type[3]
4	Label directory entry [6]	Directory type[4] (except Saved Program)	n	N/A
11	Clear directory entry (n)	Directory type[4]	n	Calculator type[3]
12	Clear all directory entries	Directory type[4]	Not used, set to zero (0)	Calculator type[3]
13	Clear all built-in user programs[7]	Not used, set to zero (0)	Not used, set to zero (0)	Calculator type[3]
21	Save current data set†	Not used, set to zero (0)	Not used, set to zero (0)	Ident 1 Ident 2[8]
22	Close data set (n)	n	N/A	N/A
23	Restore data set (n)	n	N/A	N/A
24	Save data set supplemental list (n) [9]	n	Starting position to store in archive	List data (maximum 40 elements)
25*	Get data set supplemental list size (n)[9]	n	Not used, set to zero (0)	N/A
26*	Retrieve data set supplemental list (n)[9]	n	Starting position (default = 1)	Number of elements (default = 0 {all})
31	Allocate saved list†	Number of elements in list	Not used, set to zero (0)	Ident 1 Ident 2[8]
32	Save list data (n)	n	Starting position to store in archive	List data (maximum 40 elements)
33	Close list (n)	n	N/A	N/A
34*	Get list size (n)	n	N/A	N/A
35*	Retrieve List (n)	n	Starting position	Number of elements

operation	Description	operand 1[1]	operand 2[1]	relinfolist[2]
			(default = 1)	(default = 0 {all})
41	Select programs[10]	Not used, set to zero (0)	Not used, set to zero (0)	First item is calculator type (73, 83, etc.) followed by items to retrieve
42	Deselect programs[11]	N/A	N/A	N/A
43	Retrieve supplemental programs[12]	N/A	N/A	N/A
1001	Perform garbage collection†	N/A	N/A	N/A

Notes:

[1] Operand information relating to whatever operation is being performed. (must be integer)
[2] Additional information about the operation to be performed.
[3] The Calculator Type specifies the model of the calculator on which the user program is running. This determines which programs in LabPro archive will be shown in the directory information. Available choices are: 73, 82, 83, 83.1 (for 83 Plus and 83 Plus Silver Edition), 86, 89, 92, and 92.1 (for 92 Plus).
[4] The Directory Type specifies the entries in the archive on which to perform the operation. Available choices are: 0 (Sample Data Set), 1 (Saved List), and 2 (Saved Program).
[5] If a directory entry does not have a label assigned to it, LabPro reports the label as '??????????????????????'.
[5,6] Because the TI-82, TI-89, TI-92, and TI-92 Plus do not receive string variables, the program names in the directory cannot be passed directly as strings. The Numeric List option in operation 3 provides an indirect way of representing the names. The list contains the ASCII code for each character in the name. These ASCII codes can be interpreted by the user program to display the correct letters on the calculator.
[6] Send a command with Operation 4 to set up label directory entry; then follow it with another command that contains the label.
[7] Built-in user programs: LabPro stores a collection of calculator programs (DataMate) and look-up tables in its *FLASH* memory. These programs are intended to simplify the task of data collection and analysis. Because these programs are designed to work together, they can only be stored and deleted as a group. To free up memory in LabPro, you can delete the programs for calculators that you do not use.
Upgrading User Programs: The *FLASH* Download software provides a way to update the user programs and lookup tables for all calculator platforms. The *FLASH* Download process automatically deletes all existing user programs (all calculator models) from the archive. The new look-up tables and programs are then installed into the archive. (Instructions for downloading new software are given on the TI web site at **www.vernier.com**.)
[8] Two optional identifying numbers can be used when saving a data set or list. These numbers are saved with the data in addition to the supplied label.
[9] Operations 24, 25, and 26 are provided to facilitate saving configuration information in the same data structure as a saved experiment, rather than in a separate file.
[10] Operation 41 allows you to retrieve programs saved on LabPro. You can save programs to LabPro by enabling writing {201,0,0,0,2.46802} and then sending programs from the calculator's LINK/SEND menu.
[11] Operation 42 cancels operation 41 or 43. If the TRANSFER key is not pressed within one minute, operations 41 and 43 cancel automatically.
[12] LabPro can store additional built-in programs in the same storage area as DataMate (for example, programs such as DataDir and DataGate). Because of memory space considerations, these supplemental programs are normally not transferred to the calculator with DataMate when the TRANSFER key is pressed. Operation 43 allows you to retrieve these supplemental programs by overriding the normal operation of the TRANSFER key.
General Notes:

- All data types are stored in LabPro directory in the same order in which they are received. LabPro does not attempt to sort these entries in any other order.
- If you transfer to LabPro a program with the same name as a program already in storage, the old program will be deleted and the new program will be added to the end of the directory. (A program with the same name but a different calculator model will not be affected.)
- The labels and numeric information for data sets and lists can be the same as other data sets and lists. LabPro does not check for duplicate descriptions. The uniqueness of the individual directory entries is preserved by their unique directory entry numbers.

*Operations that return values:
Some of the operations of the 201 command will prompt the LabPro to return values such as labels or list of information or data upon the next GET command. The format of the values returned is determined by the data type in the GET command.

