How To Build An Exoskeleton

a.k.a. Iron Man Suit

About Me

- Live & Work in Columbus, Ohio.
- Practice Lead ICC - JavaScript, Open Source, Mobile
- Suit at ICC Booth & Marvel History Talk @1:30
- @scottpreston & github.com/scottpreston

Why Did I Build This?

- Previous Years Build Robots, Talked on Machine Vision, Talked on JavaScript Hardware
- Last year I built J.A.R.V.I.S and spoke on home automation.
- What could 1-up that?

First Challenge
3 Months & $1500

Inspiration For Design

Iron Man MK 1 - Cave Escape Suit

Arm Prototype

1. Armor (Welding, Forming, Cutting Steel)
2. Joints
3. Some kind of lifting assistance (Pneumatic Cylinders)
4. Control of cylinders

Steel Plate

Anything above 3/16” is considered plate

Steel Angle

Great App Purpose Structural Material

Pipe

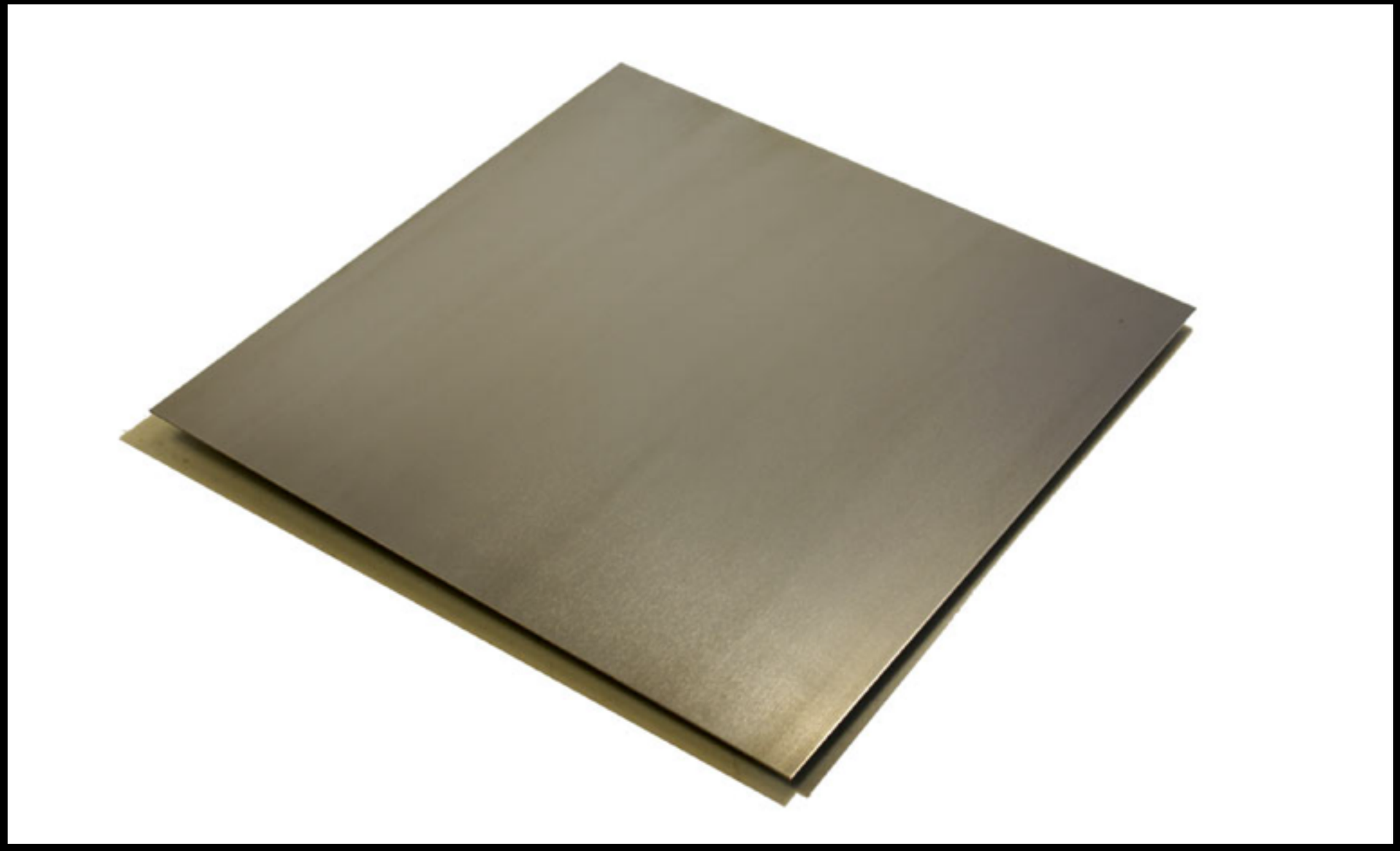
Various Types (Ranging From 18 Gauge to 1/4”)

Sheet Metal

What Size???

Sheet Metal Guide

- 22 gauge / 1.41 lbs / sq ft. 1/32”
- 18 gauge / 2.15 lbs / sq ft. 3/64”
- 11 gauge / 5.1 lbs / sq ft. 1/8”
- 1/4 plate / 10.2 lbs (9mm stopping power)
- Hot Rolled/Cold Rolled
- Low Carbon / Stainless



Sheet Metal Armor

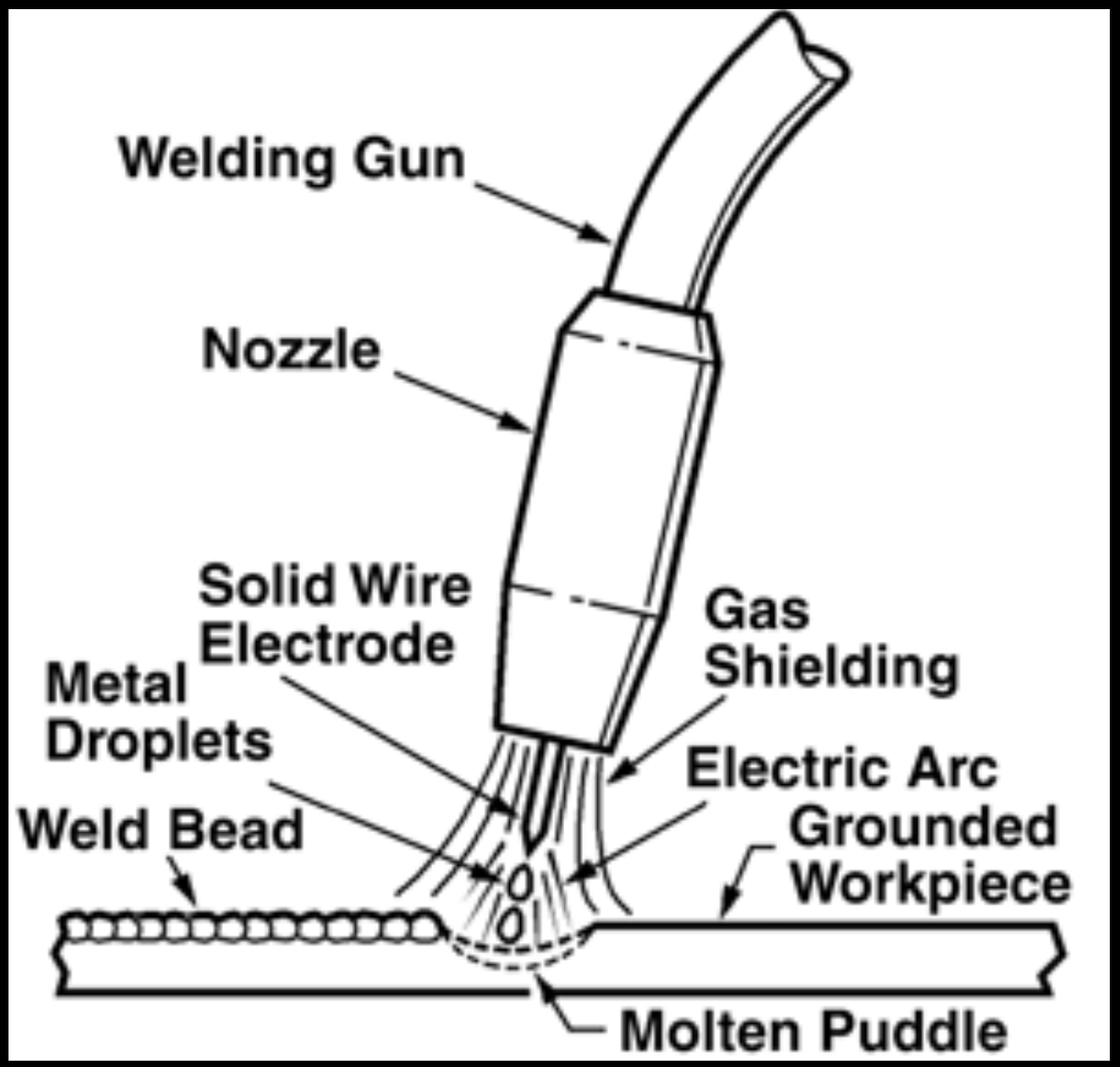
18 Gauge - Cold Rolled Steel

Welding

- No Welding Since 12 years old
- No Welder
- Not sure of what to buy, how much, etc.

