

RESEARCH ARTICLE | MARCH 01 1995

## A Buyers' Guide to Microcomputer-Based Laboratory Equipment in Physics Education

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*Comput. Phys.* 9, 185–199 (1995)

<https://doi.org/10.1063/1.4823394>



# A Buyers' Guide to Microcomputer- Based Laboratory Equipment in Physics Education

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Physics Courseware Evaluation Project  
at North Carolina State University  
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A *Computers in Physics* publication  
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# Contents

<b>Introduction</b> . . . . .	187
<b>Multiple-Sensor Systems at a Glance</b> . . . . .	191
<b>Directory of Multiple-Sensor Systems</b>	
<i>for Macintosh computers</i> . . . . .	191
<i>for PCs</i> . . . . .	194
<b>Directory of Single-Sensor Systems</b>	
<i>for Macintosh computers</i> . . . . .	197
<i>for PCs</i> . . . . .	197
<b>Directory of Suppliers</b> . . . . .	199

*The information in this Buyers' Guide is based on information supplied by the manufacturers and, in some cases, by independent sources. Computers in Physics can assume no responsibility for its accuracy. Readers requiring more information about particular products should contact the companies listed in the Directory of Suppliers.*

Computers play an important role in the laboratory research of many physicists but have not yet been fully integrated into our teaching labs. Prohibitive costs and the need for ready-to-use teaching apparatuses have kept many universities, colleges, and secondary schools from introducing computer-based activities in the past. While these obstacles may still keep computers out of the reach of many institutions, today there is no lack of choices for reasonably priced, easy-to-use microcomputer-based laboratory (MBL) equipment. Furthermore, educators and educational researchers have demonstrated that the hands-on activities possible with MBL equipment enrich and strengthen learning in physics.<sup>1</sup>

This buyers' guide presents a comprehensive listing of MBL equipment for the physics teaching lab. Interfacing equipment for use with Macintosh and PC-compatible computers is included (readers interested in interfacing with Apple II computers should consult the "1993 Directory of Physics Courseware," in CIP 7:1, 1993, p. 45).<sup>2</sup> The guide is meant to provide a starting point for those seeking to purchase MBL equipment. The "Directory of Suppliers" on p. 199 lists names and addresses so that you may further investigate your options.

## Multiple-sensor interfaces

Several interfaces support multiple probes. These interfaces are listed in the chart, "Multiple-Sensor Systems at a Glance," on p. 191. The chart has separate sections for Macintosh and PC systems. For each platform, the interfaces are listed alphabetically by supplier, and for each interface the chart indicates which

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physics-related sensors are available. Typically, the system suppliers charge extra for the sensors.

We indicate in the chart only the probes that can be purchased from the interface manufacturer. Probes and sensors have become more standardized, and some interfaces now will support probes of different manufacturers. For example, the KIS Interface, published jointly by Central Scientific Company and Tel Atomic, does support some of the probes produced by Vernier Software. You must consult with the manufacturers to determine which probes can be used with an interface. This is not a comprehensive probe list for each interface; many of the interfaces also support probes, such as pH sensors and heart-rate monitors, that are intended for use in the chemistry or biology classroom.

The following probes are considered useful for the physics lab: accelerometer, ammeter, force, light sensor, magnetic-field sensor, nuclear or radiation sensor, photogates and photogate pulleys, pressure sensors, rotary-motion sensors, sonic rangers, sound sensors (microphones), temperature sensors, thermocouples, and voltage. Voltage probes come in two varieties: low-voltage probes for testing digital circuits and high-voltage probes for testing analog circuits. Check with the manufacturer to determine the types of probes a system supports.

The capabilities of these interfaces vary greatly; the additional expense of purchasing probes varies also. Therefore, the prices listed do not necessarily reflect the total cost of purchasing a given system for a specific experiment. Suppliers often provide discounted sets of equipment aimed at a particular experiment or classroom; we have listed the most basic interface sets available from each supplier. Suppliers are also flexible in pricing large purchases; requesting a formal bid will get you the best pricing. Teachers should carefully examine their own needs and consult with suppliers to determine the cost of meeting those needs.

The "Directory of Multiple-Sensor Systems" on p. 191, gives detailed information concerning software, types of connections to the computer, and probes. The first part of this directory lists Macintosh-based interfaces. The second part, beginning on p. 192, lists PC-based interfaces. Catalog numbers are shown in italics, followed by prices. Asterisks identify items that are included for the purchase price of the interface.

Some of the interfaces require multiple programs to operate different probes, whereas for others, a single program can be used to operate all sensors. In some cases, two programs might accomplish the same task slightly differently. When purchasing a system, be careful to purchase all necessary software. The style and quality of operating software are important issues. When consulting with suppliers, consider particularly the analysis, data-export, and graphic capabilities of software.

Connections to computers often determine the portability of a system. If you will be using a dedicated room of computers, then you can use either an interface that requires an internal card (usually provided with the interface) or one that connects to an external port. However, if you must change computers frequently, only interfaces that connect to an external port will prove useful.

We have not included information regarding the interchangeability of probes between systems. The probes of some manufacturers sometimes do work with other manufacturers' systems; however, you should not assume that this will be the case. Some systems, such as the TCI-600 from Thornton Educational Products, are designed to replace traditional laboratory oscilloscopes and will work with a variety of probes that you may already possess.

The number and type of inputs available on a given interface determine how many probes you may use at once and which probes may be used in conjunction. Digital and analog inputs are found on some interfaces, whereas other interfaces support only one or the other type of input. Analog signals can be unipolar or

bipolar and must be converted to digital signals. A unipolar input typically measures only positive voltages, and the negative terminal must be grounded. This requirement can make using the unit awkward or even impossible in some common situations. In contrast, a floating, differential, or bipolar input (these are equivalent terms) does not require one terminal to be grounded and therefore can measure negative voltages and can afford more flexible connection to your circuit.