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

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

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

Continue to send GET commands until LabPro returns the 0.

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

Example 1: Saving and Restoring a Data Set to FLASH memory

IMPORTANT: Before performing any operation which writes or deletes items in the *FLASH* memory, it is very important to check that the battery level of LabPro is sufficient. Use command {7} to do so. Also, operations 21, 31, and 1001 may cause LabPro to automatically perform garbage collection on the *FLASH* memory. Any program using these operations must be sure that garbage collection is complete before sending any further commands (note the 2 successive 'g' commands).
The following example saves and labels a data set. It then shows some of the commands that are used to see some aspects of the saved data set, and restore it from the LabPro *FLASH* memory.

Host	LabPro
s{201,1,0,0,83.1}	{ +3.00000E+00, +2.00000E+00, +0.00000E+00, +4.00000E+00, +9.90000E+01, +3.00000E+00, +3.00000E+00, +0.00000E+00, +4.25578E+05 }
s{201,0,0,0,2.46802}	
s{201,21,0,0,1706,2002}	
g	{ +2.00000E+00 }
g	{ +0.00000E+00 }
s{201,4,0,4}	
s{"DATA SET A1"}	
s{201,22,4}	
s{201,1,0,0,83.1}	{ +4.00000E+00, +2.00000E+00, +0.00000E+00, +4.00000E+00, +9.90000E+01, +3.00000E+00, +3.00000E+00, +0.00000E+00, +4.25578E+05 }
s{201,3,0,4}	{ "DATA SET A1" }
s{201,2,0,4}	{ +1.70600E+03, +2.00200E+03 }
s{201,23,4}	

Example 2: Retrieving a List from FLASH memory

Host	LabPro
s{201,1,0,0,83.1}	{ +3.00000E+00, +2.00000E+00, +0.00000E+00, +4.00000E+00, +9.90000E+01, +3.00000E+00, +3.00000E+00, +0.00000E+00, +4.25578E+05 }
s{201,3,1,2}	{ "TEMP B" }
s{201,34,2}	{ +1.00000E+01 }
s{201,35,2,1,5}	{ +2.97860E+01, +3.37623E+01, +3.39524E+01, +3.41190E+01, +3.28095E+01 }

Command 401 Analog Output Setup

This command sets up parameters to control the analog output driver in LabPro. The output voltage range is +/- 3 V with a current limit of 100 mA. The output voltage is determined by:

V_{out} = 0.0024*amplitude – 0.0012*offset where the result must satisfy –3V < Vout < 3V

The analog output is present on line 1 of CH4. Therefore the Voltage clips supplied with LabPro may be used to connect the analog output to external circuits. Since this analog out shares the CH4 V_{IN} pin, you may monitor the output voltage by using the {1,4,2} command. You may also monitor the current by assigning mode 22 to any other unused channel i.e. {1,3,22}.

Once the channel has been setup, the output is enabled immediately regardless of data collection mode. It will remain active until the unit is reset or until it is disabled using Command 401(reset turns off output in operating system later than 6.06211).

Using Command 401, the program is able to choose a waveform, amplitude, offset and period and the analog output will generate the desired waveform. Waveforms other than DC values are divided into steps of discrete values. The Square wave uses 2 steps per period. The Triangle wave uses 32 steps per period (16 steps up, 16 steps down). The Ramp Up, Ramp Down, and Sine waveforms also use 32 steps per period.

Notes about waveforms:

Only OFF and DC waveforms are operational in operating system version 6.06211 or earlier.

The amplitude parameter for sine waves is set to 4V (8Vpk-pk). The amplitude parameter may be used to indicate how many times to reduce this value in half. See examples for clarification.

Syntax: {401, *waveform, amplitude*, *offset, period*}

Parameter List: (note: all parameters are mandatory)

waveform – *indicates which waveforms will be generated. The possible values are*

waveform	Description
0	OFF
1	DC Output
2	Ramp Up (Sawtooth)
3	Ramp Down (Sawtooth)
4	Triangle
5	Square
6	Sine

amplitude – *indicates which height of the wave. The possible values are from 0 to 4095. See Sine examples for exceptions.*

offset – *indicates where the wave will be centered. The possible values are from 0 to 4095.*

period – *indicates how often (in milliseconds) the waveform will repeat itself. The number must be an integer between 5 and 2000. As a result, the range of possible frequencies is 0.5 Hz to 200 Hz.*

Return values: No information is returned. However, the output voltage will be produced as follows:

V_{out} = 0.0024*amplitude – 0.0012*offset where the result must satisfy –3V < Vout < 3V

Example 1:.

Computer	Calculator
s{}	:Send({})

Examples:

DC Voltage: The easiest way to produce a DC output is usually to control the amplitude and set the offset to 0 for positive values and control the offset and set amplitude to 0 for negative output values.