Kinds Of Welders

- Torch Welding
- Stick Welding
- Flux Wire Feed Welding
- MIG (Metal Inert Gas) Welding
- TIG (Tungsten Inert Gas) Welding


Welding Gun
Nozzle
Solid Wire Electrode
Gas Shielding
Metal Droplets
Electric Arc
Weld Bead
Grounded Workpiece
Molten Puddle

MIG Welding

Harbor Freight AC 90amp Flux Core

$99

Hobart 140 115v

Gas/Flux Core Welder
$500 or $15/hr Idea Foundry

MIG (left) vs. Flux (right)

Forming Steel (Armor)

- Anvil Cost $500 - $1000+
- Heat
- Other Tools

Bending Steel

This is a sheet metal brake.

DIY Tube Bender

2 - 4” Pipe & C-Clamps

Over Bending

Cutting Steel

- Acetylene Torch $300-$500
- Plasma Cutter $600+
- Shears $46
- Abrasive Cut-Off $40-$200

Shears Good Up To 14 Gauge

$46

Abrasive Cut-Off Saw

(I had one of these) $180

Hobart Plasma Cutter

$15/hr Idea Foundry

Torch Welding?

Tested This $70 vs. $500+

Plasma Cutting Spike

Learning how to cut metal

Purchasing Metal

- Columbus (Fortin Iron Works)
- http://www.metalsdepot.com/
- http://www.discountsteel.com/

Tailoring

Still Learning This

Design Decision

- Tailoring Hard - Sizing Very Very Hard 1 handed.
- Welding (Trips To Idea Foundry)
- Off by an Inch (new round of purchase, cutting, forming, trips to idea foundry)
- Pipe too thick/heavy

80-20 Extrusion

Great Adjustable No Machining!

Aluminum Bar Stock

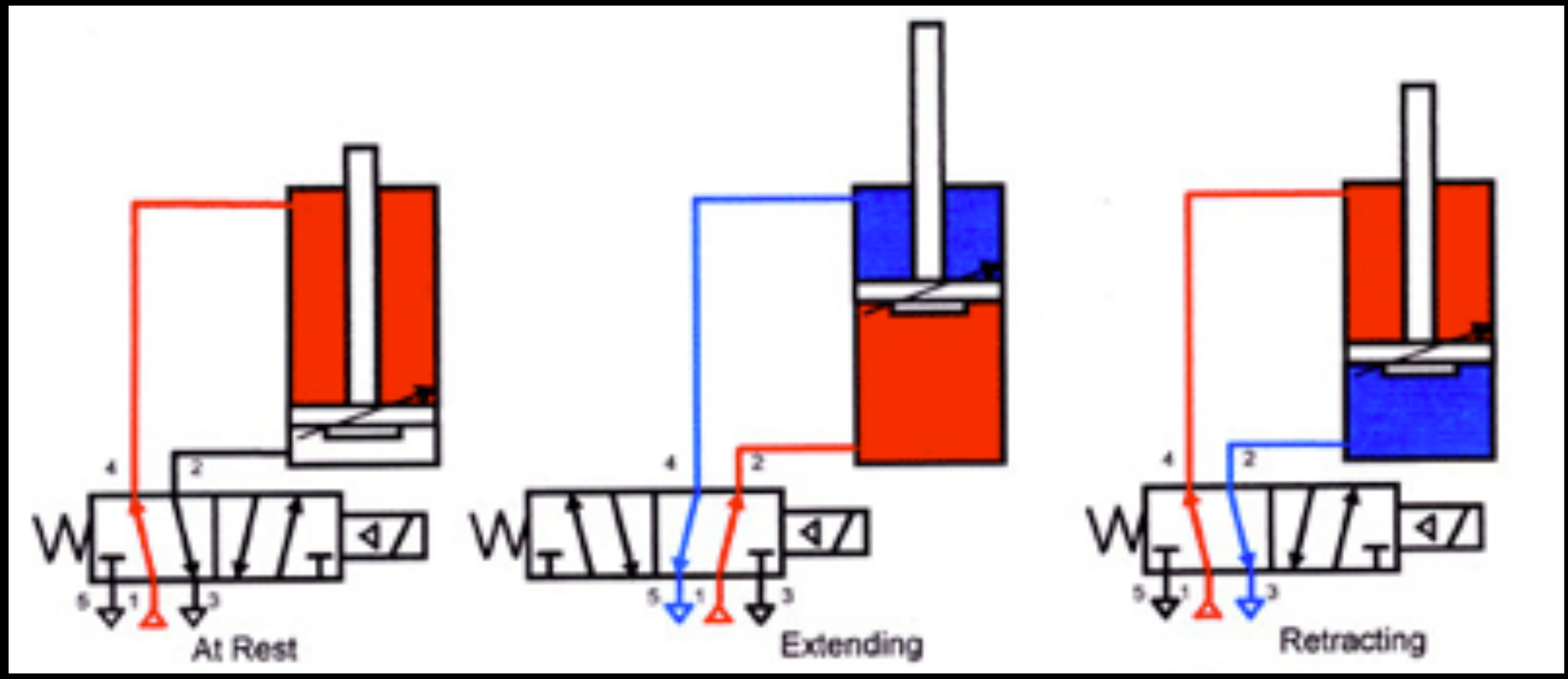
Great For Machining and Weight (Used with Most 80/20)

Fasteners

1/4” - 20 Threads Per Inch

Pivot Joints

Used For Elbows & Chest



Simple Air Cylinder Operation

Low Cost Experimentation

Amazon $10

Clevis Pivot Brackets

$8 Each x8

5 Way Valve

Allows to move 2-way cylinder in/out

Learning Summary

- Welding (Hobart 140 Idea Foundry)
- Cutting (Hobart Plasma Cutter - Idea Foundry) & Abrasive Cutoff Saw & Shears
- Forming (DIY Tube Cutter)
- Structural Angle Iron & 80/20 Extrusion

Prototype Arm Spike

Test Movement / Flow Control / Fitting

Time To Scale-Up

Beyond Prototype

- More Power & Linear Motion
- Two Arms & Shoulder Joints
- Chest & Harness
- Two Legs

Linear Motion

- Pneumatics
- Linear Actuators
- Hydraulics

Linear Actuator

100lb Force, 3” Second / 20% Duty Cycle

Linear Actuator Combos

- Standard (400lbs, 1”/sec, 20% Duty Cycle)
- Heavy Duty (900lbs, .25”/sec, 20% Duty Cycle)
- Fast (22lbs, 4.5”/sec, 20% Duty Cycle)

Hydraulics

Hydraulic Pump Cost / Fluid Leakage / Heat / 1000s PSI

Air Cylinders Wins (MK1)