The analog-to-digital conversion process can be accomplished with varying degrees of precision and flexibility.<sup>3</sup> The resolution of an analog-to-digital converter (ADC) is determined by the number of digital bits used in the output; a 12-bit converter divides its input range into  $2^{12}=4096$  steps. The range of an ADC determines the signal that will develop the maximum reading. You can find the resolution by dividing the overall range (plus to minus) by the number of steps; a 0 to 5.12-V 8-bit converter thus has a resolution of  $(5.12 \text{ V})/2^8 = 20 \text{ mV}$ . This resolution would be appropriate if your signal is several volts in size, but if your input signal were at most 200 mV, your resolution would be only 10% of full scale. More flexible units offer multiple input ranges so the available resolution can be fully devoted to the signal.

The ADC's sampling rate describes the number of times per second a unit will measure an analog signal. An ADC must be fast enough to capture the waveform of the most rapidly changing signal that you may want to measure.

The inputs available on an ADC determine the types of experiments that your students can complete with ease. Suppliers provide this information using a variety of terms. Deciding in advance which experiments you would like to perform will help you to focus on the qualities that you need in a system. Of course, this sort of detailed planning is difficult and cannot fully allow for uses that have never been considered. Ask manufacturers what experiments their equipment will perform and then ask, "How does the system do it?"

### Single-sensor interfaces

The "Directory of Single-Sensor Systems" on p. 197 is arranged alphabetically by experiment for both Macintosh computers and PCs. Single-sensor interfaces support many of the same types of experiments as are possible with multiple-sensor interfaces. However, experiments requiring many probes to be used simultaneously are generally not possible with single-sensor interfaces. For each system, we have listed type of experiment, necessary components, connection type, catalog number, and price. Single-sensor interfaces are useful for teachers with limited needs or for teachers who wish to supplement their multiple-sensor interface system.

### Conclusion

Comparing interfacing systems can be difficult because interfaces, software, and probes vary so much. Many of the systems offer unique features. The LEAP System from Quantum Technology Inc. allows several lab groups to perform independent experiments using a single interface and computer. PASCO Scientific's Mac65 and Series 6500 offer a power amplifier not available with any other system. Logal's Explorer Labs use a software interface in common with several separately available simulations. Consider your needs carefully and consult with several manufacturers about a variety of systems before making any purchase.

### References

1. Ronald K. Thornton and David R. Sokoloff, *Am. J. Phys.* **58**, 858 (1990); Priscilla W. Laws, *Phys. Today* **44** (12), 24 (1991); and Heather Brasell, *J. Res. Sci. Teaching* **24** (4), 385 (1987).
2. Paula V. Engelhardt, Margaret H. Gjertsen, and John S. Risley, *Comput. Phys.* **7** (1), 45 (1993).
3. James R. Matey and M. J. Lauterbach, *Comput. Phys.* **7** (4), 408 (1993).

# Multiple-Sensor Systems at a Glance

	Supplier	Title	Catalog Number	Price	Optional Sensors															
					Accelerometer	Ammeter	Force	Light	Magnetic Field	Nuclear/Radiation	Photogate/Pulley	Pressure	Rotary Motion	Sonic Ranging	Sound	Temperature	Thermocouple	Voltage		
Macintosh	AccuLab Products Group	Timing and Motion Input Interface	ALI-505	\$ 189																
	AccuLab Products Group	Two Channel A-to-D Input Interface	ALI-500	\$ 189			•	•	•			•						•	•	•
	AccuLab Products Group	SensorNet Interface System	ALI-650	\$ 360			•	•	•			•	•					•	•	•
	Logal	Macintosh Explorer Lab	MBL-AI-05	\$ 399	•	•	•					•	•	•	•	•	•	•	•	•
	PASCO Scientific	Mac65 Computer Interface	CI-6550	\$ 697			•	•	•	•	•	•	•	•	•	•	•	•	•	•
	Quantum Technology	LEAP-System Physical Science Lab Pac	108-258	\$ 495				•				•						•	•	•
	Tel-Atomic	Champ II System	CH915M	\$ 599	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	Tel-Atomic	Champ II System w/Advanced Upgrade	CHU915M	\$ 699	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	Thornton Educational Products	TCI-550 System	TCI-550	\$ 995			•	•	•									•	•	•
	Thornton Educational Products	TCI-600 System	TCI-600	\$ 1995			•	•	•									•	•	•
	Vernier Software	Serial Box Interface	SBI	\$ 100	•		•	•	•			•						•	•	•
Vernier Software	Universal Lab Interface	ULI-M-S	\$ 350	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	
PC	Central Scientific & Tel-Atomic	KIS Interface	KIS	\$ 425				•									•	•	•	
	HRM Software/Queue Inc.	IBM Interface Hardware	HRM592B	\$ 100														•	•	•
	Klinger Educational Products	CASSYpack-E	524 007	\$ 1615	•	•			•	•	•	•	•	•	•	•	•	•	•	•
	Logal	Windows Explorer Lab	MBL-WI-05	\$ 399	•	•	•				•							•	•	•
	PASCO Scientific	Series 6500 Computer Interface	CI-6500	\$ 597			•	•	•			•	•	•	•	•	•	•	•	•
	Quantum Technology	LEAP-System Physical Science Lab Pac	108-255	\$ 495				•				•						•	•	•
	Team Labs	Personal Science Laboratory Starter Pak	PSL100N	\$ 407	•		•					•						•	•	•
	Tel-Atomic	Champ II System	CH9151	\$ 549	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	Tel-Atomic	Champ II System w/Advanced Upgrade	CHU9151	\$ 699	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	Thornton Educational Products	TCI-550 System	TCI-550	\$ 995			•	•	•									•	•	•
	Vernier Software	MultiPurpose Lab Interface	MP-IBM	\$ 290	•		•	•	•			•						•	•	•
Vernier Software	Serial Box Interface	SBI-IBM	\$ 104	•		•	•	•			•						•	•	•	
Vernier Software	Universal Lab Interface	ULI-I-S	\$ 350	•		•	•	•			•						•	•	•	

