

Building Automation Lab Trainer- Build

BAT-111: Building Automation Systems



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SYNOPSIS

Build a small-footprint trainer for Building Automation classes under \$1000.



OBJECTIVES

Build a small-form lab trainer that can be used to teach:

- BAT-111: Building Automation Systems
- BAT-212: BAT Logic and Programming
- BAT-221: BAS Networking

MAIN COMPONENTS

- Controller
- 120 VAC power supply
- 24 VAC transformer
- 24 VDC power supply
- Actuator
- Temperature Sensor
- Humidity Sensor
- Terminal Blocks
- Switches
- LEDs
- Rack for Trainers

MAIN COMPONENTS DETAIL

These are the specific parts we used, but they may be substituted:

Part 1: Controller

- Controller
 - Purpose: Controller supporting AI, BI, AO, & BO with ethernet port supporting BACnet IP & BACnet MS/TP
 - Manufacturer: Contemporary Controls
 - Model: [BAScontrol22S](https://www.ccontrols.com/basautomation/bascontrol22s.php)
[<https://www.ccontrols.com/basautomation/bascontrol22s.php>]
 - Cost: \$231 - Contemporary Controls offers an educational discount.

Part 2: 120 VAC power supply

- 2-Gang metal box with ½” knockouts
 - Purpose: Enclosure for all 120V wiring
 - Purchase: <https://www.lowes.com/pd/RACO-2-Gang-Gray-Metal-New-Work-Standard-Square-Ceiling-Wall-Electrical-Box/3129657>
 - Cost: \$2.28
- 2-Gang metal box cover
 - Purpose: Box cover
 - Purchase: <https://www.lowes.com/pd/RACO-2-Gang-Square-Metal-Electrical-Box-Cover/50053659>
 - Cost: \$2.98
- Duplex receptacle
 - Purpose: 120 VDC for laptop and wired so receptacle is always hot.
 - Purchase: <https://www.lowes.com/pd/Eaton-White-15-Amp-Duplex-Outlet-Residential-10-Pack-Outlet/1001438408>

- Cost: \$0.56 (\$5.60 for 10)
- Toggle Switch
 - Purpose: Enable 24 VDC and 24VAC to the terminal blocks. LED is powered when 24VAC and 24 VDC is hot so that an instructor can tell if the student is wiring when there is power to the terminal blocks.
 - Manufacturer: Hubbell
 - Model: RC190WZ
 - Purchase: <https://www.amazon.com/gp/product/B0787N4FXS>
 - Cost: \$5.60
- Power cord – 12 foot 14 AWG
 - Purpose: 12 ft Power cord used for power and for to power DC rectifier and 24 VDC to terminal blocks. I cut 2 – 14” sections to provide power to DC rectifier and VDC terminal blocks.
 - Purchase: <https://www.grainger.com/product/GRAINGER-APPROVED-Power-Cord-14-AWG-Wire-Size-1TNA4>
 - Cost: \$13.40
- ½” connectors – 3 required
 - Purchase: <https://www.lowes.com/pd/Sigma-ProConnex-3-8-in-Flexible-Die-Cast-Zinc-Combination-Connector-Conduit-Fittings-100-Pack/3151099>
 - Cost: \$1.26 (\$41.98 for 100 and 3 required)

Part 3: 24 VAC

- 24 VAC transformer
 - Purpose: 24 VAC - Step-down transformer from 120 VAC to 24 VAC
 - Manufacturer: Functional Devices
 - Model: [TR100VA001](https://www.functionaldevices.com/product/tr100va001/) [https://www.functionaldevices.com/product/tr100va001/]
 - Purchase: <https://www.grainger.com/product/2ETD7>
 - Cost: \$40.28

Part 4: 24 VDC

- 24 VDC power supply
 - Purpose: 24 VDC
 - Manufacturer: Mean Well USA
 - Cost: \$26.14