401,1,1023,0,0 Vout = 2.5V signal.
401,1,0,2048,0 Vout = –2.5V signal
401,1,1023,1023,0 Vout = 1.25 V signal

Ramp:

401,2,2048,2048,10 Vout = 100Hz ramp up pk-pk = 5V centered about 0
(pk voltage = 2*2048*1.2mV – 2048*1.2mV)
401,3,1023,0,20 Vout = 50Hz ramp down pk-pk = 2.5V centered about 1.25V

Sine

401,6,0,3072,10 Vout = 100Hz Sine wave pk-pk = 8V centered about 0
(pk voltage = 2*3072*1.2mV – 3072*1.2mV)
401,6,1,1536,10 Vout = 100Hz Sine wave pk-pk = 4V centered about 0
401,6,2,768,10 Vout = 100Hz Sine wave pk-pk = 1V centered about 0

NOTE: Sine wave may be improved by adding a low pass filter to output.

Turn off Analog Out:

401,0,0,0,0 NOTE: MUST PASS ALL PARAMETERS

Command 1998 Set LED Command

This command causes LabPro's LEDs to turn on or off.

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

Parameter List:

P1 – *indicates which LED to control The possible values are:*

P1	Color of Controlled LED
1	Red
2	Yellow
3	Green

P2 – *indicates the state of the LED- zero(0) for off and one(1) for on.*

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

Return values: No information is returned. However, LabPro's LEDs will turn on or off based on the command sent.

Example 1:Turn on Red LED.

Computer	Calculator
s{1998,1,1}	:Send({1998,1,1})

Command 1999 Sound Command

This command causes LabPro to vibrate its piezo speaker. The duration and frequency of the tones emitted from the LabPro's speaker determine the tune. The time base for the duration and the frequency of the tones is 100μs.

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

Parameter List:

length – *indicates the duration or how long the tone will be generated. The possible values are 1 to 255 in 100 μsec steps.*

Pd – *indicates the period of the tone. The possible values are 1 to 255 in 100 μsec steps.*

N – *number of tones that can be generated. The possible values are 1 to 32.*

Return values: No information is returned. However, the LabPro speaker will produce a tune.

Example 1: Have LabPro play *Mary Had a Little Lamb*.

Computer	Calculator
s{1999,1}	:Send({1999,1})

Command 2001 Direct Output to Digital-Out Port

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

- One to sixteen data points may be output. If more than one point is sent, all the points will be sent out at about 200 μsec intervals before the next command is parsed. This allows the LabPro to clock data into a latch with a single command.
- The output data goes to the DIG/SONIC channels. Therefore, sending this command while the sonic port is being sampled will corrupt the data.
- Sending this command does not stop the sampling, and it should not affect the analog channels.
-

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

Parameter List:
data1. . .dataN - Data values must be between 0-15. For values outside this range, behavior is undefined.

Return values: No information is returned. The output will be effective when sampling begins.

Example 1:Turn off all lines.

Computer	Calculator
s{2001,0}	:Send({2001,0})

Example 2:Turn on all lines.

Computer	Calculator
s{2001,255}	:Send({2001,255})

Example 3:Turn on first line of port1.

Computer	Calculator
s{2001,1}	:Send({2001,1})

Example 4:Turn on first line of port2.

Computer	Calculator
s{2001,16}	:Send({2001,16})

LabPro Hardware

Connector Pinouts

LabPro sensors use 6-pin British Telecom-style connectors. Pin-1 is always farthest from the tab.

Pin	Analog CH1, CH2, CH3	Analog CH4	DIG/SONIC1 & DIG/SONIC2	
	(Right-hand Connector)	(Right-hand Connector)	(Left-hand Connector) Sonic	Digital
1	Vin (-10 to +10 V)	Analog Out and/or Vin (+/- 5V only)	Echo	D0
2	Gnd	Gnd	Init	D1
3	Vres/Smart ID Data	Vres/Smart ID Data	Auto-ID	D2
4	Auto-ID/ Smart ID CLK	Auto-ID/ Smart ID CLK	+5 Volts DC	+5 Volts DC
5	+5 Volts DC	+5 Volts DC	Gnd	Gnd
6	Vin-low (0 to 5 V)	Vin-low (0 to 5 V)	Not Applicable	D3

	Vin	Vin-low
Channels:	CH1, CH 2, CH 3, CH 4	CH1, CH2, CH3, CH 4
Input signal:	Analog data	Analog data
Input range:	±10 Volts (CH1–3) ±5 Volts (CH4)	0 to 5 Volts
Resolution (using LabPro's $12-bit$ A/D converter):	4.9 mV	1.2 mV
Input impedance:	1.0 MΩ	>10 MΩ

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

Technical Specifications for LabPro

General Specifications

Power Requirements	6VDC reg, 600mA or 4AA Alkaline Batteries
Power Connection	2.1mm Power Jack, center negative
Physical Dimensions	8.4" x 3.3" x 1.2"(214mm x 84mm x 31mm)
Weight	280g (w/o batteries)
Environmental: Operating Temperature range Storage Temperature range Relative Humidity	 -40°C to 70°C -40°C to 85°C 0 to 95% noncondensing
Analog Channels CH1 – CH4	British Telcom 6 pin Right Hand socket
Digital Channels DIG1, DIG2	British Telcom 6 pin Left Hand socket
Power at sensor connectors	5.3VDC (nominal). 180mA max.

