Tode-RC

Hardware Development

Arduino-Mega Pro + Ebyte E32-433T30D [#AMPE32T30]

by TGit-Tech [http://www.tgit-tech.com]
Build Version: 21V9 / Last Updated: 2021-11-09

Table of Contents

1. Introduction

The Tode System

- Tode-RC = Handheld Remote Control Models   https://github.com/TGit-Tech/Tode-RC
  - Model #AMP   Arduino Mega Pro (No RF Module)
  - Model #AMPE32T30   Arduino Mega Pro + Ebyte E32-433T30D (1W/30dbm) RF module
  - Model #AMPE32T20   Arduino Mega Pro + Ebyte E32-433T20D (250mW/20dbm) RF module
  - Model #AMPXBEE   Arduino Mega Pro + Digi XBee RF Module

- Tode-SideIO = Input/Output Stations
  - Model #SIOST   Tode SideIO with Screw Terminals   https://github.com/TGit-Tech/Tode-SIOST
  - Model #SIOAP   Tode SideIO with Aviation Plugs

Manuals
- User Manual   Operator Instructions including Setup and Wiring
- Hardware Development   How to build the hardware including detailed circuit diagrams
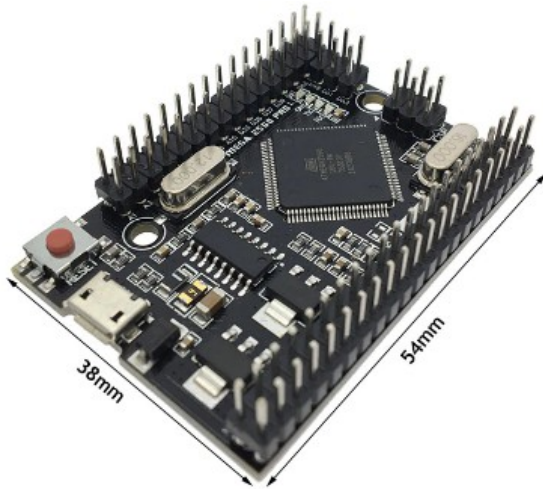- Firmware Development   How to adjust and create firmware for the Tode

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2. Tode-RC

2.1 Bill of Materials (BOM) $37

✔ See the "Tode General Hardware Development" document for required tools
  ○ Note: A 3.5mm Drill bit is required as well as general tools described in that document.
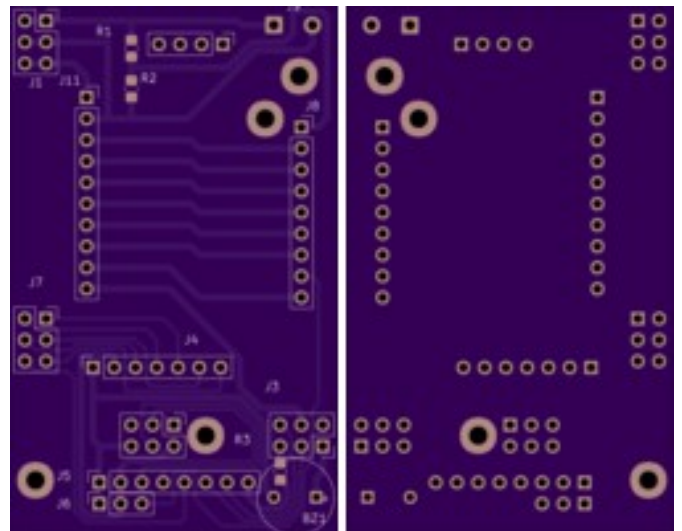
2.1.1 Parts $31

