Instructables: CPR for All

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Overview

Accurate bystander CPR training is a critical part of successful medical and academic education around the world. High quality mannequins are used in these training programs in order to simulate anatomically-correct CPR procedures. However, these high-quality CPR mannequins can be expensive, making it difficult for some organizations to afford them[1]. This can limit access to high-quality CPR training for some individuals and communities.

As a part of our INFO 6940 Participatory Design & Making course at Cornell Tech, we partnered with 4 Weill Cornell Medicine emergency physicians to develop a low cost version of a CPR training model that can be used by the Pakistan Life Saver's Program, a low-resource CPR training program in Pakistan responsible for providing CPR training to school children nationwide[2]. Using digital fabrication methods, rapid prototyping techniques and usability testing, we created a low-cost, reproducible CPR training model that provides immediate feedback on chest compression depth and rate that can be used in the Pakistan Life Saver's Program's training sessions.

The instructions to build our CPR training model are customizable and adjustable. You can skip the electronics if they aren't necessary for your purpose, or you can use cardboard instead of wood to build the main box chamber if you have limited resources. It takes 1-2 days in a makerspace to build our CPR training model and will cost ~$80 if you purchase the exact items we list below, but may be cheaper depending on your adjustments, such as purchasing in bulk packaging. This price is based on the US market, the estimation might be lower in Pakistan or other developing countries.

The final model will look like this: (read a comic about how the model works here)

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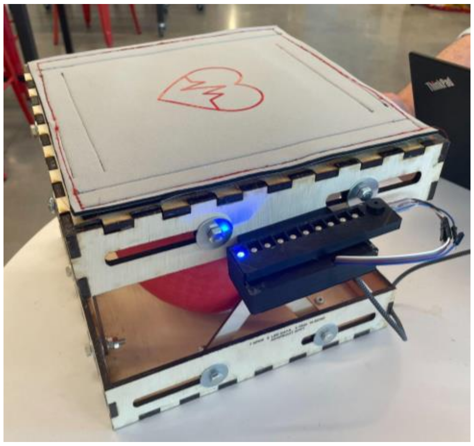
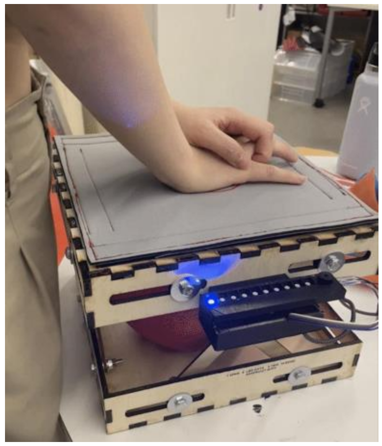
[1] Hoskins, D. S. (2016). CPR Training: Time for a Change. Journal of Emergency Medical Services, 41(8), 46-53.

[2] https://propakistani.pk/2022/06/21/cpr-training-will-now-be-mandatory-at-all-educational-levels/

Supplies

Physical & Electronic Supplies:

Total=

Name	Spec	Purpose	Quantity	Price (US $)	Link
Plywood- laser appropriate	¼” thick plywood, 24”x54” piece or larger	Box	1	19	
Plywood- laser appropriate	⅛” thick plywood, 24”x36” piece	Box-face crossmember stabilizers and carrier platform	1	15	
Kickball	8.5” diameter	Box	1	5.59	link
Fender washers	1” diameter, ¼” hole	Stabilizer crossmembers to box	16	0.36*16=$5.76	link

Nuts, washers bolts	¾' 10-24 with 2 washers and vinyl-core locking nuts *Bolt dimensions are not critical and can be resized to match local supplies.	Bolt stabilizer crossmembers to box	20 sets	$6 (estimated)	
Fabricated plastic spacers	¼" channel spacers	Low-friction sliders cut from ⅜ OD polypropylene tubing, to cover bolts in crossmember slider channels	16 spacers	1 foot of PP tube	0.79
Neoprene closed-cell foam fabric		cover box top	12" x 12"	$10	
Velcro roll with sticky back		Fasten fabric onto top of box	1" wide by at least 1.5 feet	$8	link
Arduino-based microcontroller	Adafruit QT-Py miniature Arduino micorcontroller	Monitor ultrasonic depth readings, control sound and LED signals	1	$9	https://www.adafruit.com/product/4600
Ultrasonic distance sensor	HR-SR04	Monitor box compression depth	1	$1.75	https://www.amazon.com/s?k=hc-sr04&crid=2SGU64VDWA3PD&sprefix=hc-sr04