Analog Inputs

ADC Architecture	12-bit Successive Approximation ADC
Number of inputs	8 single ended inputs (2/analog connector)
Input ranges (CH1 – CH3)	0 - 5V, +/- 10V
Input ranges (CH4)	0 - 5V, +/- 5V
Resolution 0-5V inputs	1.2mV
Resolution +/-10V inputs	4.9mV
Max Sample rate	50,000 samples per second
Max Sample Storage	12k samples
Input impedance: 0 –5V input	>10MΩ
Input impedance: +/-10V input	1MΩ
Overvoltage protection	110V powered/unpowered.
Temperature Drift	100ppm/°C

Analog Inputs (Cont.)

DC Parameters	
Integral Nonlinearity	+/- 0.5 LSB
Differential Nonlinearity	+/- 1 LSB (no missing codes)
Offset Error	1 LSB
System noise	+/- 1 LSB
AC Parameters	
Input Bandwidth: 0-5V input	50kHz (f3dB)
Input Bandwidth: +/-10V input	5kHz (f3dB)

* For the Ch4 +/-5V input, use the +/- 10V input AC and DC parameters.

Analog Output

Connector	CH4 same pin as Vin (+/- input)
Signal Output Range	+/- 2V at 100mA
Configuration	2 – 12 bit DACs (amplitude and offset)
Current sense resistor	0.1Ω 1%
Update rate	200 Hz
Max load	8Ω
Protection	Short circuit to ground

Digital I/O

Connector	British Telcom Left Hand connector
Signals	8 configurable I/O lines; 4 on each channel
Input Characteristics: Input High Voltage Input Low Voltage	 3.5V min. 1.5V max.
Output Characteristics: Output High Voltage Output Low Voltage	 4.2V min. Ioh = -400uA 0.45V max. Iol = 1.6mA
Timing Resolution	1.6µs, 100µs (depending on mode).

LabPro Sensor Details

Voltage Sensor

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

Channels	Connects to CH1, CH2, CH3, CH4 (analog channels)
Voltage range	±10 Volts
Chemical tolerance	None (air only)
Pins used	1-Signal, 2-Ground, 4-auto-ID resistor

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

Auto-ID Sensors

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

Channels 1, 2, 3 and 4		
IDENT Value[1]	**Sensor Type**	**Range**
2.2K	Thermocouple °C	-20°C to 1400 °C
33K	TI Voltage sensor	-10 to +10 Volts
6.8K	Current sensor[2]	-10 to +10 Amps
3.3K	Resistance sensor	1K to 100 KΩ
22K	Extra long temperature sensor for °C	-50 °C to 150 °C
68K	CO_2 gas sensor (PPM)	0 to 5000 ppm
100K	Oxygen gas sensor (PCT)	0 to 27%
150K	C V voltage sensor (V)	-6 to +6 Volts
220K	C V current sensor (A)	-0.6 to +0.6 Amps
10K	Stainless steel or TI temperature sensor[3] for °C	-25 °C to 125 °C
15K	Stainless steel or TI temperature sensor for °F	-13 °F to 257 °F
4.7K	TI Light sensor	0 to 1
1K	Ex heart rate sensor (BPM)	N/A
47K	Voltage sensor	0 to 5 Volts
1.5K	EKG	N/A

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

[2] Operation 3 is a mathematical conversion of voltage to a current reading (1V=1A). There is no circuitry

inside LabPro unit to convert current to voltage; this must be done in the external probe.

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

Channel 11 and 12 (SONIC)		
IDENT Value[1]	**Sensor Type**	**Range**
15K	Motion detector, meters	0.4 meter to 6 meters
22K	Motion detector, meters	0.4 meter to 6 meters
10K	Motion detector, feet	1.4 feet to 18 feet

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

Custom Sensors

To create custom-designed sensors or other circuits for the analog input channels or a Digital/sonic input channel LabPro, you can purchase sensor kits from Vernier Software & Technology.

- For a custom analog sensor, use the Analog Probe Kit (order code CB-BTA). Each sensor kit includes a four-foot length of telephone cable with a BTA connector attached to one end. The other end of the cable is not terminated.
- For a custom digital sensor, cut a CBL-MDC cable into two pieces to get two lengths of cable with connectors. (The digital probe kit used with the original CBL (CBL-DNK) will not work with LabPro.)

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

If you design a resistance-type sensor, connect pin 3 (Vres) to pin 6 (Vin-low) (refer to “Connector Pinouts” below). Connect the resistance to be measured from the junction of these pins to pin 2 (Gnd). The resistance range for useful measurements is limited from approximately 1 Kohms to 100 Kohms. When the Operation parameter in Command 1 (page 29) is set to 2, 3, 5, 6, or 7, the data is measured on the Vin pin (pin 1). The data for all other operations is measured on the Vin-low pin (pin 6).
Note: The most current that can be drained from all four analog channels is 160 mA. This is limited by the hardware.

Appendix A: Glossary

The following terms are used in LabPro documentation.