## Directory of Multiple-Sensor Systems for Macintosh Computers

Company	System	Price	Software	Connection	Sensors
AccuLab Products Group	Timing and Motion Input Interface <i>ALI-505</i>	\$189	SensorNet Software*	Serial port	Infrared Photogate <i>ALS-213</i> , \$75 Sonic Rangers Sonic Ranger Module <i>ALM-300</i> , \$111 Dual Sonic Ranger (requires Sonic Ranger Module) <i>ALM-304</i> , \$119
AccuLab Products Group	Two Channel A-to-D Input Interface <i>ALI-500</i>	\$189	SensorNet Software*	Serial port	Force probes Force Transducer (-15 to +15 N) <i>ALS-207</i> , \$169 Force Transducer (-60 to +60 N) <i>ALS-215</i> , \$169 Magnetic Field Sensor <i>ALS-208</i> , \$84 Pressure Barometric Pressure Monitor <i>ALS-220</i> , \$99 Differential Pressure Monitor <i>ALS-221</i> , \$99 Relative Light Intensity Probe <i>ALS-206</i> , \$79 Temperature probes

Continued next page

\*These items are included with purchase of the system described.

# PRODUCT REVIEW

Company	System	Price	Software	Connection	Sensors
					Standard Temperature Probe <i>ALS-200</i> , \$40 Fast Response Temperature Probe <i>ALS-201</i> , \$40 Test Lead Set <i>ALS-216</i> , \$12 Thermocouple <i>ALS-202</i> , \$99
AccuLab Products Group	SensorNet Interface System <i>ALI-650</i>	\$360	SensorNet Software*	Serial port	The SensorNet Interface System supports all of the probes listed above for AccuLab's Timing and Motion Input Interface and Two Channel A-to-D Input Interface.
Logal	Explorer MBL <i>MBL-AI-05</i>	\$399	Explorer MBL Software*	Serial port	Ammeter <i>P-AMP-05</i> , \$199 Force Probe <i>P-FRC-05</i> , \$169 Light Sensor <i>P-LIT-05</i> , \$39 Microphone <i>P-MCR-05</i> , \$29 Photogate <i>P-PHO-05</i> , \$169 Sonar Ranger <i>P-SON-05</i> , \$189 Temperature Probe <i>P-TMP-05</i> , \$59 Voltmeter <i>P-VLT-05</i> , \$199
PASCO Scientific	Mac65 Computer Interface <i>CI-6550</i>	\$697	Science Workshop*	Macintosh SCSI port	Force probes Student Force Sensor <i>CI-6519</i> , \$99 Dynamic Force Transducer <i>CI-6511</i> , \$245 Light Probe <i>CI-6504</i> , \$98 Magnetic Field Probe <i>CI-6520</i> , \$135 Motion Sensor <i>CI-6521A</i> , \$155 Nuclear probes Nuclear Sensor <i>SE-7997</i> , \$295 Introductory Geiger-Müller System <i>SE-7981</i> , \$295, and Nuclear Sensor Adapter Cable <i>CI-6522</i> , \$30 Introductory Geiger-Müller System <i>SE-7985</i> , \$295, and Nuclear Sensor Adapter Cable <i>CI-6522</i> , \$30 Photogate <i>ME-9204A</i> , \$75 Power Amplifier Option <i>CI-6552</i> , \$310 Power Amplifier Accessories RLC Network <i>CI-6512</i> , \$75 Motor/Generator Kit <i>CI-6513</i> , \$160 Thermodynamics Kit <i>CI-6514</i> , \$32 Pressure probes Barometer <i>CI-6531</i> , \$94 Absolute Pressure Probe <i>CI-6533</i> , \$94 Differential Pressure Probe <i>CI-6533</i> , \$94 Smart Pulley <i>ME-9387</i> , \$85 Sound Probe <i>CI-6506</i> , \$35 Temperature probes Temperature Probe <i>CI-6505</i> , \$59 High Accuracy Temperature Probe <i>CI-6525</i> , \$149 Infrared Temperature Probe <i>CI-6528</i> (requires Voltage Probe <i>CI-6503</i> ), \$219 Thermocouples Type K Thermocouple <i>CI-6526</i> , \$99 High Temperature Type K Thermocouple <i>CI-6536</i> (requires Type K Thermocouple <i>CI-6526</i> ), \$27 Voltage Probe <i>CI-6503</i> , \$19
Quantum Technology Inc.	LEAP-System Physical Science Lab Pac <i>108-258</i>	\$495	Physical Science Leap Software*	Serial Port	Clip Leads <i>105-025</i> ,* \$15 Light probes Photoresistive Cell <i>105-040</i> ,* \$13 Photovoltaic Cell <i>105-030</i> ,* \$12 Pressure probes Differential Pressure Sensor (0-1 psi) <i>105-460</i> , \$250 Differential Pressure Sensor (0-30 psi) <i>105-461</i> , \$250 Temperature probes Thermistor <i>105-010</i> ,* \$15 Thermistor (stainless steel) <i>105-225</i> , \$22 Spec 20 Cable <i>105-470</i> , \$52, and SPECTRONIC 20 (not available from Quantum Technology) Standard Dynamic Microphone <i>105-450</i> , \$450
Tel-Atomic Inc.	Champ II System <i>CH915M</i>	\$599	Champ II Software*	Serial port	Ammeters Ammeter Sensor TEL 113, \$119

Continued next page

\*These items are included with purchase of the system described.