$60 Each

Solenoid Valve

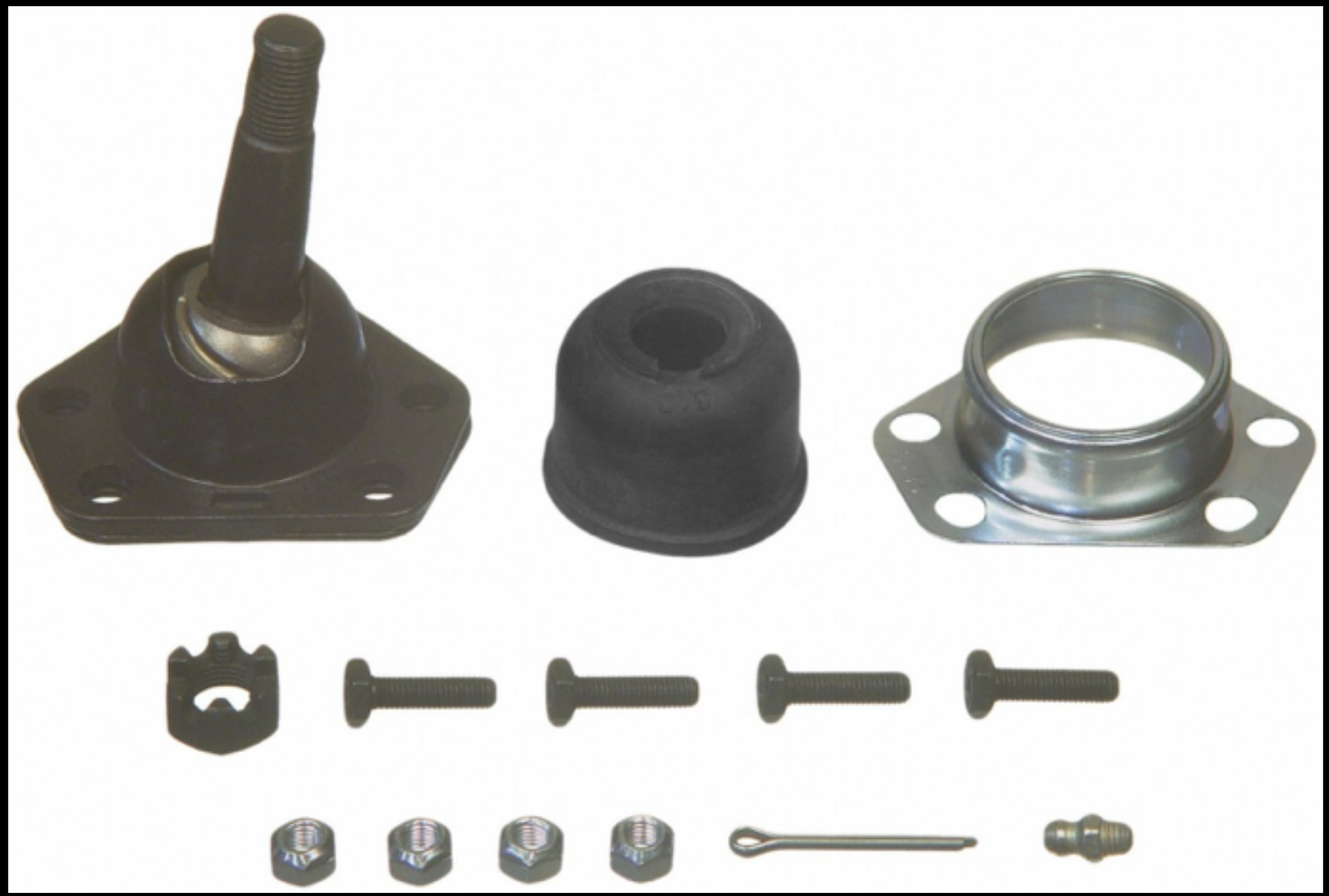
$50 Each / Manifold $20

Flow Control

Amazon $20/each

Arm Specs

- Arm Pull / Cage Open Force@100psi ~300lbs
- Arm Push / Cage Close Force @100psi ~340lbs
- Forearm Armor 18 Gauge DIY Rolled/Cut/Weld
- Bicep Armor 18 Gauge DIY Rolled/Cut/Weld



Shoulders

Moog Ball Joint (For 71 Chevelle)

Shoulder Joint

Beyond Prototype

- **More Power & Linear Motion**
- **Two Arms & Shoulder Joints**
- Chest & Harness
- Two Legs