Solderable electronic project board	Tinned perforation project board	For forming electronic components into soldered circuits	1	$1	https://www.amazon.com/s?k=solderable+project+board&crid=12L0ADX51UZ8I&sprefix=solderable+project+board
Separable ribbon cable 30cm	Standard 0.4mm circuitboard pin-to-socket	Circuit interconnections and connections from microcontroller to audio/LED feedback strip	1	$9	https://www.amazon.com/s?k=breadboard+jumper+wires&crid=5LV5GKQRU3EG&sprefix=breadboard+jumper+wires
Addressable RGB miniature LEDs	WS2812B	Visual feedback signals	10	9.99	https://www.amazon.com/BTF-LIGHTING-WS2812B-Heatsink-10mm3mm-WS2811/dp/B01DC0J3UM/
Piezo beeper	5V Piezo buzzer 12mm diameter	Audio feedback signals	1	0.359/unit	https://www.amazon.com/s?k=12mm+piezo+buzzer&i=tools&crid=2D7M8RHTJ7PFB&sprefix=12mm+piezo+buzzer
Generic PLA filament, 0.175" diameter		3D-printed electronics mounts	1 roll will produce all 3D printed components		See STL files linked below
USB cable	USB-A to USB-C	Arduino computer and	1	$5	

	cable	power interface			
USB portable battery	USB-A power output	Standalone power for CPR training	1	$8	
Wood glue		Connect wood box parts	1 container	$4	link
Hook and Loop fastener (Velcro) adhesive strips		Removably fasten top cloth covering to operating surface of box.	Determined by box top surface area.		
Needle and thread		Sew portions of fastener strips onto fabric top and onto canvas straps	1 kit	$5	link
Cardboard		Top barrier to protect hands from wood	1 4"x4" piece	$1-5 or recyclable	
Canvas ribbon or other thick, fabric ribbon		Straps for box carrier	Roll that's 1.25" wide by 2 foot long	$8	link

Building Supplies:
- Wire stripper/cutter
- soldering iron, solder
- Scissors
- Clamps
- hot glue & gun
- Hand saw

Software:
- 3D CAD/CAM
- Arduino IDE programming environment- https://www.arduino.cc/en/software
- Adobe Illustrator or comparable for laser cutting machine
- MakerCase's Easy Laser Cut Box if you need to adjust the box size to accommodate a different ball size

Files & Attachments:

- Laser cutter file for plywood main box parts
- Laser cutter file for carrier platform and stabilizer crossmembers [one file]
- STL file for LED display and Piezo mount
- STL file for external display clamp
- Arduino .INO source code for sensor and LED functions

Building Process

Step 1: Laser cut wood and glue parts together

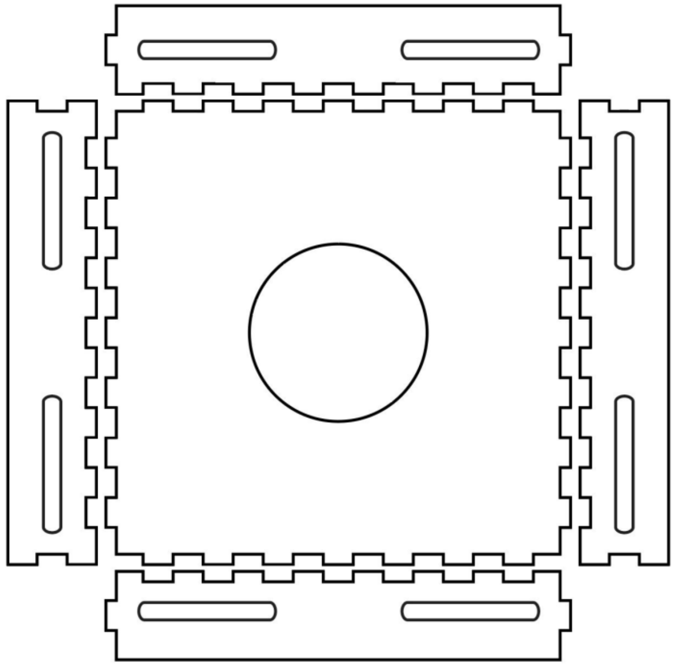
1. You will begin by laser cutting your ¼" wood (the thicker panel) which will create the main box. Start by preparing your ¼" wood panel for the laser cutting machine bed. Depending on the size of your machine's bed, you may need to cut your wood to fit exactly in the bed. Use your hand saw, clamps, and protective equipment to cut your ¼" wood panel if needed.

2. Place your ¼" wood panel in your machine bed. Upload the main box laser cutting file in Illustrator on the computer connected to your laser cutter machine. Use your machine settings for ¼" wood cutting (vector cutting for a 40W machine: 500freq, 10speed, 100power).