Company	System	Price	Software	Connection	Sensors
					Milliamp Sensor <i>TEL 115</i> , \$ 119 Force probes Strain Gauge Sensor <i>TEL 110</i> , \$254 Force Forty Force Transducer <i>TEL 280</i> , \$199 Light probes Light Sensor <i>TEL B102</i> , \$50 Linear Light Sensor <i>TEL 117</i> , \$152 Infra-red Sensor <i>TEL 119</i> , \$260 Magnetic Sensor <i>TEL 111</i> , \$143 Pressure probes Pressure Sensor <i>TEL 107</i> , \$231 Electronic Barometer <i>TEL 109</i> , \$279 Electronic Manometer <i>TEL 108</i> , \$134 Ratemeter Sensor <i>TEL 114</i> , \$199 Sound probes Microphone Sensor <i>TEL B100</i> , \$35 Sound Sensor <i>TEL 120</i> , \$164 Temperature probes Temperature Sensor <i>TEL B103</i> , \$75 Temperature Sensor <i>TEL 103</i> , \$139 Thermocouple Sensor <i>TEL B105</i> , \$80 Voltmeter Sensor <i>TEL 112</i> , \$119
Tel-Atomic Inc.	Champ II System with Advanced Upgrade <i>CHU915M</i>	\$699	Champ II Advanced Upgrade Software*	Serial port	The Champ II System with Advanced Upgrade supports all the probes listed above for the Champ II system and supports the following additional probes: Bidirectional Photogate <i>TEL 223</i> , \$82 Rotogate <i>TEL 224</i> , \$87
Thornton Educational Products	TCI-550 System <i>TCI-550</i>	\$995	TCI-550 Software*	Serial port	Force probes Force Transducer (0-100g) <i>T-420</i> , \$190 Force Transducer (0-1000g) <i>T-422</i> , \$190 Light Source Probe <i>ILS-500</i> , \$85 Magnetic Field Detector <i>MFD-101</i> , \$120 Microphone <i>MIC-500</i> , \$75 Temperature probes Temperature Probe <i>THP-500</i> , \$80 Thermister Temperature <i>TTP-100</i> , \$65 Thermocouple Probe Set <i>TCP-100</i> , \$75
Thornton Educational Products	TCI-600 System <i>TCI-600</i>	\$1995	MacScope Software,* \$495 MacScope Student Version Software, \$49	Serial port	Force probes Force Transducer (0-100g) <i>T-420</i> , \$190 Force Transducer (0-1000g) <i>T-422</i> , \$190 Light Source Probe <i>ILS-500</i> , \$85 Magnetic Field Detector <i>MFD-101</i> , \$120 Microphone <i>MIC-500</i> , \$75 Temperature probes Temperature Probe <i>THP-500</i> , \$80 Thermister Temperature <i>TTP-100</i> , \$65 Thermocouple Probe Set <i>TCP-100</i> , \$75
Vernier Software	Serial Box Interface <i>SBI</i>	\$99	Data Logger <i>DL-SBI</i> , \$30 Spectrophotometer Program <i>SPT-MAC</i> , \$40 Serial Box Starter Stack, free	Serial port	Accelerometer <i>ACC-DIN</i> , \$99 Cable from ULI or SBI to SPEC20 <i>SPC-5</i> , \$25, and SPECTRONIC 20 (not available from Vernier) Force probes Student Force Sensor <i>SFS-DIN</i> , \$99 Strain Gauge Force Sensor Kit <i>SGK-DIN</i> , \$30 Light Sensor <i>LS-DIN</i> , \$39 Magnetic Field Sensor <i>MG-DIN</i> , \$44 Pressure probes Pressure Sensor <i>PS-DIN</i> , \$60 Barometer <i>BAR-DIN</i> , \$56 Temperature probes Direct-Connect Temperature Probe <i>DCT-DIN</i> , \$25 Standard Temperature Probe <i>TAP-DIN</i> , \$43 Standard Temperature Probe Parts Kit <i>TPK-DIN</i> , \$28 Quick-Response Temperature Probe <i>TPAQ-DIN</i> , \$49 Thermocouples

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\*These items are included with purchase of the system described.

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# PRODUCT REVIEW

Company	System	Price	Software	Connection	Sensors
					Thermocouple <i>TCA-DIN</i> , \$35 Thermocouple Parts Kit <i>TCK-DIN</i> , \$20 Voltage Measurement Leads <i>TL</i> ,* \$7
Vernier Software	Universal Laboratory Interface <i>ULI-M-S</i> , Macintosh		Data Logger 4.5* ULI Timer <i>M-UT</i> ,* \$50 MacMotion <i>M-MO</i> , \$25 MacTemp <i>M-TP</i> , \$25 Sound <i>M-SD</i> , \$25 Event Counter <i>M-EC</i> , \$25 Spectrophotometer Program <i>SPT-MAC</i> , \$40 ULI Software Developer's Guide (including ULI Starter Stack) <i>U-SDG</i> , \$15	Serial port	The Universal Laboratory Interface supports all the probes listed above for the Serial Box Interface and the following additional probes Force Probe <i>U-FP</i> , \$125 Photogates Photogate <i>9204-M</i> , \$80 2-Photogate Parts Kit <i>2PUL</i> , \$38 Radiation Monitor <i>U-RM</i> , \$190 Smart Pulley <i>9387-M</i> , \$90 Sound probes ULI Microphone/Amplifier <i>MCA-U</i> , \$30 ULI Microphone/Amplifier Parts Kit <i>MIC-U</i> , \$15 Ultrasonic Motion Detector <i>U-MD</i> , \$89