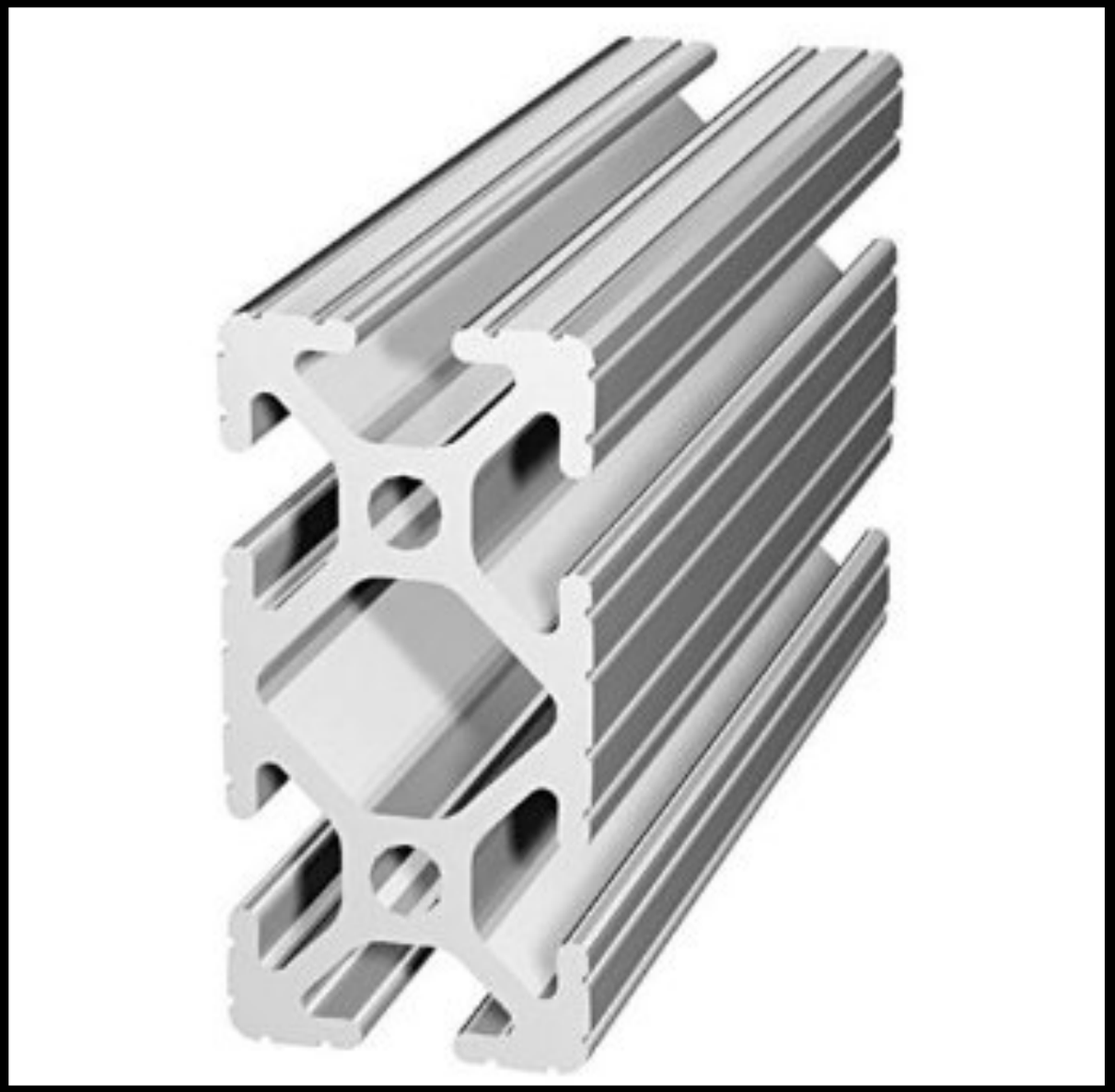
A.L.I.C.E. Backpack Frame

Amazon $40

Competed Chest Frame

Chest Piece

4” Pipe, 18 Gauge Steel, MIG Welds, Rough Cut



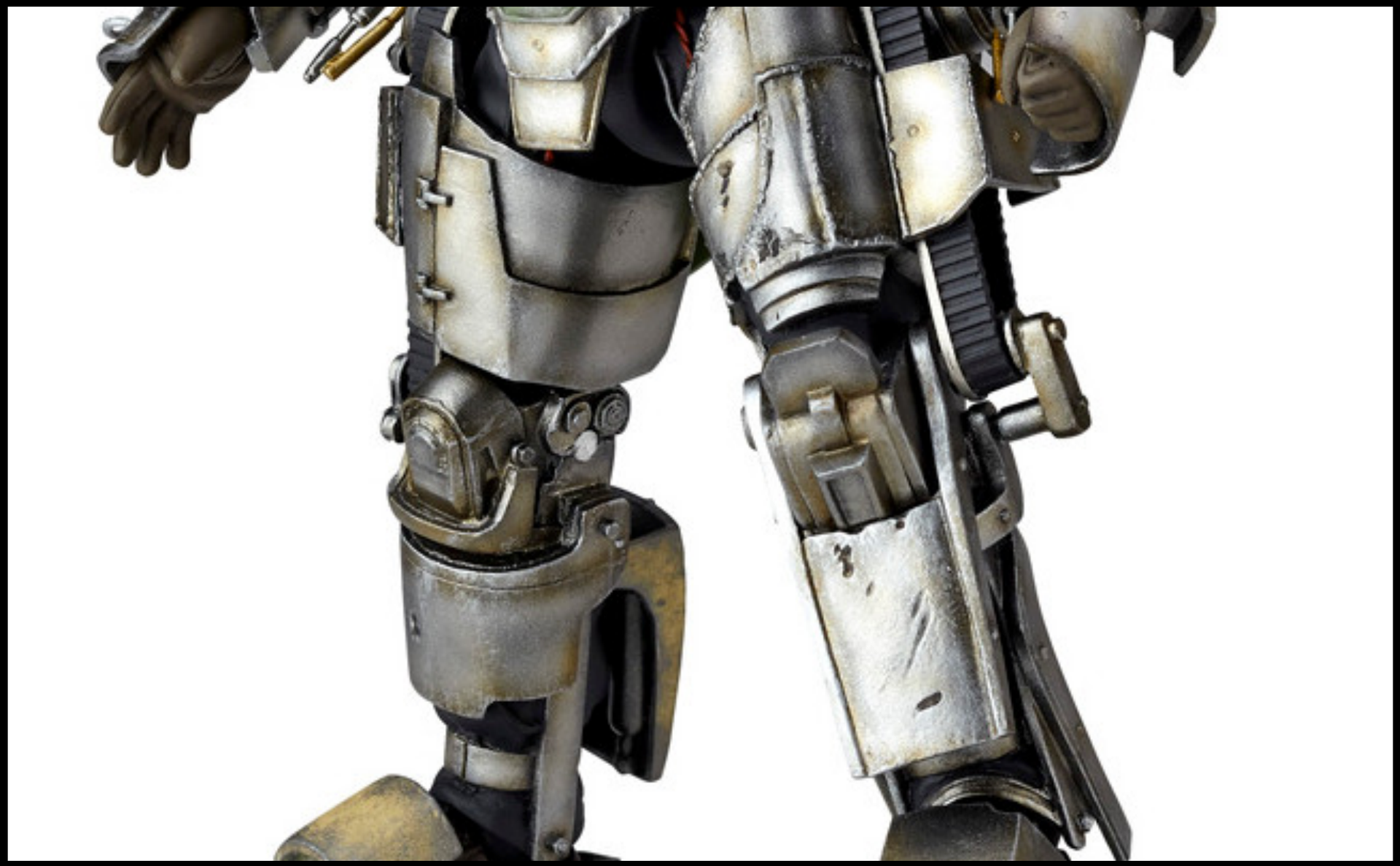
Heavier 80/20

For Frame & Hips

Stronger Pivots Hinge

Used For Top Pivot

Finished Chest



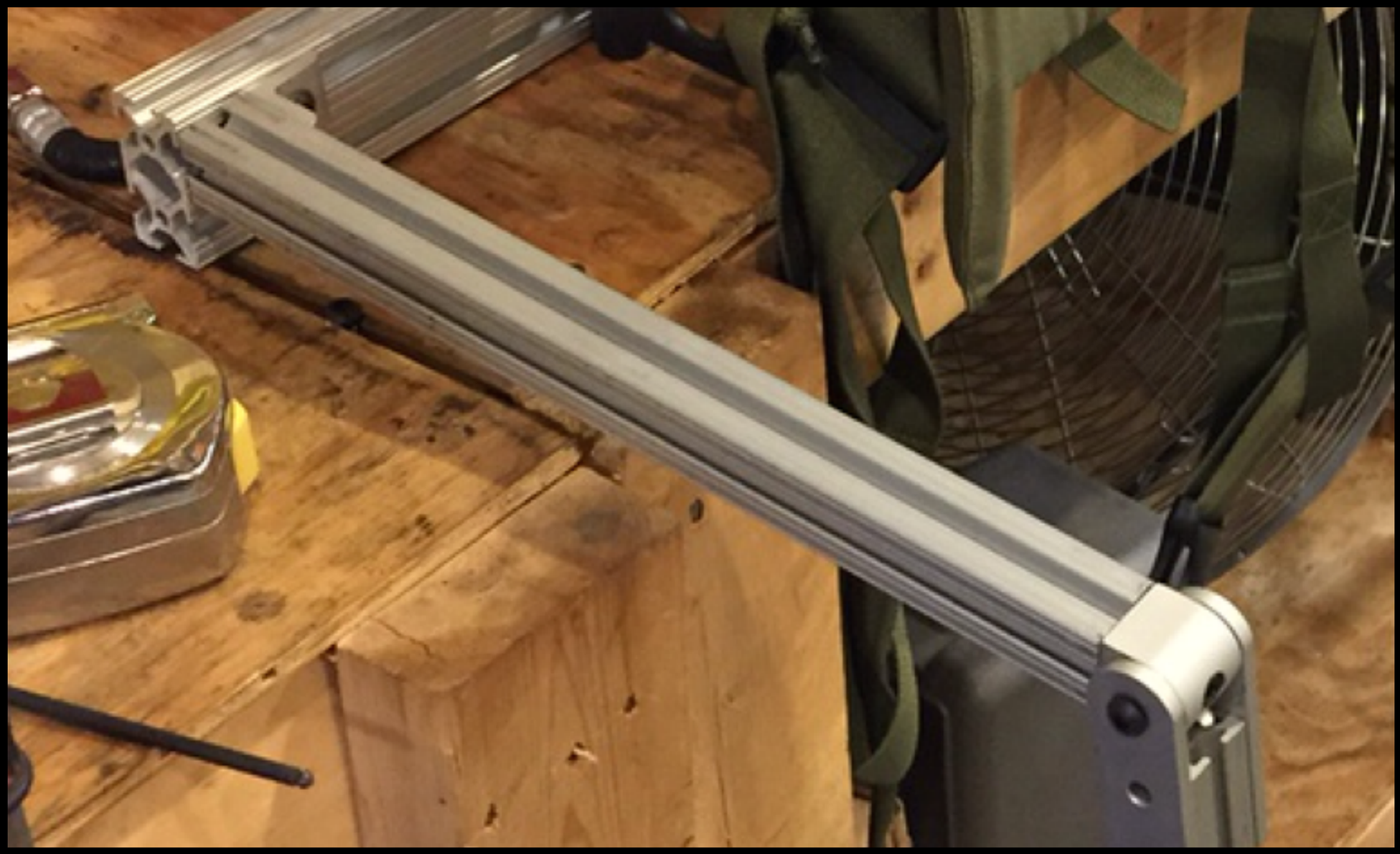
Legs

Leg Designs???

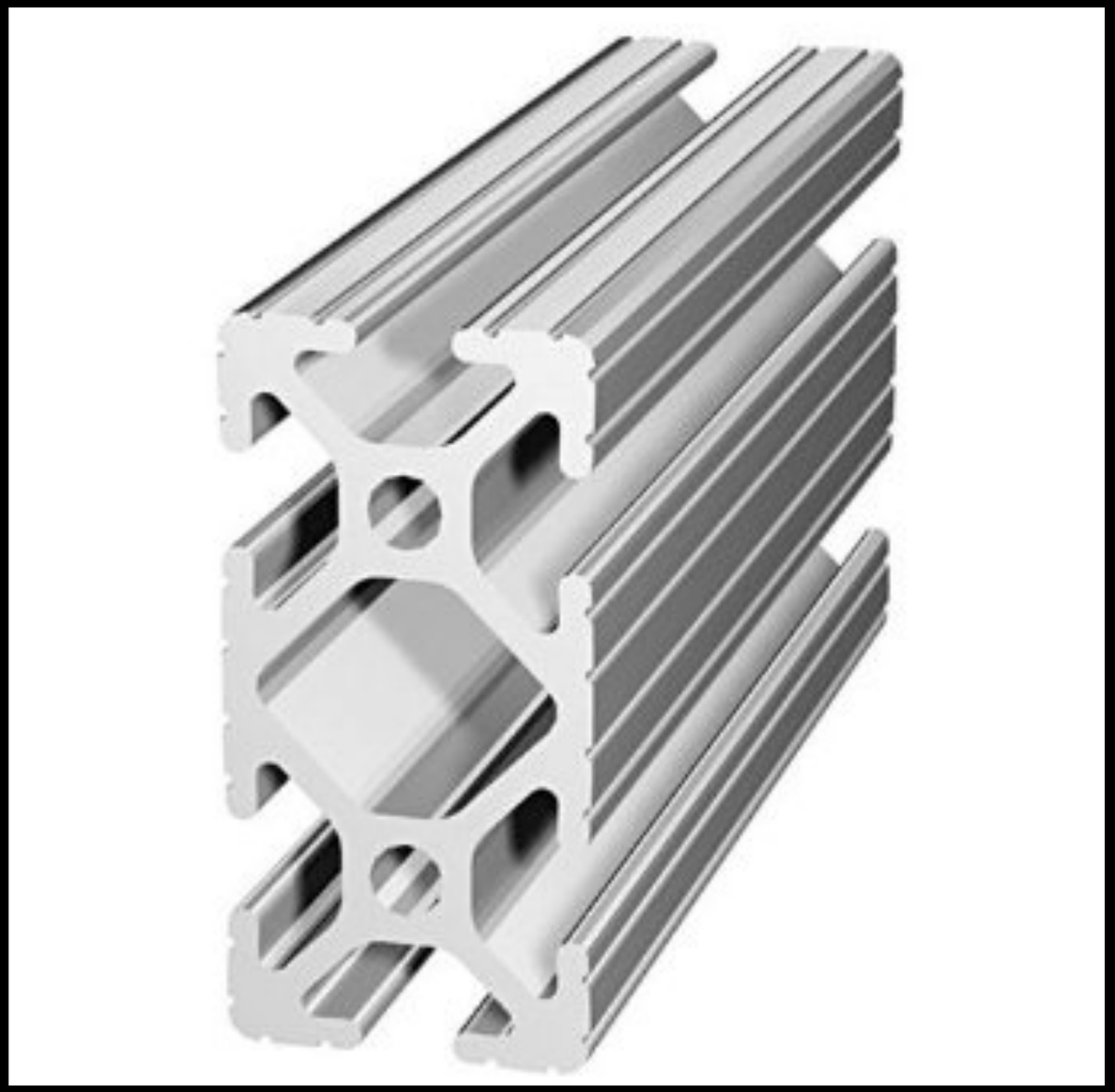
(too many cylinders)