✔ Arduino Mega Pro Mini [ATmega2560 @ 16MHz]
  ○ Power In: 6Vdc to 9Vdc (Peek 18Vdc)
  ○ Power Out: 5Vdc @ 800mA + 3Vdc @ 800mA
  ○ Load Amps: 5Vdc @ 220mA
  ○ IO-Pins: 54-Digital, 16-Analog
  ○ Memory: 256kb RAM, 4kb EEPROM
  ○ Temp Rng: -40C to 85C
  ○ Pricing: ~ $10/each
  ○ Web @ https://robotdyn.com/mega-2560-pro-embed-ch340g-atmega2560-16au.html
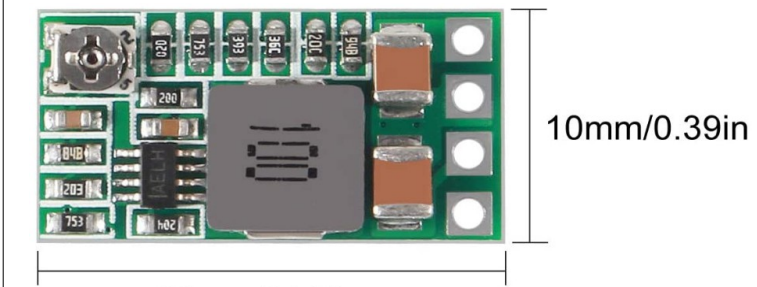

✔ Ebyte E32433T30D
  ○ Power In: 3.3Vdc to 5.2Vdc (+ = Damage)
  ○ Load Amps: Tx @ 106mA, Rx @ 15mA
  ○ Data Rate: 0.3Kbps to 19.2Kbps
  ○ Antenna Plg: SMA-K
  ○ Frequency: 410MHz to 441MHz
  ○ RF: Tx @ 30dBm, Rx @ -147dBm
  ○ Pricing: ~ $10/each
  ○ Web @ https://www.ebyte.com/en/index.aspx
https://www.ebyte.com/en/product-view-news.html?id=108

✔ 1.8 / 1.77 -Inch TFT LCD Display
  ○ Power-In: 5Vdc
  ○ Resolutions: 128 x 160dpi ST7735 RGB
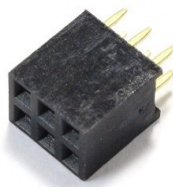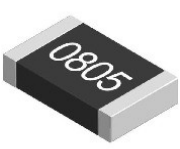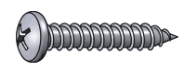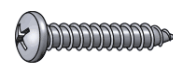
✔ Tode #EMPE32T30 PCB
  ○ Manufacturer: Oshpark.com
  ○ Pricing: $3.84

○ Dimensions: 35mm x 56mm
○ Temp: -20C to 70C
○ (8)Pin-Order: GND,VCC,SCL,SDA,RES,DC,CS,BL
○ Pricing: ~ $4.75/each

○ Batch Price: $115.20 per 30

✔ Tode Buttons PCB
  ○ Manufacturer: Oshpark.com
  ○ Pricing Each: $1.41
  ○ Batch Price: $112.80 per 80

10mm/0.39in

20mm/0.78in

✔ Dorhea 5V @ 3A Buck Power Supply Module
  ○ Input Voltage: 4.5Vdc to 24Vdc
  ○ Output Voltage: 0.8-17V (Fixed Voltage by Trace-Cut)
  ○ Max Output: 3A
  ○ Nominal Output: 1.5A
  ○ Pricing: $1/ea
  ○ Web @ https://www.amazon.com/dp/B08Y674Z6F