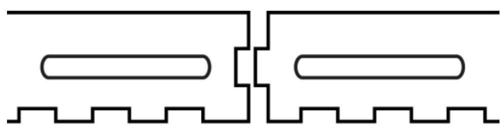
3. Now you will laser cut the stabilizer crossmembers and carrier platform. Use the ⅛" wood plank for both of these components, and cut your plank as needed to fit into your laser cutting machine.

4. Upload carrier platform and crossmembers laser cut file [note these are in one singular file because you use the same materia] in the same was as #2 above and use machine settings for ⅛" wood cutting (vector cutting for a 40W machine: 500freq, 30speed, 100power). Set carrier platform aside along with the crossmembers, you will use these in the next step.

5. Glue the main box together using wood glue, positioning the teeth of the sides and the top or bottom like so: Do this for both the top and bottom boxes.



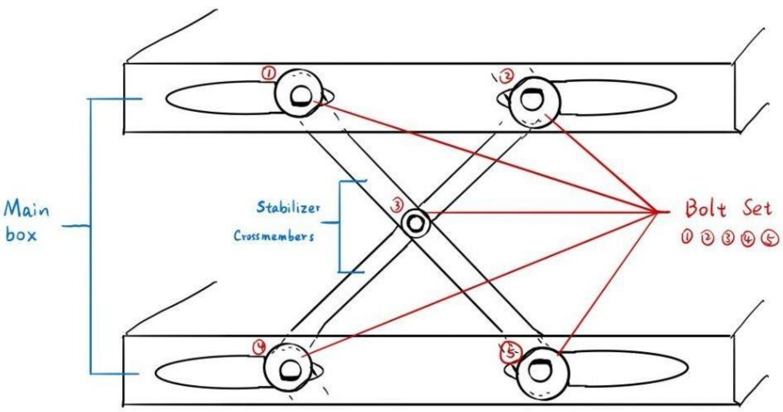
The corner edges will line up like this:

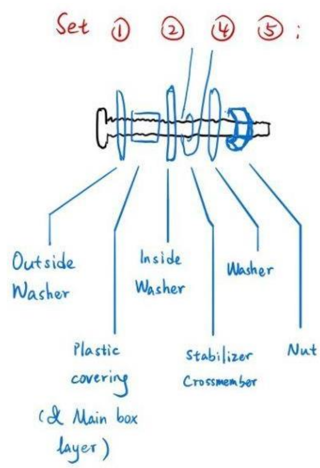


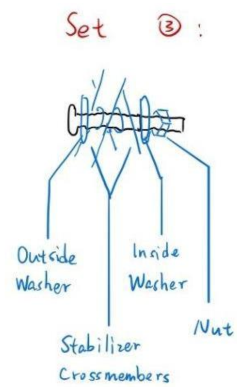
6. Set aside for at least 30 min to dry and set on a flat surface. You can use masking tape or other tape to hold the parts together when drying:

Step 2: Assemble the main box and carrier

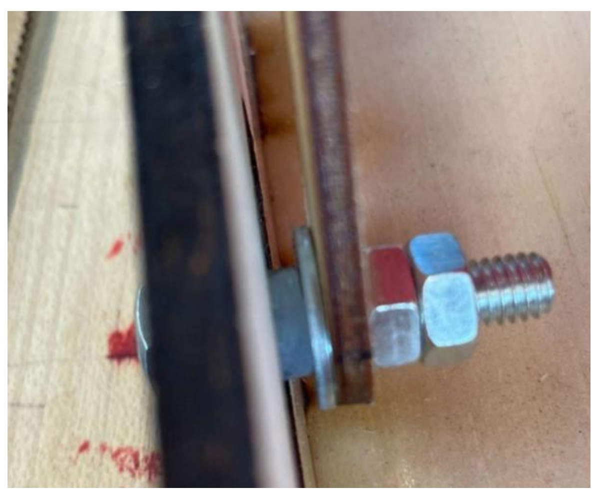
1. Retrieve your stabilizer crossmembers that you laser cut, and your dried top and bottom boxes. You will now use your nuts, bolts, plastic coverings, and washers to connect the stabilizer crossmembers, the kickball, and the top and bottom boxes together to form the final main box.
2. Start by fastening the stabilizer crossmembers into the box slots like the photo, by placing the washer on outside of slots, a plastic covering around the bolt, and a nut inside of the slot to hold the crossmembers in place. Place the inflated ball into the box before completing the final pair of stabilizers.