Backwards Knee?

Normal Knee



Moving Hip Forward

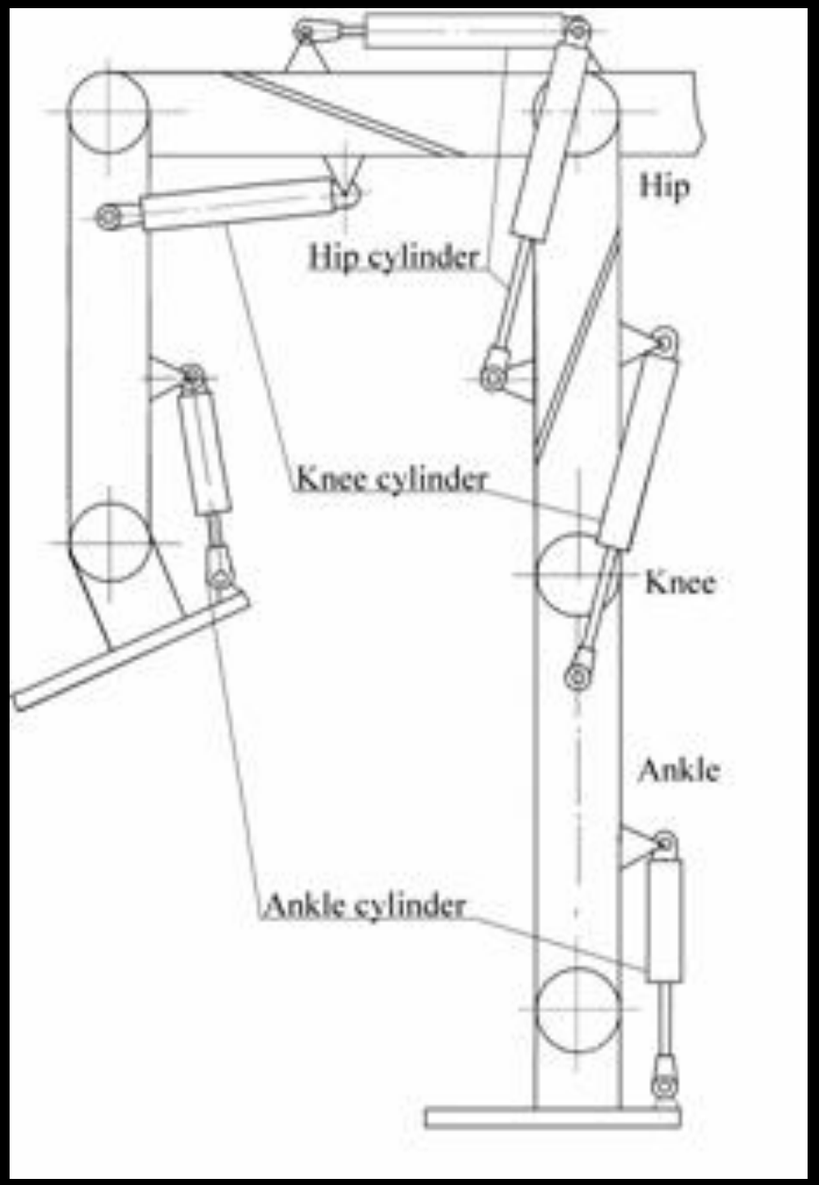


Heavier 80/20

Stronger DIY Hips

Bronze Bushings + 1/2” Shaft

All was going great until…



3 Cylinders Per Leg

6 Cylinders & 6 Valves & 12 Flow Control Valves
~$1,500

I needed something to help with weight.