Part 5: Actuator

- Actuator
 - Manufacturer: Johnson Controls

- Model: [M9108-GGA-2](#)
[https://cgproducts.johnsoncontrols.com/MET_PDF/1201429.pdf]
- Purchase: <https://www.grainger.com/product/41P497?RIID=147958148>
- Cost: \$244.70

Part 6: Temperature Sensor

- 10K Thermistor
 - Purpose: Temperature Sensor
 - Manufacturer: Veris
 - Model: [TIWA1W2](#) [<https://www.veris.com/996279/product/veris-tiwa1w2-pipeimmersion-temperature-sensor>]
 - Cost: \$131.18
 - Recommended
 - We bought immersion thermistors, but this isn't needed. I would in the future purchase basic air duct 10K thermistors.
 - Manufacturer: Dwyer
 - Model: [TE-DFN-A0444-00](#) [<https://dwyer-inst.com/en/te-dfn-a0444-00.html>]
 - Purchase: <https://www.grainger.com/product/DWYER-Duct-Temperature-Probe-Bare-6CTR6>
 - Cost: \$13.95

Part 7: Humidity Sensor

- Humidity Sensor
 - Purpose: Humidity Sensor
 - Manufacturer: Kele
 - Model: [HW20K](#) [<https://www.kele.com/product/humidity/wall-mount/kele/hw20k>]
 - Cost: \$212.40

Part 8: Terminal Blocks

- Terminal Blocks
 - 8 red (ac hot & dc positive)
 - 4 black (dc negative)
 - 4 green (ground)
 - 4 blue (ac common)
 - 2 grey (thermistor)
 - 2 yellow
 - 2 white
 - 2 orange
 - Purchase: <https://cdn.automationdirect.com/static/specs/konnectsingle.pdf>
 - Cost: \$9.66 (\$34.50 for 100)
- Terminal End Blocks – 6 required

- Purchase:
https://www.automationdirect.com/adc/shopping/catalog/wiring_solutions/terminal_blocks/end_brackets/kn-eb7
 - Cost: \$6.00 (\$50 for 50 and 6 required)
- Terminal Block labels – 3 required
 - Purchase:
https://www.automationdirect.com/adc/shopping/catalog/wiring_solutions/terminal_blocks/terminal_block_accessories/kn-ma-2
 - Cost: \$3.24 (\$54 for 50 and 3 required)
- Din rail
 - Purpose: Support DC Power supply terminal blocks – 9.75” (¼m)
 - Purchase:
https://www.automationdirect.com/adc/shopping/catalog/wiring_solutions/din_rail/din_rail/dn-r35s1-2
 - Cost: \$1.63 (\$13 for 2m & 1/4 m required)

Part 9: Switches

- Three-way switches – 2 required
 - Manufacturer: Carlington Technologies
 - Model: [2GK51-73](https://www.carlingtech.com/eParts-catalog/g-series-toggle-switches/2GK51-73) [<https://www.carlingtech.com/eParts-catalog/g-series-toggle-switches/2GK51-73>]
 - Purchase: <https://www.grainger.com/product/CARLING-TECHNOLOGIES-Toggle-Switch-DPST-4X849>
 - Cost: \$9.52 (\$4.26 each and 2 required)
- Strut Corner Connector – 2 required
 - Purpose: Hold 30-way switch
 - Purchase: <https://www.grainger.com/product/GRAINGER-APPROVED-Corner-Connector-5YE32>
 - Cost: \$7.24 (\$3.62 each and 2 required)
- 3/16” x 1-1/4” Flat Washer – 2 required
 - Purpose: Secure Strut Corner Connector to board
 - Purchase: <https://www.lowes.com/pd/Hillman-30-Count-3-16-in-x-1-1-4-in-Zinc-Plated-Standard-SAE-Fender-Washers/3026330>
 - Cost: \$0.47 (\$6.98 for 30 and 2 required)
- 7/16” Flat Washer – 2 required
 - Purpose: Secure Three-way switch to Strut Corner Connector
 - Purchase: <https://www.lowes.com/pd/Hillman-30-Count-3-16-in-x-1-1-4-in-Zinc-Plated-Standard-SAE-Fender-Washers/3026330>
 - Cost: \$0.46 (\$1.38 for 6 and 2 required)