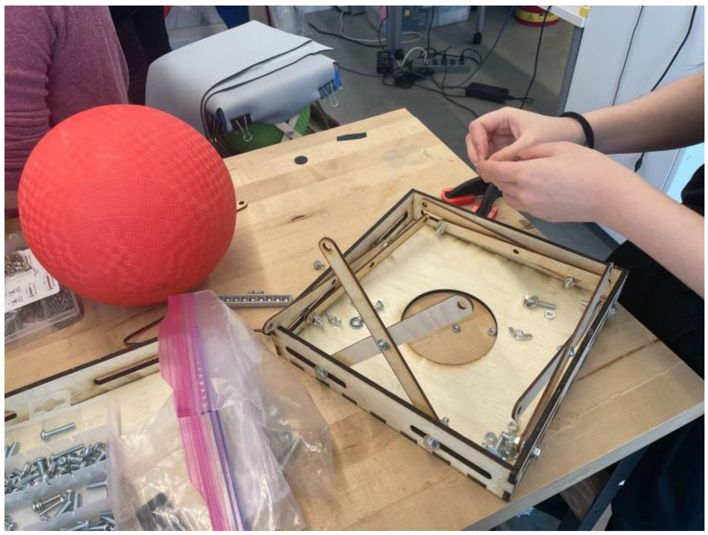






Your nuts, bolts, washers and plastic coverings
will look like this from the outside of the box (left image) and the inside of the box (right image). Note- self-locking 'aircraft' type nuts with plastic cores will provide more vibration-resistance and fewer loosenings than the shown 'jam-nut' pairs of nuts tightened against each other:





3. Now cut your cardboard into a 4”x4” square and use your wood glue to fasten the cardboard directly on top of the hole for the kickball on the top of the main box. This serves to cushion the edges of the wood so your hands won’t be cut or affected in any way when practicing CPR compressions.

4. You will now prepare the neoprene fabric which will be placed on top of the cardboard on the top of the main box. This serves as extra cushioning. Cut your neoprene or other thick fabric with scissors to form a 10”x10” square.

5. Now, cut 4 pieces of your velcro roll to form a perimeter on your fabric square, like this: Don't stick your velcro to your fabric just yet, make sure your velcro strips fit inside the border of the fabric.

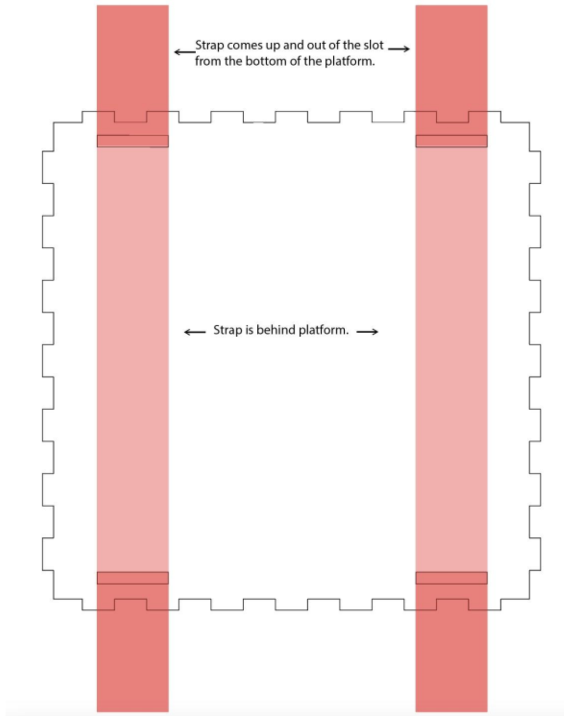
6. Now stick one side of each velcro strip on the same side of the neoprene fabric. This will serve as the bottom of the fabric. Sew your velcro strips onto fabric to make sure that they are durable and long-lasting.

7. Stick the complementary side of each velcro strip onto the top of the wood box, surrounding the cardboard in the same orientation and perimeter as on the backside of your neoprene fabric.

8. Match up the neoprene fabric velcro with the velcro on the top of the box to apply the cushion, sticking the velcro together.

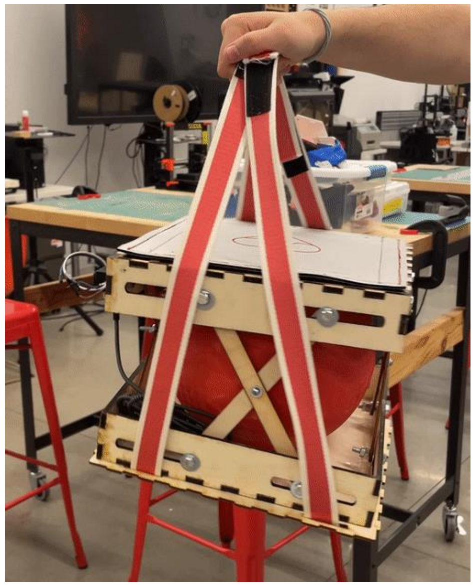
9. You will now start assembling the carrier platform and straps. Retrieve your carrier platform. Start by cutting two pieces of your canvas ribbon each at at least 24 inches long.