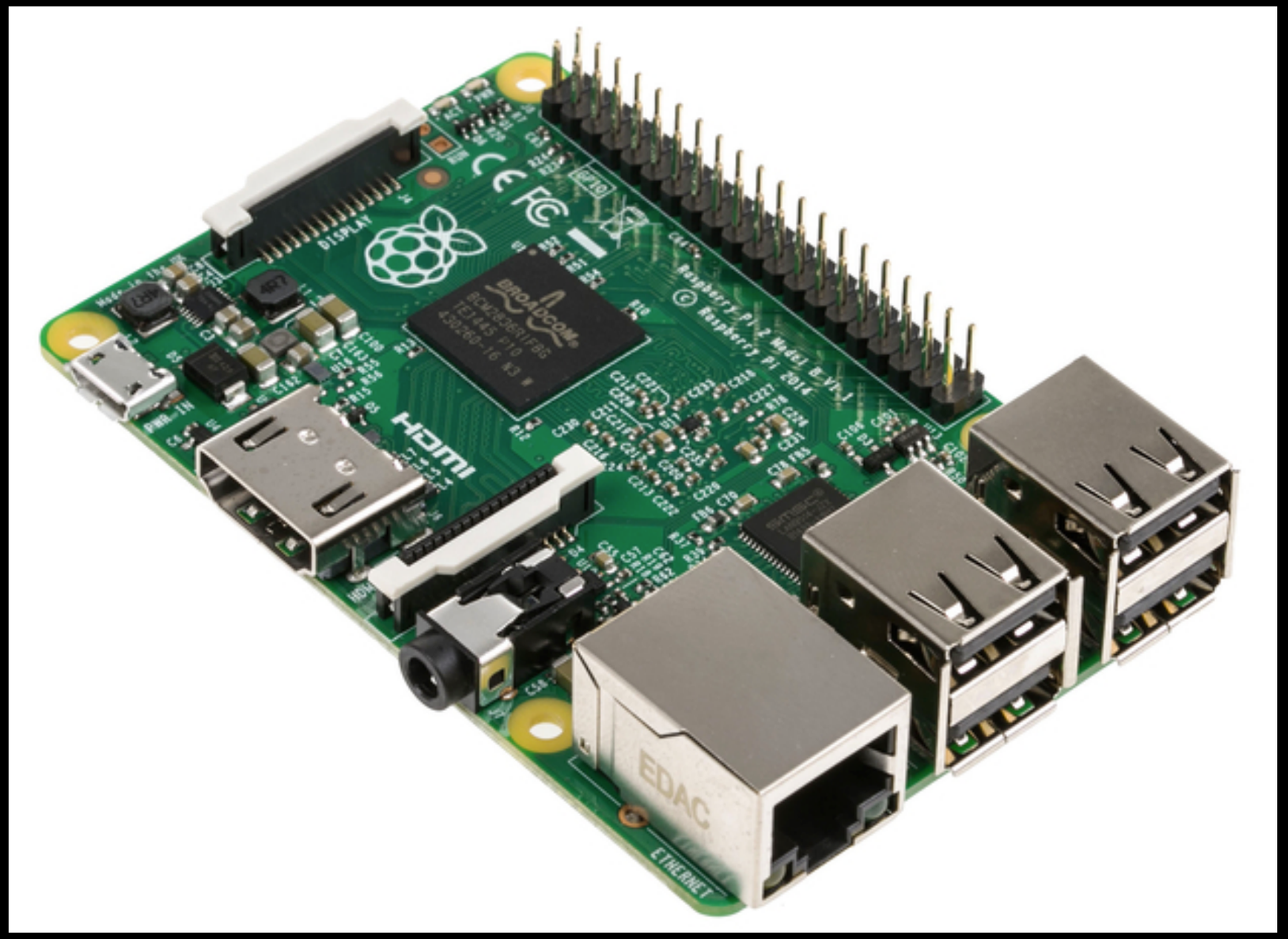
Simplified Hip/Ankle Pivot

No Pneumatics

Electronics

12 V Battery

Batteries Plus $40



Raspberry Pi 2

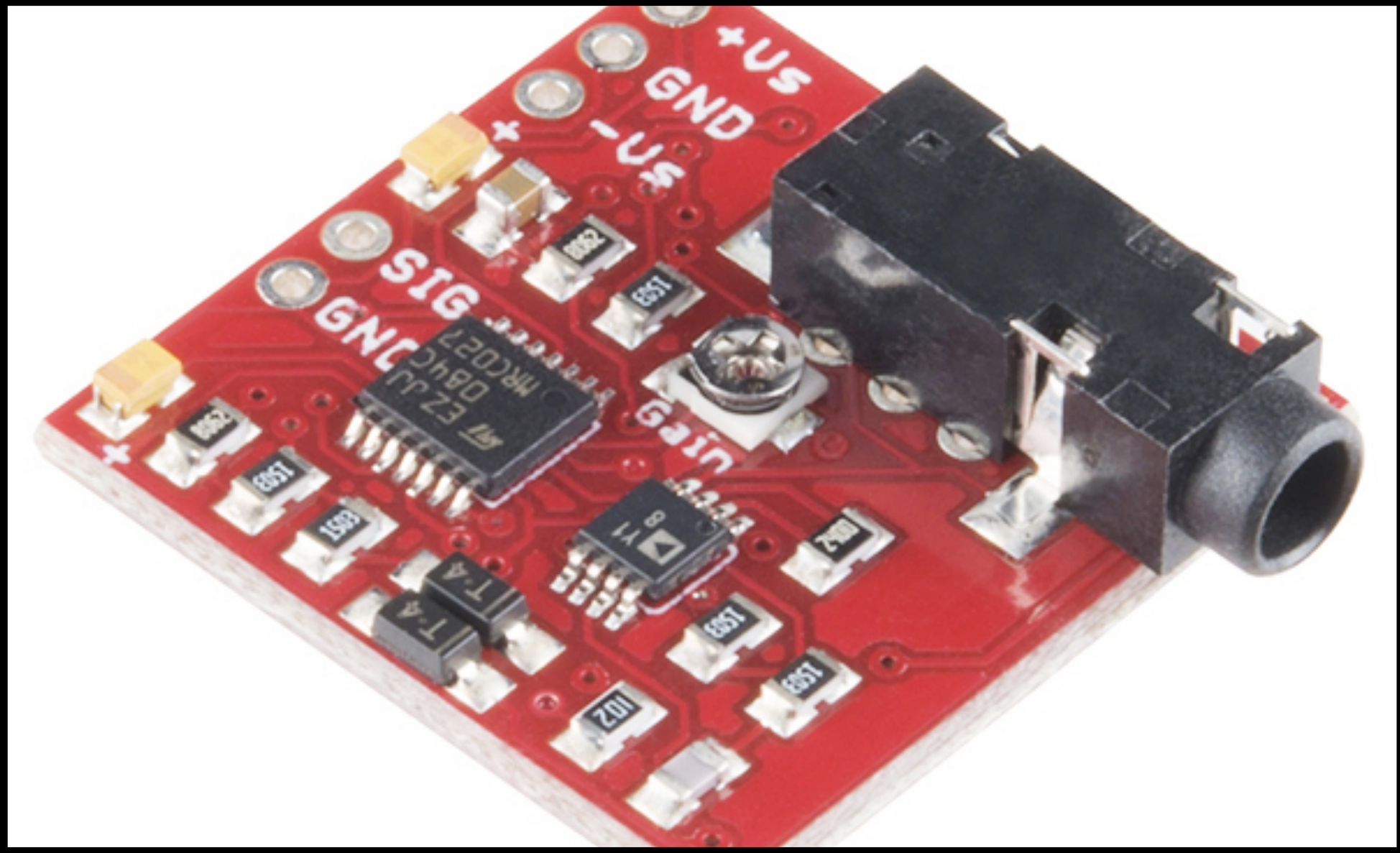
With Case/Wifi/SD Micro $60

Relay Board

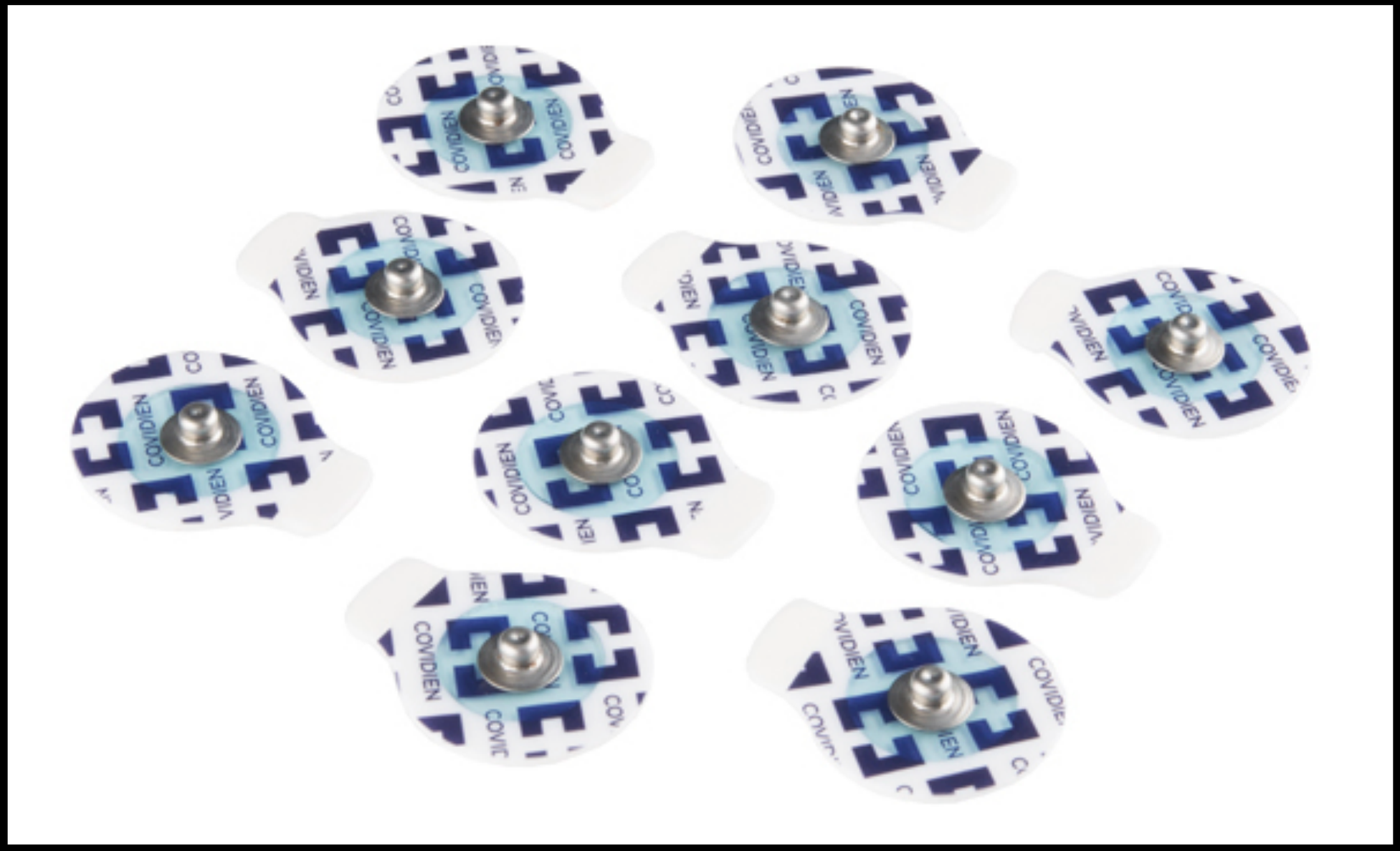