## Directory of Multiple-Sensor Systems for PCs

Company	System	Price	Software	Connection	Sensors
Central Scientific Company and Tel-Atomic Inc.	KIS Interface	\$425	KIS Software*	Serial port	Light Sensor, \$39 Motion Sensor, \$125 Sound Sensor, \$41 Temperature Sensor, \$51
HRM Software/ Queue Inc.	IBM Interface Hardware <i>HRM592B</i>	\$100	Each sensor comes with software	Internal interface card*	Motion sensors Motion: A Microcomputer Based Lab <i>HRM553H</i> , \$165 Sound sensors Sound: A Microcomputer Based Lab <i>HRM564H</i> , \$150 Temperature sensors Heat and Temperature: A Microcomputer Based Lab 3.5" diskette <i>HRM514H</i> , \$300
Klinger Educational Products	CASSYpack-E 524 007	\$1615	Test Software* Measuring and Evaluating 524 112, \$295 LH-Pascal CASSY 524 102, \$175 LH-Utilities 524 281, \$85 Motion (Spoked Wheel) 524 332, \$175 Motion (Motion Transducer) 524 702, \$230 Impact Experiments (Light Barrier) 524 722, \$230 Poisson Distribution (Radioactive Radiation) 524 742, \$230 Transient Recorder w/FFT 524 762, \$295 Temperature 525 012, \$230	Internal interface card (MS DOS-Connector L 524 001)* CASSY-E interface box connects to standalone sensors and to sensors through additional subinterface boxes	Standalone probes Multi-purpose Microphone 586 26, \$475 Forked Light Barrier 337 46, \$230 Spoked Wheel 337 461 (requires Forked Light Barrier 337 46), \$55 Motion Transducer Box 524 032, \$230 Motion Sensing Element 337 631, \$410 Pair of Recording Pulleys 337 16, \$272 GM-Box 524 033, \$290 End-Window Counter for $\alpha$ , $\beta$ , $\gamma$ , and X-rays 559 01, \$542 End-Window Counter for $\beta$ , $\gamma$ , and X-rays 550 05, \$510 KTY-Box 524 036, \$275 KTY-Sensor 529 036, \$135 B-Box 524 038, \$270 Tangential B-probe 516 60, \$295 Axial B-probe 516 61, \$295 Pressure Sensor 2000 hPa (differential) 529 038, \$453 Vacuum Sensor (absolute pressure) 529 039, \$495 Pressure Sensor 70 hPa (differential) 529 040, \$519 Differential Amplifier Box 524 039, \$270 Bridge Box 524 041, \$620 Force Sensor 314 261, \$1155 30 A-Box 524 043, \$270 Temperature Box 524 045, \$300 Temperature Sensor NiCrNi 666 193, \$247 Temperature NTC 666 212, \$270

\*These items are included with purchase of the system described.

Company	System	Price	Software	Connection	Sensors
Logal	Explorer MBL <i>MBL-WI-05</i>	\$399	Explorer MBL Software*	Serial port	Ammeter <i>P-AMP-05</i> , \$199 Force Probe <i>P-FRC-05</i> , \$169 Light Sensor <i>P-LIT-05</i> , \$39 Microphone <i>P-MCR-05</i> , \$29 Photogate <i>P-PHO-05</i> , \$169 Sonar Ranger <i>P-SON-05</i> , \$189 Temperature Probe <i>P-TMP-05</i> , \$59 Voltmeter <i>P-VLT-05</i> , \$199
PASCO Scientific	Series 6500 Computer Interface <i>CI-6500</i>	\$597	Data Monitor* Precision Timer* Motion Plotter (included with Motion Sensor) Smart Pulley software: Smart Pulley Software 575-04880, \$20	Internal interface card (Advanced Interfacing Board)*	Force probes Student Force Sensor <i>CI-6519</i> , \$99 Dynamic Force Transducer <i>CI-6511</i> , \$245 Light Probe <i>CI-6504</i> , \$98 Magnetic Field Probe <i>CI-6520</i> , \$135 Motion Sensor & Motion Plotter software <i>CI-6521A</i> , \$155 Photogate <i>ME-9204A</i> , \$75 Power Amplifier Option <i>CI-6502A</i> , \$310 Power Amplifier Accessories: Motor/Generator Kit <i>CI-6513</i> , \$160 RLC Network <i>CI-6512</i> , \$75 Thermodynamics Kit <i>CI-6514</i> , \$32 Pressure probes Barometer <i>CI-6531</i> , \$94 Absolute Pressure Probe <i>CI-6533</i> , \$94 Differential Pressure Probe <i>CI-6533</i> , \$94 Smart Pulley <i>ME-9387</i> , \$85 Sound Probe <i>CI-6506</i> , \$35 Temperature probes Temperature Probe <i>CI-6505</i> , \$59 High Accuracy Temperature Probe <i>CI-6525</i> , \$149 Infrared Temperature Probe <i>CI-6528</i> (requires Voltage Probe <i>CI-6503</i> ), \$219 Thermocouples Type K Thermocouple <i>CI-6526</i> , \$99 High Temperature Type K Thermocouple <i>CI-6536</i> (requires Type K Thermocouple <i>CI-6526</i> ), \$27 Voltage Probe <i>CI-6503</i> , \$19
Quantum Technology Inc.	LEAP-System Physical Science Lab Pac 108-255	\$495	Physical Science Leap Software*	Serial port	Clip Leads 105-025,* \$15 Light probes Photoresistive Cell 105-040,* \$13 Photovoltaic Cell 105-030,* \$12 Pressure probes Differential Pressure Sensor (0-1 psi) 105-460, \$250 Differential Pressure Sensor (0-30 psi) 105-461, \$250 Temperature probes Thermistor 105-010,* \$15 Thermistor (stainless steel) 105-225, \$22 Spec 20 Cable 105-470, \$52, and SPECTRONIC 20 (not available from Quantum Technology) Standard Dynamic Microphone 105-450, \$45
Team Labs	Personal Science Laboratory (PSL) Starter Pak 1 PSL 100N	\$407	Explorer 1.0 Extended 64G1744,* \$192 PSL Hardware User's Guide and Support Disk 57F7936, \$12	Base Unit 84F9096,* \$166, with Power Supply 57F79231,* \$26, and Communication Cable 57F-7932,* \$24, connects to 25-pin serial port Various modules for Base Unit	Digital Input/Output (DIO) Module 04G5940, \$149 DIO Modular Jack Adapter 04G5942, \$43 Rotary Motion Probe 04G5944, \$198 Photo Event Probe 04G5948, \$159 DIO Cable Adapter 04G5941, \$49 Digital Multimeter (DMM) Module 04G5956, \$299 Digital Multimeter Leads 37G0031, \$21 Motion and Mechanics Pak (includes module and distance probe) 57F7922, \$148 Temperature, Light, and pH (TLp) Module 57F7925,* \$87 Temperature probes Standard Temperature Probe (2) 84F9106,* \$44 Extended Temperature Probe (2) 84F9107,* \$60 Light probes Photometric Light Probe 57F7929, \$117 Radiometric Light Probe 57F7930, \$117