10. Insert the canvas straps you just cut into the slots on the carrier platform, looping each straps underneath the platform so both ends of one strap extend out of the slots and are vertical:



11. Finally, cut two 6-inch long pieces of velcro. Stick each velcro strip along the edge of each canvas strap, and sew the velcro onto the ends of the canvas straps to make sure they're durable. Your straps will cross at the top like this:

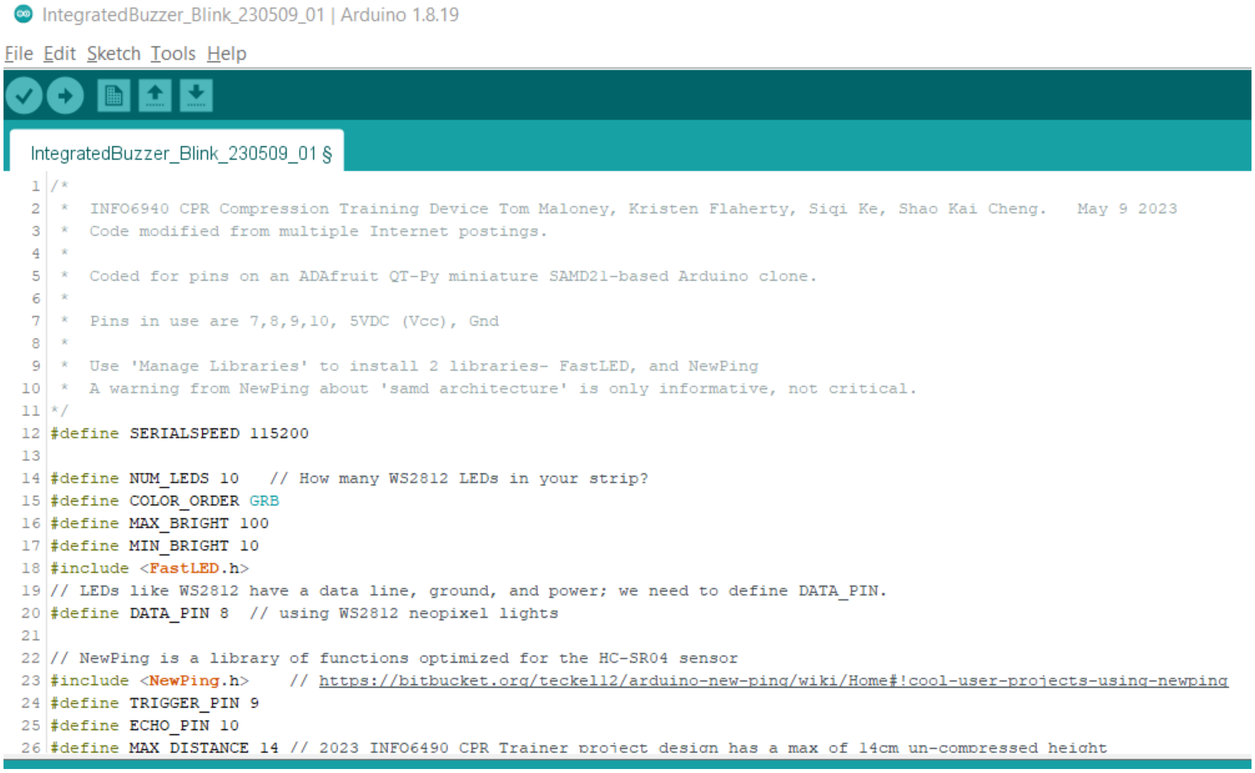
12. Your main box and carrier platform should look like this:



Step 3: Set up the electronics

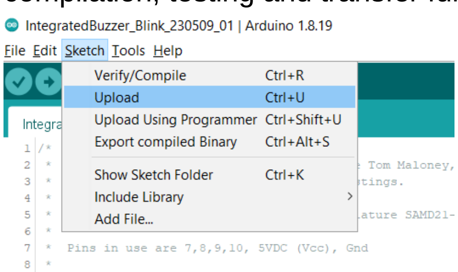
To assure durability in the field while minimizing the parts count and circuit complexity, four widely available, inexpensive components were selected with the expectation that comparable parts will remain available for many years. Visual and audio feedback of compression depth, full release, and rate are provided by 1) WS2812B addressable RGB miniature LEDS, 2) a 5-volt Piezo buzzer, 3) an HC-SR04 ultrasonic distance ranging sensor, coordinated by a miniaturized Arduino (ADAfruit QT-Py) microcontroller. The system operates by processing the echo delay of ultrasound bounced from the HC-SR04 on the floor of the box off the inner surface of the upper box deck. Arduino programming categorizes the echo into zones of distance and provides LED and Piezo buzzer feedback to the CPR Trainee.