Amazon $9

12V to 5V DC Converter

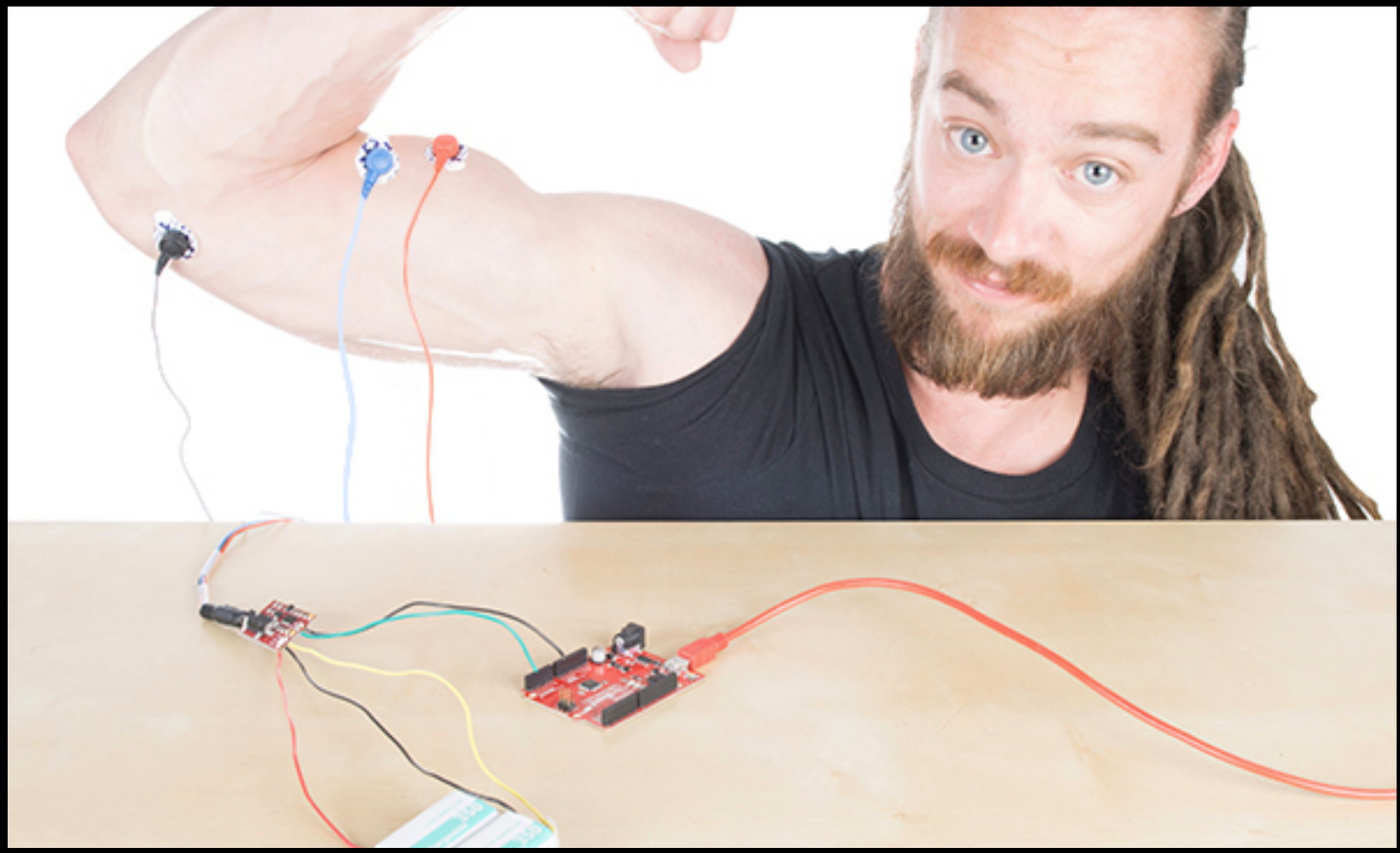
Powers Raspberry Pi2



Muscle Sensor



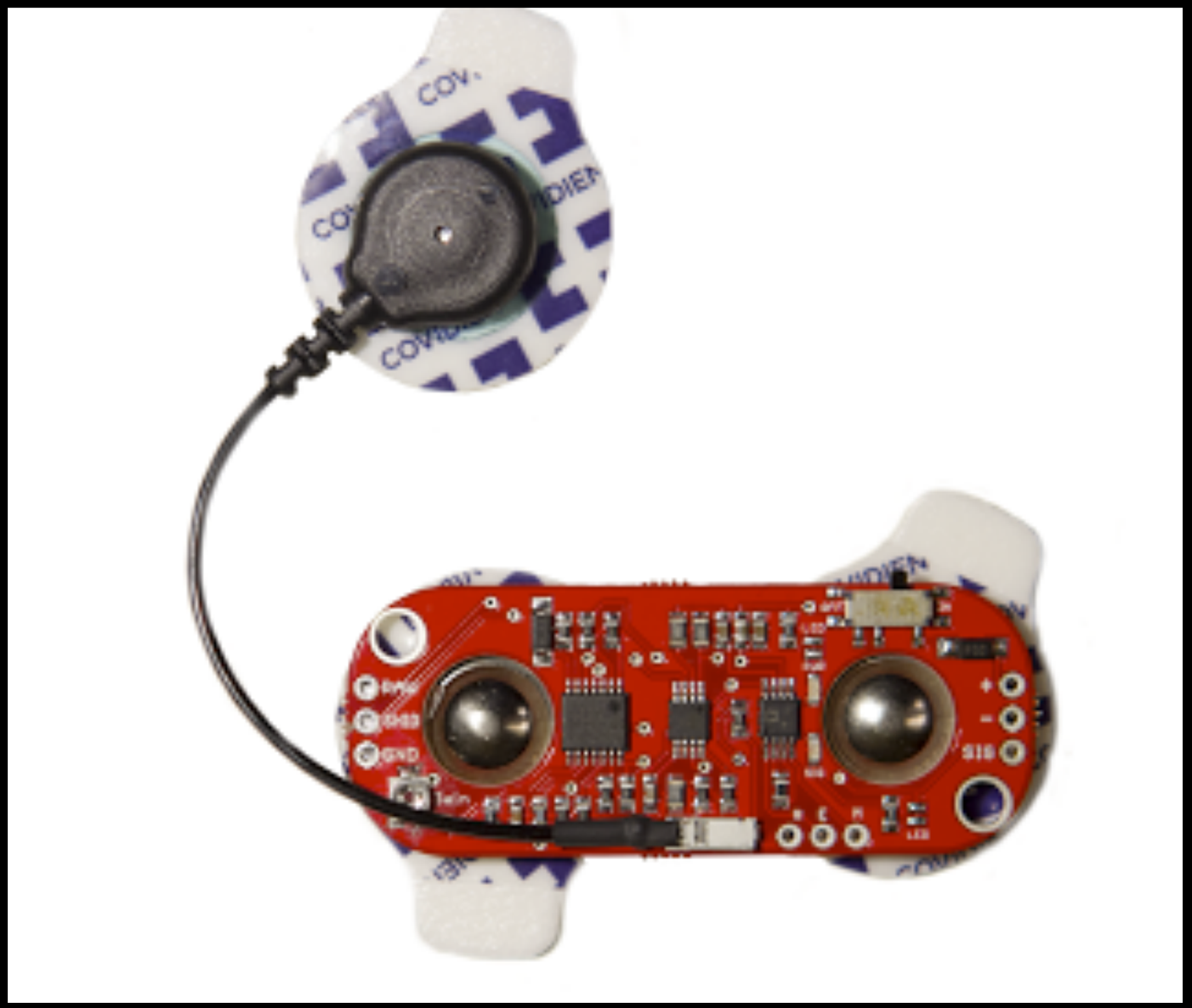
Biometric Sensor Pads



Muscle Data

Out Of Stock :(

Discontinued…



New Version ?