\*These items are included with purchase of the system described.

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# PRODUCT REVIEW

Company	System	Price	Software	Connection	Sensors
Tel-Atomic Inc.	Champ II System <i>CH9151</i>	\$549	Champ II Software*	Serial port	<p>Ammeters</p> <p>Ammeter Sensor <i>TEL 113</i>, \$119 Milliamp Sensor <i>TEL 115</i>, \$119</p> <p>Force probes</p> <p>Strain Gauge Sensor <i>TEL 110</i>, \$254 Force Forty Force Transducer <i>TEL 280</i>, \$199</p> <p>Light probes</p> <p>Light Sensor <i>TEL B102</i>, \$50 Linear Light Sensor <i>TEL 117</i>, \$152 Infra-red Sensor <i>TEL 119</i>, \$260</p> <p>Magnetic Sensor <i>TEL 111</i>, \$143</p> <p>Pressure probes</p> <p>Pressure Sensor <i>TEL 107</i>, \$231 Electronic Barometer <i>TEL 109</i>, \$279 Electronic Manometer <i>TEL 108</i>, \$134</p> <p>Ratemeter Sensor <i>TEL 114</i>, \$199</p> <p>Sound probes</p> <p>Microphone Sensor <i>TEL B100</i>, \$35 Sound Sensor <i>TEL 120</i>, \$164</p> <p>Temperature probes</p> <p>Temperature Sensor <i>TEL B103</i>, \$75 Temperature Sensor <i>TEL 103</i>, \$139 Thermocouple Sensor <i>TEL B105</i>, \$80 Voltmeter Sensor <i>TEL 112</i>, \$119</p>
Tel-Atomic Inc.	Champ II System with Advanced Upgrade <i>CHU9151</i>	\$699	Champ II Advanced Upgrade Software*	Serial port	<p>The Champ II System with Advanced Upgrade supports all the probes listed above for the Champ II system and supports the following additional probes:</p> <p>Bidirectional Photogate <i>TEL 223</i>, \$82 Rotogate <i>TEL 224</i>, \$87</p>
Thornton Educational Products	TCI-550 System <i>TCI-550</i>	\$995	TCI-550 Software*	Serial port	<p>Force probes</p> <p>Force Transducer (0-100g) <i>T-420</i>, \$190 Force Transducer (0-1000g) <i>T-422</i>, \$190</p> <p>Light Source Probe <i>ILS-500</i>, \$85 Magnetic Field Detector <i>MFD-101</i>, \$120</p> <p>Microphone <i>MIC-500</i>, \$75</p> <p>Temperature probes</p> <p>Temperature Probe <i>THP-500</i>, \$80 Thermister Temperature <i>TTP-100</i>, \$65 Thermocouple Probe Set <i>TCP-100</i>, \$75</p>
Vernier Software	MultiPurpose Lab Interface Windows Version MP-WIN or DOS Version MP-DOS	\$310 or \$290	MPLI Program for Windows <i>MPP-WIN</i> , \$50 or MPLI Program <i>MPP-IBM</i> ,* \$50 and Motion Plotter Program <i>MOP-IBM</i> , \$40 (for Motion Detector <i>MD-IBM</i> )	Interface board inserted in computer*	<p>Force probes</p> <p>Student Force Sensor <i>SFS-DIN</i>, \$99 Strain Gauge Force Sensor Kit <i>SGK-DIN</i>, \$30</p> <p>Light Sensor <i>LS-DIN</i>, \$39 Magnetic Field Sensor <i>MG-DIN</i>, \$44 Motion Detector <i>MC-IBM</i>, \$90</p> <p>Pressure probes</p> <p>Pressure Sensor <i>PS-DIN</i>, \$60 Barometer <i>BAR-DIN</i>, \$56</p> <p>Sound probes</p> <p>Microphone <i>MCA-M</i>, \$30 Microphone Parts Kit <i>MIC-M</i>, \$15</p> <p>Temperature probes</p> <p>Direct-Connect Temperature Probe <i>DCT-DIN</i>, \$25 Standard Temperature Probe <i>TAP-DIN</i>, \$43 Standard Temperature Probe Parts Kit <i>TPK-DIN</i>, \$28 Quick-Response Temperature Probe <i>TPAQ-DIN</i>, \$49</p> <p>Thermocouples</p> <p>Thermocouple <i>TCA-DIN</i>, \$35 Thermocouple Parts Kit <i>TCK-DIN</i>, \$20 Voltage Measurement Leads <i>TL-DIN</i>,* \$7</p>
Vernier Software	Serial Box Interface <i>SBI-IBM</i>	\$350	Serial Box Plotter <i>SBP-IBM</i> , \$30 Data Logger <i>PC-LG</i> , \$30 Serial Box	Serial port	<p>Accelerometer <i>ACC-DIN</i>, \$99 Cable from ULI or SBI to SPEC20 <i>SPC-5</i>, \$25, and SPECTRONIC 20 (not available from Vernier)</p> <p>Force probes</p> <p>Student Force Sensor <i>SFS-DIN</i>, \$99</p>

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\*These items are included with purchase of the system described.