The Arduino runs C-language Arduino code programmed using the free Arduino IDE integrated development environment. Two community-contributed Arduino function libraries (**FastLED** and **NewPing**) are used to simplify control of the sensor and LED displays. Example code is provided for improvement and uploading to the microcontroller. Once uploaded, a USB-C 5VDC power connection (e.g. from a cell phone charging pack) is the only required external connection. Powering the system from a computer running the Arduino IDE enables the option of monitoring performance through messages printed to the IDE’s Serial Monitor display.

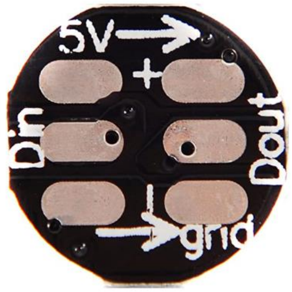



```
/*
 *  INFO6940 CPR Compression Training Device Tom Maloney, Kristen Flaherty, Siqi Ke, Shao Kai Cheng.   May 9 2023
 *  Code modified from multiple Internet postings.
 *
 *  Coded for pins on an ADAfruit QT-Py miniature SAMD21-based Arduino clone.
 *
 *  Pins in use are 7,8,9,10, 5VDC (Vcc), Gnd
 *
 *  Use 'Manage Libraries' to install 2 libraries- FastLED, and NewPing
 *  A warning from NewPing about 'samd architecture' is only informative, not critical.
*/
#define SERIALSPEED 115200

#define NUM_LEDS 10   // How many WS2812 LEDs in your strip?
#define COLOR_ORDER GRB
#define MAX_BRIGHT 100
#define MIN_BRIGHT 10
#include <FastLED.h>
// LEDs like WS2812 have a data line, ground, and power; we need to define DATA_PIN.
#define DATA_PIN 8  // using WS2812 neopixel lights

// NewPing is a library of functions optimized for the HC-SR04 sensor
#include <NewPing.h>    // https://bitbucket.org/teckel12/arduino-new-ping/wiki/Home#!cool-user-projects-using-newping
#define TRIGGER_PIN 9
#define ECHO_PIN 10
#define MAX_DISTANCE 14 // 2023 INFO6490 CPR Trainer project design has a max of 14cm un-compressed height
```

Note that beyond the initial physical construction, this Arduino-based system remains software-reconfigurable. The same USB-C port that powers the CPR trainer by battery during use remains available for future reconnection to the Arduino programming IDE, allowing repeated field updates, loading alternative training algorithms for multiple purposes, or development of additional monitoring capabilities. Uploading code to the Arduino microcontroller uses the inbuilt compilation, testing and transfer functions of the IDE.



We opted to create a 4-color display using 10 LEDs. One LED is dedicated for a Blue display indicating full release of compression, and a ‘climbing’ display to reflect the depth of compression. Depth is presented in 3 distinct colors- Yellow for too-shallow, Green for effective, and Red for excessive. Control of each LED unit and color is controlled using a chained single wired connection. Suitable LEDs are available in bulk for local soldering, or pre-wired in consumer multi-color lighting strips. When bought in a $17 grid of 100, single columns of 10 LEDs can be broken out easily, but at the cost of laborious soldered assembly; pre-made strips simplify soldering but impose larger space requirements:



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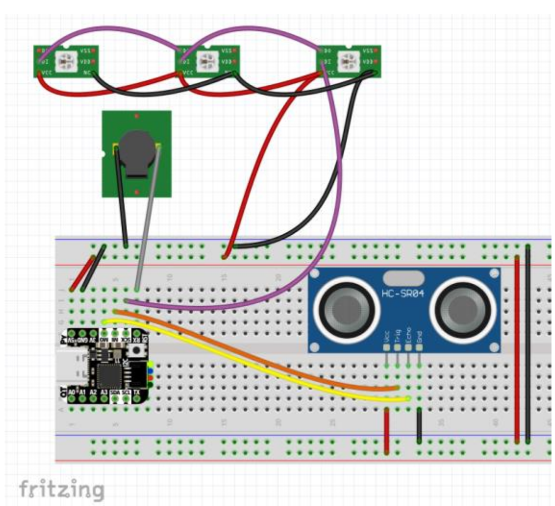
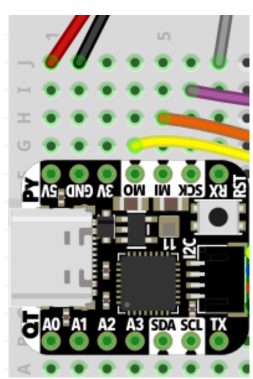
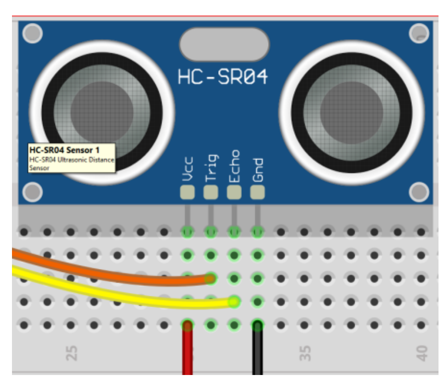
The electronic components shown should be assembled as follows:

1. Carefully bend the 4 connector pins on the HC-SR04 at 90 degrees, one at a time, for insertion into a socket mounted on a small perfboard below.
2. In addition to the 4-socket strip for the HC-SR04, you will solder a pair of 7-socket strips to the same perfboard, at right angles to the socket strip for the HC-SR04. Solder a strip of mating pin headers to the pads on each side of the Ardino QT-Py. Note- only the strip shown below needs to make electrical connections. The other can even hang over the socket strip if necessary since those pins are only used to provide physical stability.

3. Referring to the Fritzing component map below, make 4 internal connections between Power (5V and GND) and the TRIG and the ECHO pins on the HC-SR04:







4.Referring to the Fritzing map above, connect signals from 5V

(VCC), GND, SCK (LED data), and RX (Piezo buzzer) to outgoing wires that terminate in 2.54mm female sockets. These will be routed to connect with the 2.54mm male pin wires attached to the LED and Piezo buzzer devices. (Using consistent color wires for the lower and upper cables reduces connection confusion later!)

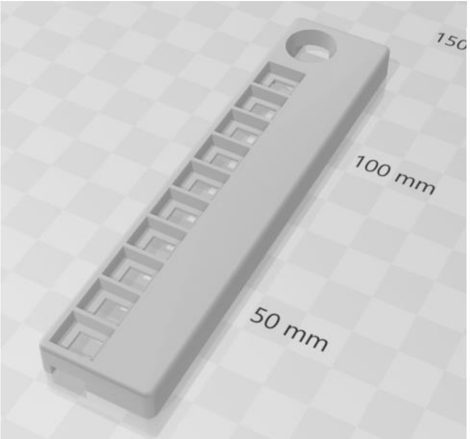
The point-to-point wiring from the Fritzing map above can be patiently accomplished on the small perfboard. Future development of a dedicated circuit board would greatly improve that process.

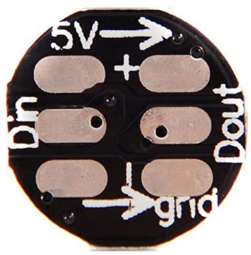
The combined HC-SR04 and QT-Py microcontroller form a very small assembly. You will now hot-glue the circuit base to a small plastic rectangle so the assembly stands straight up completes the assembly, which should be placed and tested for clearance before hot-gluing into a base corner of the box. The 4 female socket connector leads should be routed away from zones where operations might crimp them or they might obstruct compression, for connection to the audio and LED display's male connector pins.

Step 4: 3D-print electronics holders and attach to main box

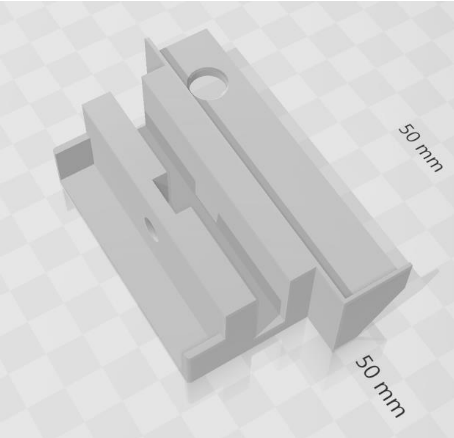
You will now 3D-print two holders to contain the hardware you just set up. Print the STL LEDcarrier file and second STL clamp-on base file according to your 3D-printer instructions using generic PLA filament. We used 0.175" diameter filament, and a Creality Ender Pro 3 to print the files sliced by Cura. Infill for the LEDcarrier was set to 25% since it bears little to no stress. To strengthen the clamping walls of the base file, the floor and walls of the channel for the box wall were designed with extra thickness and slicing was set to use 40% infill.

The included STL LEDcarrier file prints a grid spaced for 10 of the linked WS2812B miniature units. While this allows a more compact spacing than common consumer lighting, it does require a complex assembly requiring fine wire (e.g. 28-30ga) and soldering. By contrast, a segment cut from a consumer strip requires only 3 straightforward solder connections for 5VDC, GND and DATA. Note that the single control connection of the WS2812B design allows as few as 1 LED that displays any of the desired 4 colors, or 4 LEDs to reflect each threshold depth, or other designs suited for local customization.