2.1.2 Supplies $4

	QTY: 1 @ $0.10/ea = $0.10 1x9P Female Pin Header Dupont 2.54mm-Pitch *(J8) On AMPE32T30*		**QTY**: 4 @ $0.10/ea = $0.40 2x3P Female Pin Header Dupont 2.54mm Pitch *(J1-PWR)(J2-ISCP)(J3)(J7) on AMPE32T30*
	QTY: 1 @ $0.10/ea = $0.10 1x10P Female Pin Header Dupont 2.54mm-Pitch *(J11) On AMPE32T30 for Side-IO*		**QTY**: 1 @ $0.10 = $0.10 1x3P LONG-Lead Female Pin Header Dupont 2.54mm-Pitch *(J6-Keypad) on AMPE32T30*
	QTY: 1 1x4P @ $0.01/pin = $0.04 **QTY**: 1 1x3P @ $0.01/pin = $0.03 Male Pin Header (Cut from 40-Pin) Dupont 2.54mm-Pitch *E32 Align & Keypad*		**QTY**: 1 @ $0.10 = $0.10 1x8P LONG-Lead Female Pin Header Dupont 2.54mm-Pitch *(J5-Display) on AMPE32T30*
	QTY: 1 @ $0.50 (OPTIONAL) 9x4.2mm [0942] Active Piezo Buzzer 2-Lead, 5Vdc, Ultra-Thin		**QTY**: 4" Red @ $0.10/ft = $0.05 **QTY**: 4" Black @ $0.10/ft = $0.05 22AWG Stranded Colored Wire
	QTY: 1 @ $0.20/ea = $0.20 5.5x2.1mm DC Barrel Jack + Nut Female Panel Mount 2-Terminal		**QTY**: 6 @ $0.15/ea = $0.90 6x6x7mm DIP-4 Tactile Push Buttons Through-Hole leads
	QTY: 10 @ $0.01/ea = $0.10 0805 SMT Resistors #AMPE32T30 uses 910K, 470K, 39 #DispKB uses (2)1500, 1200 910, 680, 330, 10		**QTY**: 2 @ $0.10/pair = $0.20 M2.5x0.45 x 6mm Machine Screw & Nut *To fasten Mega-Pro to AMPCenter* 2.4 AMPE32T30	Final Assembly	Step #1
	QTY: 1 @ $0.05/ea = $0.05 3mm Green LED		**QTY**: 2 @ $0.10/pair = $0.20 M2x0.4 - 8mm Machine Screw & Nut *To fasten Keypad & Display to DispKB* 2.2.2 Display	Hardware Assembly	Step #1,3 **QTY**: 1 @ $0.10/ea = $0.10 M2x0.04 – 20mm Machine Screw Only *To heat and push Nuts into plastic* 2.2.2 Display	Hardware Assembly	Step #1
	QTY: 4 @ $0.10/ea = $0.40 #2 - 3/8" Pan Sheet Metal Screws *Used to Attach DispKB to AMPCenter* 2.4 Final Assembly	Step #7		**QTY**: 4 @ $0.10/ea = $0.40 #2 – 5/8" Pan Sheet Metal Screws *Used to Attach AMPE32T30 Casing to AMPCenter* 2.4 Final Assembly	Step #7

2.1.3 3D-Prints $2

✔ 3D Print the Following Casing (Order according to Assembly Needed)
  ○ Files in Folder: /3DPrints/

File Name	Grams	Plastic Cost $0.02/g	Time	Power + Machine Use $0.01/hr	Total Cost	Supports
Tode-DispKB-Cover.stl	13-grams	$0.26	2h 31m	$0.03	$0.29	YES
Tode-Handheld-AMPE32T30.stl	24-grams	$0.48	4h 50m	$0.05	$0.53	NO
Tode-Handheld-AMPCenter.stl	17-grams	$0.34	3h 25m	$0.04	$0.38	NO
Tode-DispKB-Buttons.stl	1-gram	$0.02	0:16m	$0.01	$0.03	NO