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

Appendix B: Beeps, Lights and Errors

Beep and Light Sequences

LabPro makes use of three LED indicators and four kinds of sounds:

- A red LED (error indicator).
- An amber LED (warning indicator).
- A green LED (ready indicator).
- A low tone followed by a high tone (low-to-high beep).
- A medium tone followed by another medium tone (medium-medium beep).
- A high tone followed by another high tone (high-high beep).
- A "tick" sound when a key is pressed.

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

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

Note 1: If the sampling timing causes the beeps to run together, LabPro software may not sound all the beeps.
Note 2: You will not get all the beeps when Fast Sampling is enabled.
Note 3: You will not get all the beeps when using triggering.

- Hold the Start/Stop button for 5 seconds (firmware version 6.022 or newer only) to reset the LabPro.
- When you set LabPro for manual trigger and press the START button, a medium-medium beep sounds.
- When you press the TRANSFER BUTTON:
  - the low-to-high beep sounds when the transfer succeeds.
  - the high-high beep sounds if the transfer fails for any reason.
- When an overcurrent condition is detected, five high-high beeps sound. (This causes an error, which causes even more beeps to sound.)
- When LabPro begins a full self-test, three low-to-high beeps sound.
- When self-test completes:
  - the low-to-high beep sounds if self-test passes.
  - the high-high beep sounds if self-test fails.
- When LabPro's base code detects an error in the commands sent from the host, a high-high beep sounds twice (4 high pitch beeps in a row.)
- When LabPro powers up:
  - two high-high beeps sound if the base code is not loaded.
  - three high-high beeps sound if the power-up self-test fails.

- During base code download, three high-high beeps sound when any errors occur. (The unit resets and then the two high-high beeps mentioned in the previous bullet sound.)

Error Codes

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

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

Error Code	Error Cause
	mode and 0, 7, 8, or 9 for real time data collection mode. This error results from a filter selection outside of this range.
31	Command 3 was sent prior to performing any channel setups.
32	Sample time must be greater than 0 and less than 16000 seconds. The value is normally rounded to the nearest 100 µsec, but can be rounded to the nearest 50 µsec in FASTMODE. If the selected channels cannot support the rate selected, a slower sample rate will be used.
33	The number of samples must be 1 for real time sampling and between 1 and 12,000 for NON-REALTIME sampling. 0 is not allowed except for a special case of real time sampling with manual entry.
34	Trigger type must be an integer between 0 and 6. Any other value will produce this error.
35	The trigger channel must be a valid channel number (e.g., 1-3 or 11) and must be have been enabled using the channel select command.
37	The prestore value must be an integer between 0 and 100%. Any other values will produce this error message.
38	The external clock parameter is limited to values of 0 or 1. Any other value will produce this error.
39	The record time parameter is limited to values between 0 and 2. Any other values will produce this error message.
40	This error will occur when too few parameters are sent in the list. For example, setting up an equation with 5 constants and sending only 4.
42	The equation channel number must be a 0 to reset equation, or a 1-3 for the analog channels or 11 for the sonic channel. Equation numbers outside of this range will produce this error.
43	The equation number must be in the range of 0.1 to 12 for analog channels and either 0 or 13 for the sonic channel. Equation numbers outside of this range will produce this error.
44	The order of the equation must be appropriate for the equation type selected. For example, an equation order of 5 is not valid for the mixed polynomial equation.
45	This error occurred because (1) equations were enabled when sending Command 1, but the equation was never sent using Command 4, or (2) GET statement was issued before sending Command 4.
49	Invalid units were selected for temperature when sending the temperature for the sonic to use. Valid values are from 0 to 4.
52	A channel was selected that is not a valid channel. The channel numbers are 1-3, 11, 21, and 31.
53	A data group was selected that is not valid. Valid values are from 0 to 5.
54	The beginning-of-data selector must be 0 (for start of data) or 1 through the number of points collected. A number outside of this range will produce this error message.

Error Code	Error Cause
55	The end-of-data selector must be 0 (for end of data) or 1 through the number of points collected. A number outside of this range will produce this error message. In addition, the end of the data must not be before the beginning of the data.
59	Digital probe has failed to read or write as commanded by the host.
61	An attempt has been made to collect more data than can be stored in one data collection. This unit has 24K of memory dedicated to data storage, allowing up to 12K samples to be stored. (for example, 3072 samples per channel for 4 channels.) If more than this is attempted, an error will result.
62	This error results when an attempt to return data is made and data has not been collected.
63	This error results when sending Command 6 and an invalid second parameter.
76	This error results when sending Command 10 for a channel that does not have data stored.
77	This error results when sending a Command 10 and selecting an algorithm that has not been defined.
78	This error results when advanced algorithm is selected and the input parameters for it are not correct.
80	This error indicates that the battery voltage is too low to safely write to FLASH memory and an attempt has been made to write to FLASH memory. The batteries should be replaced immediately for the unit to continue to perform properly.
81	This error indicates that an attempt to write to the FLASH memory failed and that the FLASH memory did not retain the value written. This problem can occur under several circumstances including the batteries becoming low after a FLASH write has been started (or removing the AC9920 adapter during FLASH writes). If the problem occurs often, this could indicate a hardware failure.
82	This error indicates an attempt was made to change the contents of FLASH memory without properly enabling FLASH writes.
83	This error indicates that the FLASH memory directory is full and an attempt to write to the FLASH memory occurred. If this occurs, delete some items from FLASH memory and repeat.
84	This error indicates an attempt was made to access an item in the FLASH memory that does not exist.
85	This error indicates that an attempt was made to access an item that is in the FLASH memory, but hasn't been properly opened for access.
86	This error indicates that the archive data type is not one of the data formats supported. This error can result from trying to archive a data set that has not been properly stored.
87	This error results when trying to archive real time data. Only Non-Real time