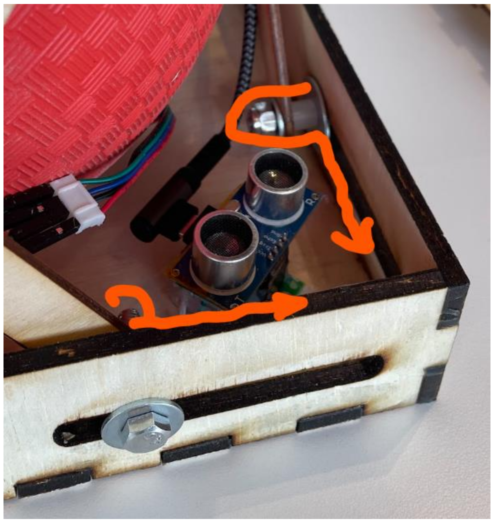


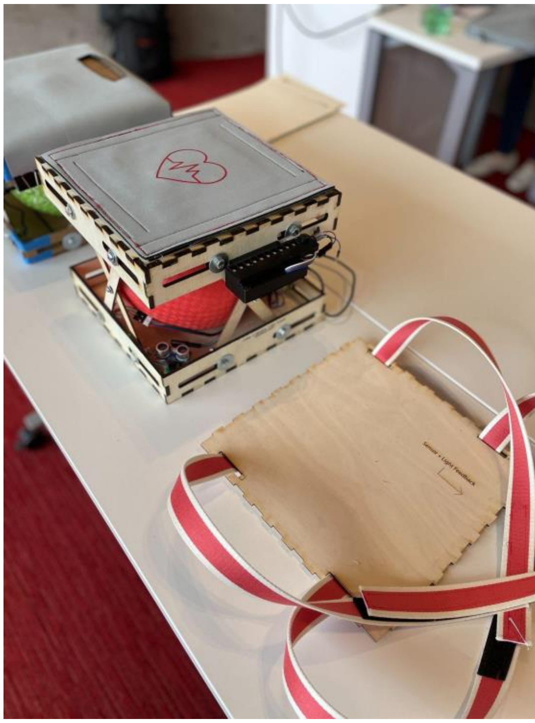
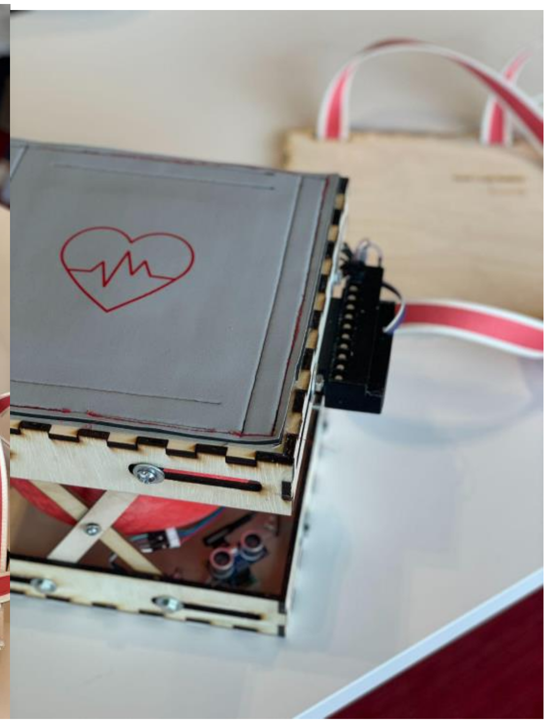
The second STL file prints a clamp-on base to mount the 10 LEDcarrier strip. Either or both STL files might be appropriate for local needs. In other cases (e.g. using portions of a consumer addressable LED strip) would be more desirable. In the image below, the hole through the leftmost wall holds a knurled ¾” 10-24 hex-capped bolt captured inside the channel by a mating 10-24 nut. The nut is locked in position by the walls of the small vertical slot inside the 8mm channel between the thickest walls. The channel between those walls fits against the mid upper box side. Tightening the bolt presses into the box wall, clamping the assembly between the stabilizer guides on the upper box. The 10-grid LEDcarrier is hot-glued to the shelf on the right side (see next image after 3D-print image). The shelf hole allows routing of the 4 LED and Piezo wires, down to connectors on the sensor/microcontroller assembly.



The schematic circuit for controlling and reading distance measurements requires only a few connections, but each requires good soldering skills. The intended placement of the sensor in a bottom box corner requires the smallest profile possible, to avoid restricting (or being displaced by) the sliding crossmember bolts. In a future revision, expanding the box design to allow larger clearances would be the most direct solution. For the current design, mounting the sensor/microcontroller assembly as shown gives good performance.



Your mounted electronics, glued sensor and final model will look like the following:

Step 5: Practice your CPR compressions!