  ○ Pricing at $20/per 1KG Roll
  ○ 0.15 Layer Height

✔ See separate Section #3.Battery Tray|outline for the Battery Tray Extension

Assembly Diagram
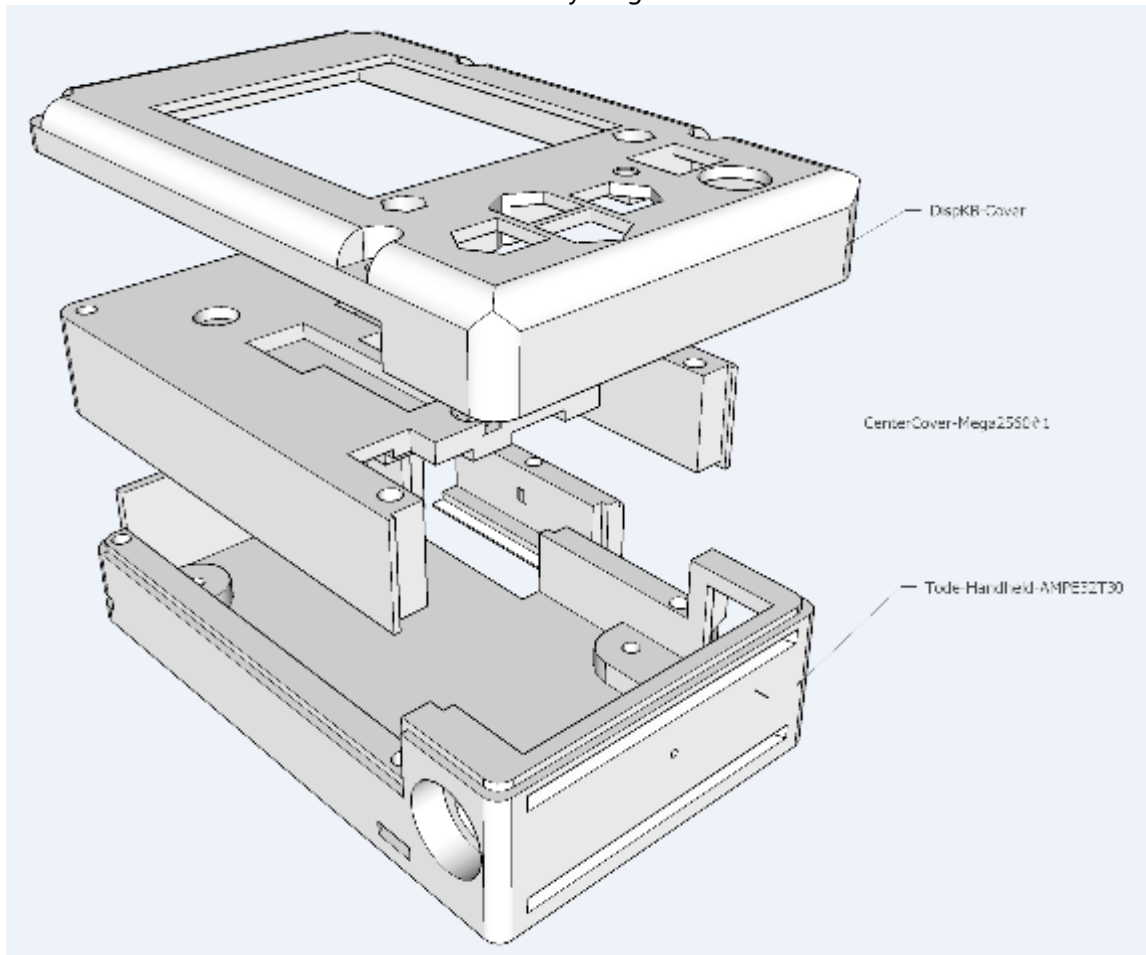
2.2 Display Assembly

2.2.1 PCB Assembly

Printed Circuit Boards can be either ordered from a Custom PCB Manufacturer or created with a CNC Router.

- ✔ Custom Manufactured PCB
  - ○ Benefits - Custom PCB manufacturing is by far the better approach.
    - ▪ Copper through holes provide better connection
    - ▪ A Silk Sscreen for better corrosion resistance
    - ▪ Far easier to solder

 - ○ Common Custom Manufacturing Businesses
    - ▪ https://oshpark.com/
    - ▪ https://jlcpcb.com/
    - ▪ https://www.pcbway.com/orderonline.aspx
    - ▪ https://www.customcircuitboards.com/
    - ▪ https://custompcb.com/

- ✔ CNC Routed PCB
  - ○ Benefits
    - ▪ Generally cheaper by a couple dollars
    - ▪ Instant product (No shipping/manufacturing wait time)
    - ▪ Good for designing phases; not good for finished design production.