Error Code	Error Cause
	data can be archived.
88	This error results when an attempt is made to archive data during sampling. Archive operations must occur only when the unit is idle.
97	This error indicates an attempt to use a channel that does not exist on LabPro (for example, channel 42).
98	This error indicates an undefined error has occurred.
99	This error indicates that the current load on the analog or digital ports is more than can be supplied by the unit and the power has been turned off to prevent damage. Do not attempt to restart sampling until the problem has been corrected.
970	Out Of Data Memory. This is when you collect too much data. Usually there is another error that happens if you try to setup 4 channels and 12K data points but if you setup an analog channel and a digital channel, the overflow depends on how many events you detect. This error happens when the data pointers overlap.

Appendix C: DataMate Sensor Setup Default Settings

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

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

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

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

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

Sensor Name	Short Name	Y-Min	Y-Max	Sample Interval (in seconds)	No. Of Samples
Barometer (MMHG)	BARO (MMHG)	600	800	600	180
Barometer (INHG)	BARO (INHG)	24	32	600	180
Barometer (MBAR)	BARO (MBAR)	810	1060	600	180
Relative Humidity (PCT)	REL HUM (PCT)	0	100	600	180
Oxygen Gas (PCT)	O2 GAS (PCT)	15	25	15	40
Oxygen Gas (PPT)	O2 GAS (PPT)	150	250	15	40
Custom 0 to 5 (V)	CUSTOM	0	5	1	180
Custom -10 to 10 (V)	CUSTOM	-10	10	1	180
Motion (M)	MOTION (M)	0	6	0.05	100
Motion (FT)	MOTION (FT)	1	20	0.05	100
Current Probe (A)	CURRENT (A)	-10	10	0.1	180
Resistance (OHMS)	RES (OHMS)	0	100000	0.1	180

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

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

Appendix D: Computer Programming Examples

These programs were created in Microsoft Visual Basic 6.0 to set up specific LabPro operations. Samples of various types of programs follow. Each program includes both program commands and comments explaining what the commands do.

General Structure of a VB Program

```
Labpro.Output = "s{0} + vbCrLf resets LabPro (clears RAM)
Labpro.Output = "s{1,……}"             sends the initialize command to set up collection
Labpro.Output = "s{3,……}"             sends the sample rate, data points, triggering info
```

Channels 1-3 are Analog, Channel 21 is Digital in, Channel 11 is SONIC, and Channel 31 is Digital out.

Example 1: Temperature Non-Realtime Data Collection

In this example we AutoID the probe, set up channel 1, and send a command to collect 100 points in metric units (a point every 0.1 seconds). The onComm() event is called whenever data is transferred and is used to update the listbox with new data.

Create a standard .exe file
Open the Project menu and click on Components, add a Microsoft Comm Control
Name the Comm Control LabPro
Add a command button and name it cmdCollect
Add a listbox and name it lstInput
Add the following code to your form:

```
Private Sub Form_Load()        your forms load event
LabPro.PortOpen = True                opens the Comm port
LabPro.Settings = "38400,N,8,1"       sets the proper settings for LabPro
End Sub

Private Sub cmdCollect_Click() your button's click event
LabPro.Output = "s{0}" + vbCrLf       reset LabPro (clears RAM)
LabPro.Output = "s{1,1,1}" + vbCrLf   set up channel 1 for collection
LabPro.Output = "s{3,.1,100,0}" + vbCrLf      takes a sample every 0.1
                                      second (100 samples)
LabPro.Output = "g " + vbCrLf         "get" data command
End Sub

Private Sub labpro_OnComm()           your Comm port's communication event
lstInput.AddItem LabPro.Input         adds the data to your listbox
End Sub

Private Sub Form_Unload(Cancel As Integer)    your forms unload event
LabPro.PortOpen = False                       closes the Comm port
End Sub
```

Example 2: Temperature Realtime Data Collection

In this example we AutoID the probe, set up channel 3, and send a command to collect points in realtime in metric units. cmdStop is used to tell LabPro to stop collecting data and to return the data.