Company	System	Price	Software	Connection	Sensors
			Developer's Toolkit <i>SBI-DEV</i> , \$10		Strain Gauge Force Sensor Kit <i>SGK-DIN</i> , \$30 Light Sensor <i>LS-DIN</i> , \$39 Magnetic Field Sensor <i>MG-DIN</i> , \$44 Pressure probes Pressure Sensor <i>PS-DIN</i> , \$60 Barometer <i>BAR-DIN</i> , \$56 Temperature probes Direct-Connect Temperature Probe <i>DCT-DIN</i> , \$25 Standard Temperature Probe <i>TAP-DIN</i> , \$43 Standard Temperature Probe Parts Kit <i>TPK-DIN</i> , \$28 Quick-Response Temperature Probe <i>TPAQ-DIN</i> , \$49 Thermocouples Thermocouple <i>TCA-DIN</i> , \$35 Thermocouple Parts Kit <i>TCK-DIN</i> , \$20 Voltage Measurement Leads <i>TL</i> ,* \$7
Vernier Software	Universal Laboratory Interface <i>ULI-I-S</i>	\$350	Data Logger <i>PC-LG*</i> Motion <i>PC-MO</i> Temperature <i>PC-TP</i> Sound <i>PC-SD</i>	Serial port	The Universal Laboratory Interface supports all the probes listed above for the Serial Box Interface and the following additional probes: Force Probe <i>U-FP</i> , \$125 Ultrasonic Motion Detector <i>U-MD</i> , \$89

## Directory of Single-Sensor Systems for Macintosh Computers

Type	Supplier	Title	Connection	Catalog Number(s)	Price
electronic balance	Vernier Software	Mass Plotter Software, Cable to Ohaus Balance, and Ohaus Balance (not supplied)	serial port	MAP-MAC (\$40) and MPC-8 (\$25)	\$65
nuclear/radiation	Daedalon Corporation	Geiger Tube Computer Interface (without tube)	serial port	EN-19	\$325
sonic ranging	Daedalon Corporation	Dual Ultrasonic Measurement System	serial port	EG-93	\$600
sonic ranging	Daedalon Corporation	Ultrasonic Measurement System	serial port	EG-90	\$425
spectrophotometer	Daedalon Corporation	Computer Controlled Spectrophotometer	serial port	EO-85	\$2000
spectrophotometer	Vernier Software	Spectrophotometer Program, Cable from Mac to Spec20D, and Spectronic 20D (not supplied)	serial port	SPT-MAC (\$40) and SPC-MAC (\$25)	\$65
timing	PASCO Scientific	MacTimer	serial port	CI-6700	\$150

## Directory of Single-Sensor Systems for PCs

Type	Supplier	Title	Connection	Catalog Number(s)	Price
electronic balance	Vernier Software	Mass Plotter Software, Cable from 25-pin or 9-pin serial port to Ohaus Balance, and Ohaus Balance (not supplied)	serial port	MAP-IBM (\$40) and MPC-25 or MPC-9 (\$25)	\$65
force	Vernier Software	Voltage Plotter Software and Student Force Sensor	IGPC** necessary	VP-IBM (\$40) and SFS-DIN (\$99)	\$139
force	Vernier Software	Voltage Plotter Software and Strain Gage Parts Kit	IGPC** necessary	VP-IBM (\$40) and SGK-DIN (\$30)	\$70
light	Vernier Software	Voltage Plottter Software and Light Sensor	IGPC** necessary	VP-IBM (\$40) and LS-DIN (\$39)	\$79

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\*These items are included with purchase of the system described.

\*\*Internal Game Port Card. Vernier Software and PASCO Scientific sell these, and they are available at computer stores.