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STEP #1 – Obtain (Purchase/Make) the BUTTONS – PCB
 	
✔ Design File
  ○ FOLDER = /kicad/Buttons/output/
  ○ GERBER FILE = Buttons-F_Cu.gbr
 	
✔ CNC Routing
  ○ CNC File = Buttons-F_Cu.45S045D.gbr.nc
  ○ Hole Sizes = 0.8mm, 2.7mm	
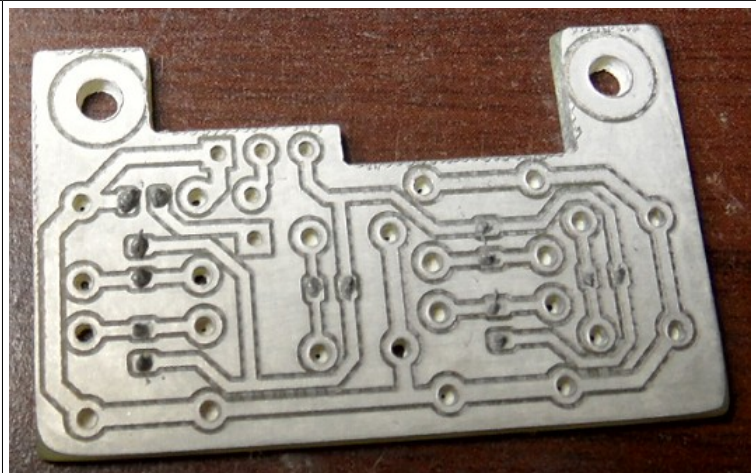
STEP #2 – Attach SMT Resistors ✔ Use Schematic & Layout to determine Resistor Locations ✔ Apply solder paste at all Resistor locations (as shown) ✔ Place SMT Resistors at correct Locations **STEP #3** – Use Reflow Oven to solder SMT Resistors ✔ Place Board w/Resistors & Paste in Reflow Oven T-962 Select Wave #3 and Start the Reflow Oven	
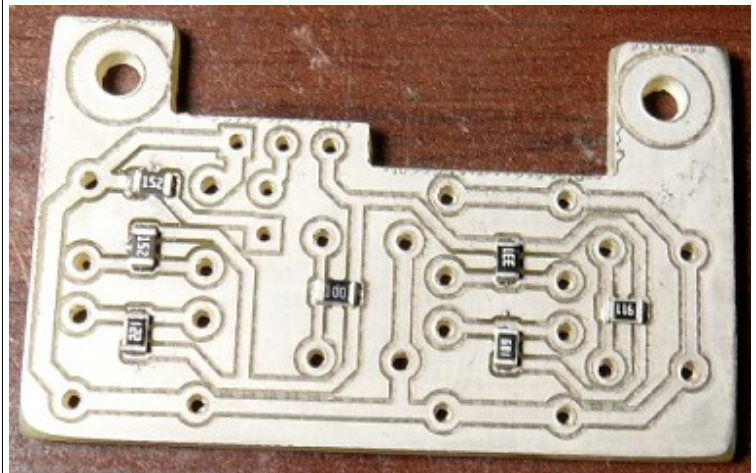
STEP #4 - Install and Solder Buttons Set the board asside and proceed to Assembly Instructions. NOTICE: The 3P Male Header and Power LED will be installed to fit during assembly.	
STEP #5 – Keypad Connection ✔ Push the pins of a 3P Male Header flush with Top	
Step #6 – Insert and Solder 3P Male Header ✔ Solder from the bottom-side instead of top	
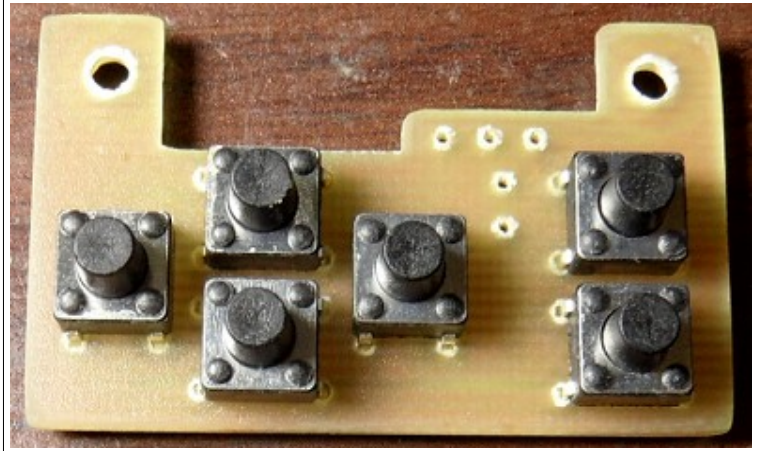
A. Schematic & Layout