Part 10: LEDs

- LEDS – 12 VDC prewired – 3 required

- Manufacturer: lkelyonewy
 - Purchase: <https://www.amazon.com/dp/B094YNNCC2>
 - Cost: \$1.19 (\$11.90 for 10 sets)
- Angle – 1½” W x 1½” H x 8’ L Mill Finished Aluminum Solid Angle
 - Purpose: Hold LED lights – 3”
 - Purchase: <https://www.lowes.com/pd/Steelworks-1-1-2-in-W-x-1-1-2-in-H-x-8-ft-L-Mill-Finished-Aluminum-Solid-Angle/3058175>
 - Cost: \$0.78 (\$24.98 and 32 per 8’)

MISCELLANEOUS MATERIALS

Part 1: Board

- Board – 18” x 24” x ¾” MFD
 - Purpose: Support all the equipment in a form-factor that can be stored
 - Purchase: <https://www.lowes.com/pd/MDF-Actual-0-75-in-x-4-08-in-x-8-08-ft/1000957536>
 - Cost: \$5.98 (\$59.98 for 10 boards)

Part 2: Screws & Ring terminals

- # 8 x ¾” screws – 10 required
 - Purchase: <https://www.lowes.com/pd/Hillman-8-x-3-4-in-Socket-Hex-Drive-Sheet-Metal-Screws-75-Count/3037587>
 - Cost: \$0.93 (\$6.98 for 75 and 10 required)
- #8 x 1-¼” screws – 2 required
 - Purchase: <https://www.lowes.com/pd/Hillman-8-x-1-1-4-in-Socket-Hex-Drive-Sheet-Metal-Screws-50-Count/3043427>
 - Cost: \$0.42 (\$6.98 for 50 and 3 required)
- #8 x 1-¾” screws – 2 required
 - Purchase: <https://www.lowes.com/pd/Hillman-8-x-1-1-2-in-Socket-Hex-Drive-Sheet-Metal-Screws-50-Count/3030126>
 - Cost: \$0.28 (\$6.98 for 50 and 2 required)
- Ring terminals – 4 required
 - Purchase: <https://www.lowes.com/pd/Utilitech-20-Count-Ring-Wire-Connectors/999953462>
 - Cost: \$0.92 (\$4.58 for 20 and 4 required)

Part 3: Wire

- #14 AWG stranded:
 - #14 AWG
 - Purpose: #14 for 120 VAC as well as 24 VDC
 - Colors: Red, Black, White, & Green
 - Cost: ~\$2.00

STORAGE RACK



- Rack for Trainers
 - Purpose: Store trainers. Each trainer is approximately 5” tall including the board so shelves need to be 6” apart since students put them in slight angles.
 - Sheet Pan Rack – 20 pans (every other shelf used)
 - Manufacturer: Regency
 - Model: [600PR1820ZWD](https://www.regencyequipment.com)
[<https://www.regencyequipment.com>]
 - Purchase: <https://www.webstaurantstore.com/regency-20-pan-end-load-bun-sheet-pan-rack-with-non-marking-casters-unassembled/109APR1820L.html>

- Cost: \$150 each and supports 10 trainers

COSTS

Supplies for trainers were purchased between March and May of 2023. Some items were sourced from our labs, but this write-up includes the cost as if they were purchased.

Each trainer using an air duct thermistor and not including the Storage Racks.

For each trainer:

• Controller	\$231.00
• 120 VAC power supply	26.08
• 24 VAC transformer	40.28
• 24 VDC power supply	26.14
• Actuator	244.70
• Temperature Sensor	13.95
• Humidity Sensor	212.40
• Terminal Blocks	20.53
• Switches	17.69
• LEDs	1.97
• Board	5.98
• Screws & Ring Terminals	2.55
• Wire (approximately)	2.00

Total: \$845.27

• Rack for Trainers (10 trainers)	\$150.00
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