http://www.advancertechnologies.com/p/myoware.html

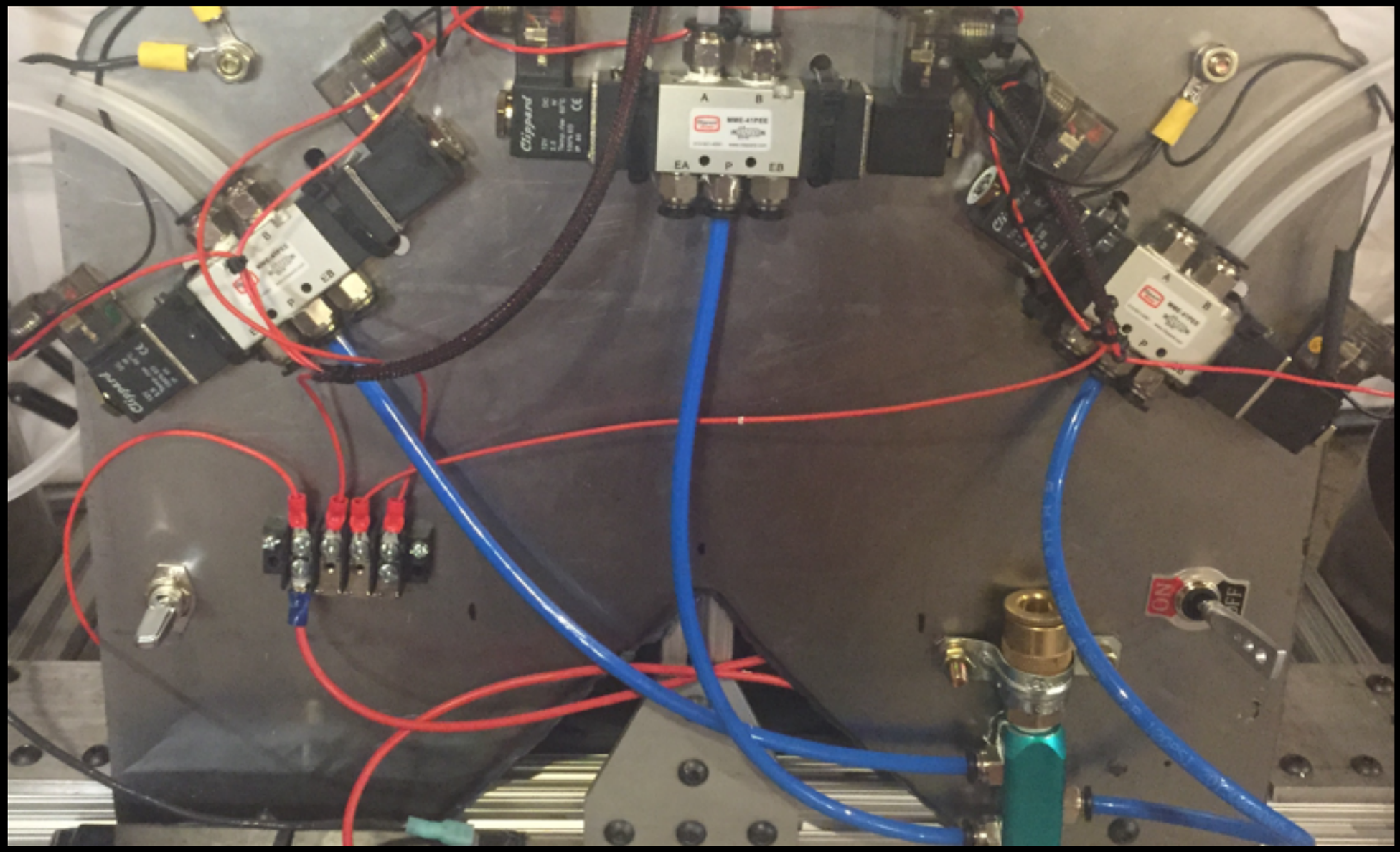
Software I Did Use

- npm install onoff

```
var Gpio = require('onoff').Gpio,
  led = new Gpio(14, 'out'),

  led.writeSync(1); // relay off

  led.writeSync(0); // relay on

});
```

Combine Relays/Switches

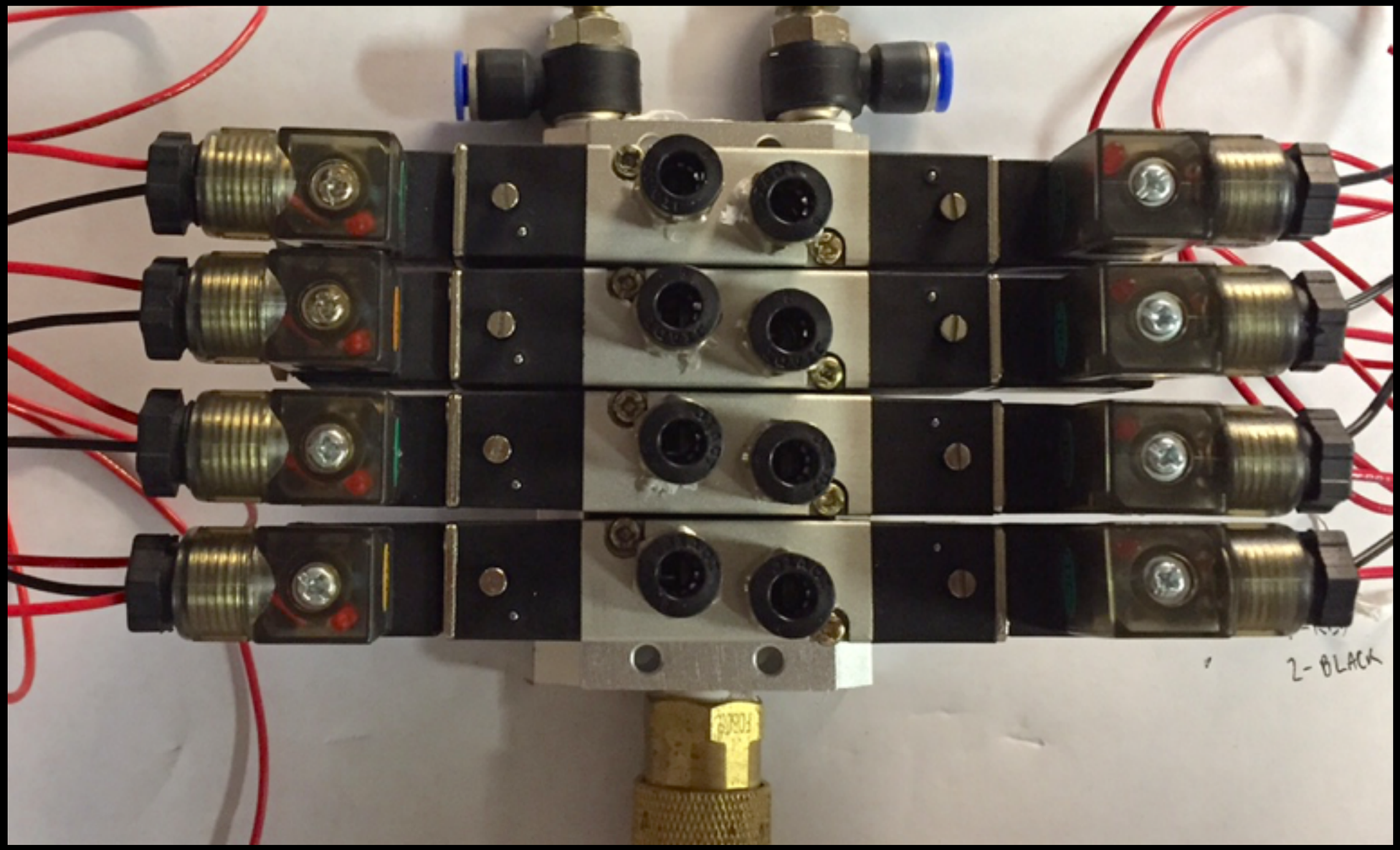
You can control your suit & cylinders.



Backside

Stand (Work In Progress)

Abandoned Parts



Valve Manifold

Leaked 12/31/15

Lots Of Armor

More Armor

MK 1 Specs

- Movement Rate: 6”/sec
- Lifting Capacity (Arms): 300lbs
- % Body Armor Coverage: Front 70%, Rear 30%
- Ballistics Reduction: 23% 9mm
- Movement Radius: 25ft
- Cave Escape Ready: No
- Battery Life: 12V @ 9AH ~4hr runtime with R PI2

Bullet Reduction Steel

- 18 Gauge Steel Sheer is 2,800 PSI for 3/8” hole
- 18 Gauge Roughly Stops .25 Bullet at 25ft
- 1/4” Plate Sheer is 14,800 PSI
- Muzzle Energy of 9mm is roughly 11,887 PSI

Mark 2 - Plans

- Legs w/Knees
- Better fitting & More Armor
- Working Leg Motion Cylinders
- More Armor
- 100% Steel
- Hydraulics

DEMO &
Suit Overview

Thanks!

@scottpreston
http://github.com/scottpreston