# PRODUCT REVIEW

Type	Supplier	Title	Connection	Catalog Number(s)	Price
magnetic field	Vernier Software	Voltage Plotter Software and Magnetic Field Sensor	IGPC** necessary	VP-IBM (\$40) and LS-DIN (\$44)	\$84
nuclear/radiation	Daedalon Corporation	Geiger Tube Computer Interface (without tube)	serial port	EN-18	\$325
nuclear/radiation	PASCO Scientific	Advanced Computer Geiger-Müller Interface	serial port	SN-7982	\$613
nuclear/radiation	PASCO Scientific	Introductory Computer Geiger-Müller System	IGPC* necessary	SE-7985	\$295
nuclear/radiation	Tel-Atomic Inc.	GMX Experimenter	parallel port	TEL GMX1-I	\$569
pressure	Vernier Software	Voltage Plotter Software and Pressure Sensor	IGPC** necessary	VP-IBM (\$40) and PS-DIN (\$60)	\$100
pressure	Vernier Software	Voltage Plotter Software and Barometer	IGPC** necessary	VP-IBM (\$40) and BAR-DIN (\$56)	\$96
sonic ranging	Daedalon Corporation	Dual Ultrasonic Measurement System	serial port	EG-83	\$600
sonic ranging	Daedalon Corporation	Ultrasonic Measurement System	serial port	EG-82	\$425
sonic ranging	PASCO Scientific	Two Target Sonic Ranger	parallel port	ME-9381A	\$325
sonic ranging	Tel-Atomic Inc.	Sonic Motion Sensor	parallel port	TEL 353	\$270
sound	Vernier Software	Frequency Meter Software and Microphone-Amp Assembled	IGPC** necessary	FM-IBM (\$40) and MCA-IBM (\$30)	\$70
sound	Vernier Software	Frequency Meter Software and Microphone-Amp Parts Kit	IGPC** necessary	FM-IBM (\$40) and MIC-IBM (\$15)	\$55
spectrophotometer	Daedalon Corporation	Computer Controlled Spectrophotometer	serial port	EO-85	\$2000
spectrophotometer	Vernier Software	Spectrophotometer Program, Cable from 25-pin serial port to Spec20D, and Spectronic 20D (not supplied)	serial port	SPT-IBM (\$40) and SPC-25 (\$25)	\$65
spectrophotometer	Vernier Software	Spectrophotometer Program, Cable from 9-pin serial port to Spec20D, and Spectronic 20D (not supplied)	serial port	SPT-IBM (\$40) and SPC-9 (\$25)	\$65
temperature	Vernier Software	Temperature Plotter Software and 2-Probe Assembled Temperature Probe System	IGPC** necessary	TP-IBM (\$40) and 2PA-IBM (\$65)	\$105
temperature	Vernier Software	Temperature Plotter Software and 4-Probe Assembled Temperature Probe System	IGPC** necessary	TP-IBM (\$40) and 4PA-IBM (\$95)	\$135
temperature	Vernier Software	Temperature Plotter Software and 2-Probe Parts Kit Temperature Probe System	IGPC** necessary	TP-IBM (\$40) and 2PK-IBM (\$40)	\$80
temperature	Vernier Software	Temperature Plotter Software and 4-Probe Parts Kit Temperature Probe System	IGPC** necessary	TP-IBM (\$40) and 4PK-IBM (\$65)	\$105
thermocouple	Vernier Software	Voltage Plotter Software and Assembled Thermocouple	IGPC** necessary	VP-IBM (\$40) and TCA-DIN (\$35)	\$75
thermocouple	Vernier Software	Voltage Plotter Software and Thermocouple Parts Kit	IGPC** necessary	VP-IBM (\$40) and TCK-DIN (\$20)	\$60
three-dimensional motion	Eshed Robotec	V-scope VS-100	serial port	VS-100	\$2500
timing	PASCO Scientific	Smart Pulley with Software and Manual	IGPC** necessary	ME-9384	\$99
timing	Tel-Atomic Inc.	IBM Photogate Interface Timing Package (with game port card)	IGPC** included	TEL 22-346IG	\$365

\*These items are included with purchase of the system described.

\*\*Internal Game Port Card. Vernier Software and PASCO Scientific sell these, and they are available at computer stores.

Type	Supplier	Title	Connection	Catalog Number(s)	Price
timing	Tel-Atomic Inc.	IBM Photogate Interface Timing Package (without game port card)	IGPC** not included	TEL 22-346I	\$326
timing	Vernier Software	Precision Timer Software and 4-Photogate Parts Kit	IGPC** necessary	PT-IBM (\$40) and 4PG-IBM (\$60)	\$100
timing	Vernier Software	Precision Timer Software and PASCO Photogate	IGPC** necessary	PT-IBM (\$40) and ME9204A (\$60)	\$115
voltage	Vernier Software	Voltage Plotter Software and Voltage Input Unit Assembled	IGPC** necessary	VP-IBM (\$40) and VIU-IBM (\$45)	\$85
voltage	Vernier Software	Voltage Plotter Software and Voltage Input Unit Parts Kit	IGPC** necessary	VP-IBM (\$40) and VIK-IBM (\$30)	\$70

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\*\*Internal Game Port Card. Vernier Software and PASCO Scientific sell these, and they are available at computer stores.

## Directory of Suppliers

### AccuLab Products Group

614 Scenic Drive  
Suite 104  
Modesto, CA 95350  
Tel: (209) 522-8874  
Fax: (209) 522-8875

### Central Scientific Company

3300 CENCO Parkway  
Franklin Park, Illinois 60131-1364  
Tel: (800) 262-3626  
Fax: (708) 530-1109

### Daedalon Corporation

PO Box 2028  
33 Congress Street  
Salem, MA 01970-6228  
Tel: (800) 233-2490  
Tel: (508) 744-5310  
Fax: (508) 745-3065

### Eshed Robotec

445 Wall Street  
Princeton, NJ 08540  
Tel: (800) 777-6268  
Tel: (609) 683-4884  
Fax: (609) 683-4198

### HRM Software/Queue Inc.

338 Commerce Drive  
Fairfield, CT 06430  
Tel: (800) 232-2224  
Tel: (203) 335-0906  
Fax: (203) 336-2481

### Klinger Educational Products

112-19 14th Road  
College Point, NY 11356  
Tel: (718) 461-1822

### Logal

PO Box 1499  
East Arlington, MA 02174-0022  
Tel: (800) 564-2587  
Fax: (617) 491-5855

### PASCO Scientific

PO Box 619011  
10101 Foothills Boulevard  
Roseville, CA 95678-9011  
Tel: (800) 772-8700  
Tel: (916) 786-3800  
Fax: (916) 786-8905

### Quantum Technology Inc.

30153 Arena Drive  
Evergreen, CO 80439  
Tel: (303) 674-9651  
Fax: (303) 674-6763

### Team Labs

6390B Gunpark Drive  
Boulder, CO 80301  
Tel: (800) PSL-HELP  
Fax: (303) 530-4071  
E-mail: [pslhelp@teamlabs.com](mailto:pslhelp@teamlabs.com)

### Tel-Atomic Inc.

PO Box 924  
Jackson, MI 49204  
Tel: (800) 622-2866  
Tel: (517) 783-3039  
Fax: (517) 783-3213

### Vernier Software

8565 S.W. Beaverton-Hillsdale Hwy.  
Portland, OR 97225-2429  
Tel: (503) 297-5317  
Fax: (503) 297-1760  
E-mail: [308-3077@mcimail.com](mailto:308-3077@mcimail.com)