Create a standard .exe file
Open the Project menu and click on Components, add a Microsoft Comm Control
Name the Comm Control LabPro
Add a command button and name it cmdCollect
Add another command button and name it cmdStop
Add a listbox and name it lstInput
Add the following code to your form:

```
Private Sub Form_Load()                 your forms load event
LabPro.PortOpen = True                  opens the Comm port
LabPro.Settings = "38400,N,8,1"         sets the proper settings for LabPro
End Sub

Private Sub cmdCollect_Click()          your button's click event
LabPro.Output = "s{0}" + vbCrLf         reset LabPro (clears RAM)
LabPro.Output = "s{1,3,1}" + vbCrLf     set up channel 3 for collection
LabPro.Output = "s{3,1,-1}" + vbCrLf    take sample every second, re-arms, and
                                        fires again
End Sub

Private Sub cmdStop_Click()             your button's click event
lstInput.Additem LabPro.Input           adds the data to your listbox
LabPro.Output = "s{0}" + vbCrLf         tells LabPro to stop collecting
End Sub

Private Sub Form_Unload(Cancel As Integer)    your forms unload event
LabPro.PortOpen = False                 closes the Comm port
End Sub
```

Example 3: Distance and Velocity Non-Realtime Data Collection

In this example we AutoID the probe, set up SONIC 1, and send a command to collect 100 points in metric units (a point every 0.1 seconds). The onComm() event is called whenever data is transferred and is used to update the listbox with new data.

Create a standard .exe file
Open the Project menu and click on Components, add a Microsoft Comm Control
Name the Comm Control LabPro
Add a command button and name it cmdCollect
Add a listbox and name it lstInput
Add the following code to your form:

```
Private Sub Form_Load()                 your forms load event
LabPro.PortOpen = True                  opens the Comm port
LabPro.Settings = "38400,N,8,1"         sets the proper settings for LabPro
End Sub

Private Sub cmdcollect_Click()          your button's click event
LabPro.Output = "s{0}" + vbCrLf         reset LabPro (clear RAM)
LabPro.Output = "s{1,11,4,1}" + vbCrLf sets up SONIC 1 and returns velocity
                                        and distance
LabPro.Output = "s{3,0.1,100}" + vbCrLf       take sample every 0.1 second
                                        (100 samples)
LabPro.Output = "g" + vbCrLf            "get" data command
End Sub

Private Sub labpro_OnComm()             your Comm port's communication event
lstInput.AddItem LabPro.Input           adds the data to your listbox
End Sub

Private Sub Form_Unload(Cancel As Integer)    your forms unload event
LabPro.PortOpen = False                 closes the Comm port
End Sub
```

Example 4: Digital Output

In this example we set up Channel 31 and send a command to light up LEDs connected to DIG/SONIC1. Every 0.5 second, the command is sent.

Create a standard .exe file
Open the Project menu and click on Components, add a Microsoft Comm Control
Name the Comm Control LabPro
Add a command button and name it cmdSend
Add the following code to your form:

```
Private Sub Form_Load()                 your forms load event
LabPro.PortOpen = True                  opens the Comm port
LabPro.Settings = "38400,N,8,1"         sets the proper settings for LabPro
End Sub

Private Sub cmdSend_Click()             your button's click event
LabPro.Output = "s{0}" + vbCrLf         reset LabPro (clear RAM)
LabPro.Output = "s{1,31,16,0,1,2,3,4,5,6,7    sets up Channel 31 to output
                                        the listed
,8,9,10,11,12,13,14,15}" + vbCrLf       values to digital in source
LabPro.Output = "s{3,0.5,10,0}" + vbCrLf      every 0.5 seconds send the
                                        digital out value
End Sub

Private Sub Form_Unload(Cancel As Integer)    your forms unload event
LabPro.PortOpen = False                 closes the Comm port
End Sub
```

Example 5: Digital In Data Collection

In this example we AutoID the probe, set up Channel 21, and send a command to collect 100 points in metric units (a point every 0.1 seconds). The onComm() event is called whenever data is transferred and is used to update the listbox with new data.

Create a standard .exe file
Open the Project menu and click on Components, add a Microsoft Comm Control
Name the Comm Control LabPro
Add a command button and name it cmdCollect
Add a listbox and name it lstInput
Add the following code to your form:

```
Private Sub Form_Load()                 your forms load event
LabPro.PortOpen = True                  opens the Comm port
LabPro.Settings = "38400,N,8,1"         sets the proper settings for LabPro
End Sub

Private Sub cmdcollect_Click()          your button's click event
LabPro.Output = "s{0}" + vbCrLf         reset LabPro (clear RAM)
LabPro.Output = "s{1,21, 1}" + vbCrLf   sets up Channel 21 for digital data
                                        collection
LabPro.Output = "s{3,0.1,100}" + vbCrLf       take sample every 0.1 second
                                        (100 samples)
LabPro.Output = "g" + vbCrLf            "get" data command
End Sub

Private Sub labpro_OnComm()             your Comm port's communication event
lstInput.AddItem LabPro.Input           adds the data to your listbox
End Sub

Private Sub Form_Unload(Cancel As Integer)    your forms unload event
LabPro.PortOpen = False                 closes the Comm port
End Sub
```

Data and String Manipulation

The data you receive from LabPro, in these examples, is in String format. For a real or non-real collection a string of data would look like: { +4.40904E+00,+4.40904E+00, +4.40904E+00 }. So if you want to access this data and receive numerical values you need to use string manipulation. The easiest way to do this is by using the Mid function. It returns a portion of a string or caption. For example: if you want to store the input value as a Double. You could use the following code:

(We will use labpro.Input = { +4.40904E+00 } for this example.)

```
If Mid(labpro.Input, 15, 1) = "0" Then returns the exponent (0)

        REM input value is equal to 4.409
```

```
        inputvalue = Mid(labpro.Input, 5, 4)

Else   REM the exponent is not zero

        REM input value is equal to 4.40904 ^ 00
         range = "." + Mid(labpro.Input, 5, 4) ^ Mid(labpro.Input, 15, 1)
End If
```

If you are using negative numbers you will need to add If statements to check if the 4th and 13th characters are "+" or "-". (Mid(labpro.Input, 4,1) and Mid(labpro.Input, 13,1))

Comm Object Settings

In the Property Window of your Comm Object you will need to set some properties so that it can communicate with LabPro correctly.

DtrEnable = False
EofEnable = False
HandShaking = 0-comNone
RtsEnable = True
Settings = 38400,n,8,1
SThreshold and RThreshold = 0

Make sure that the baud rate = 38400 and the parity is off.

Appendix E: Calculator Programming Examples

Although you can create and edit your programs using the calculator keypad, calculator programs are most easily dealt with on a computer using the TI-GRAPH LINK software (available from www.ti.com/calc). Once written, the program can be transferred to the calculator via a TI-GRAPH LINK cable (available from Vernier Software). Samples of various types of programs follow. Each of the following programming examples includes both program commands and comments explaining what the commands do. These examples are written using a TI-83 calculator.

Example 1: Temperature Non-Realtime Data Collection

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

Example 2: Temperature Realtime Data Collection

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

Example 3: Distance and Velocity Non-Realtime Data Collection

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

```
:ZoomStat
```

Example 4: Multiple Channels Non-Realtime Data Collection

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

Example 5: Conversion Equation Setup (Command 4)

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

Example 6: Data Control Setup (Command 5)

```
:ClrAllLists
:ClrHome
:Send({0})                Reset LabPro. (This clears LabPro RAM.)
:Send({6,4})              Turn LabPro sound on.
:Send({1,2,11})           Set up Channel 2 for temperature data collection in Fahrenheit.
```

```
:Send({3,.1,100,0})        Take a sample every .1 second, 100 times.
:Get(L2)                   Retrieve temperature in Fahrenheit data to L2.
:Get(L1)                   Retrieve time data to L1.
:Send({5,2,0,35,45})       Process temperature data 35 through 45 for retrieval.
:Get(L3)                   Retrieve temperature data 35 through 45 to L3.
```

Example 7: Digital In Data Collection

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

Example 8: Digital Out

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

Example 9: LabPro LED Display

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

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

Example 10: Playing Music on LabPro

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

```
:1500→K                    K = 0.15 second
:{2*K,2*K,K,K,K,K,2*K,     Play the short notes for 0.15 seconds and the long
```

```
2*K,2*K,2*K,K,K,K,K,                          ones for 0.3 seconds.
2*K,2*K,2*K,2*K,K,K,K,K,
2*K,2*K,K,K,2*K,2*K,2*K,2*K}→L1
:{182,136,136,121,136,144,162,                Enter each note value in the list.
162,162,121,121,108,121,136,
144,182,182,108,108,102,108,121,
136,162,182,182,162,121,144,136}→L2
:For(N,1,30,1)
:Send({1999,L1(N),L2(N)})                     Send each time and note to LabPro so that it can
:End                                          play every note in the order of the lists.
```

Example 11: Command 8 Program

This is a program to receive data points while sampling.

```
:Send({0})          Clear sampling settings.
:Send({1,1,1})      Set up Channel 1 with auto-ID.
:Send({3,.2,100,0}) Take 100 samples in 20 seconds.

:For(N,1,80,1)      Use a loop to get samples as they are taken.
:Send({8,1,0})      Ask for Channel 1's last sampled data point.
:Get(L2)            Get the sensor type, most recent data point, and position in list.
:Disp L2            Display the three-element list to the screen.
:End
:Get(L1)            Get the resulting list of data.
```

Example 12: Command 9 Program

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

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

Example 13: Command 10 Program

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

```
:Send({0})          Clear sampling settings.
:Send({1,1,1})      Auto-ID the TI temperature sensor.
:Send({3,6,100,0})  Collect 1 sample every 6 seconds for 10 minutes.
:Get(L1)            Get the data for later use or display.

:Send({10,1,1,20,80,5})  Send the advanced data reduction command with the heartbeat
                         algorithm. Set the lower threshold to 20% above the minimum
                         point. Set the upper threshold to 80% above the minimum point.
                         Set the standard temperature variance to 5ºC. If the maximum
                         temperature minus the minimum temperature is less than 5ºC,
                         then the test proves there are no oscillations in temperature outside
                         of 5ºC in the 10-minute experiment. If the variance is more than
                         5ºC, then this will count how many times it goes over the 80%
                         threshold level plus how many times it goes below the 20%
                         threshold level.

:Get(A)             Get the number of times the samples went above the upper
                    threshold and went below the lower threshold (the edge count). If
                    the data range was less than 5ºC, the result is zero.
```

:A/6→B	Divide the edges per sample by the sample time. This returns true frequency (edges per second).
:Disp B	Display the frequency.

Example 14: Archive Program (Command 201)

This program stores and retrieves a data set.

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