SCHEMATIC

LAYOUT

23.622 mm

38.354 mm

- ✔ Surface Mount (SMT) 0805 Resistors
  - ○ LFT–SW6   = (R1) 910-ohm
  - ○ UP–SW3   = (R2) 330-ohm
  - ○ DWN–SW5 = (R3) 680-ohm
  - ○ RHT–SW4   = (R4) 10-ohm or less
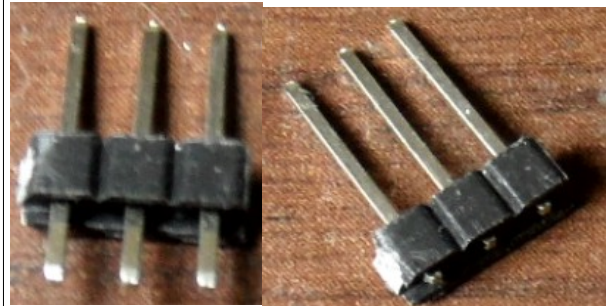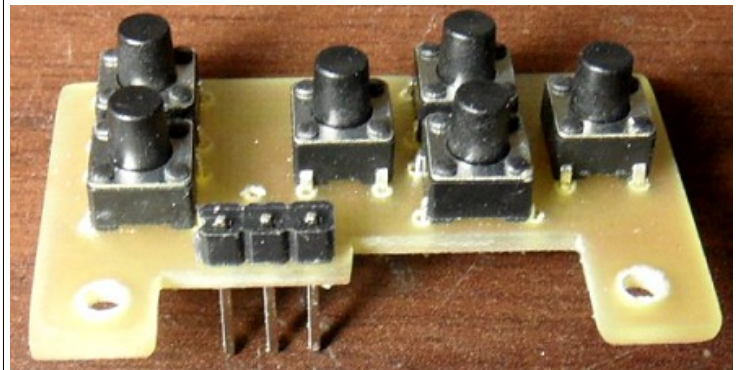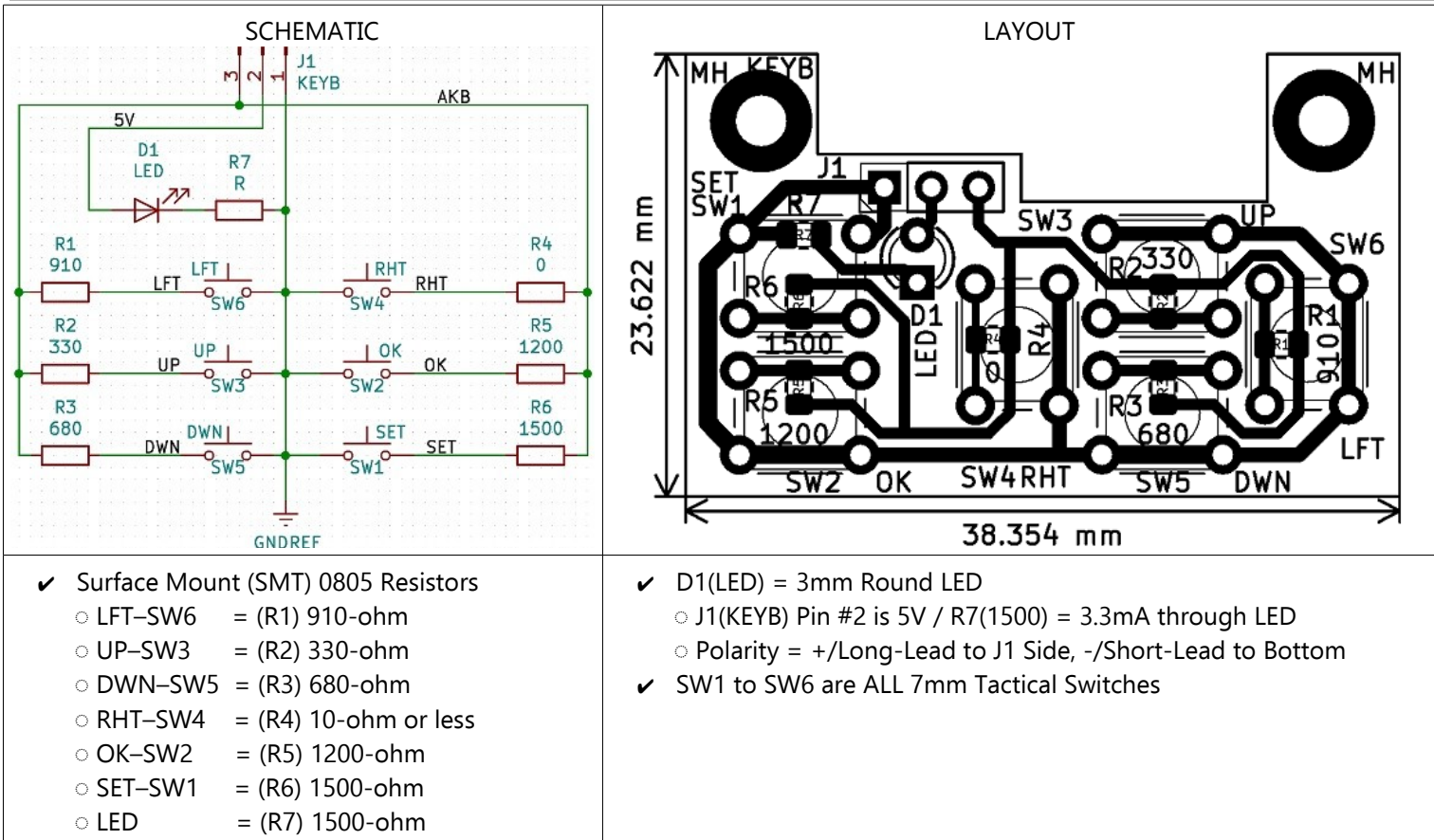 - ○ OK–SW2   = (R5) 1200-ohm
  - ○ SET–SW1   = (R6) 1500-ohm
  - ○ LED   = (R7) 1500-ohm

- ✔ D1(LED) = 3mm Round LED
  - ○ J1(KEYB) Pin #2 is 5V / R7(1500) = 3.3mA through LED
  - ○ Polarity = +/Long-Lead to J1 Side, -/Short-Lead to Bottom
- ✔ SW1 to SW6 are ALL 7mm Tactical Switches

2.2.2 Hardware Assembly

STEP #1 – Install Nuts to Tode-DispKB-Cover.stl

- ✔ Melt-in two M2 Nuts
  - ○ Hold Nut with a long M2 screw and pliers as shown
  - ○ Heat the Nut using a heat gun
  - ○ Press the nut, edges lined up to shell & flush with top

STEP #2 – Prepare and Insert Tode-DispKB-Buttons.stl

- ✔ Place Buttons on Keypad Switches
  - ○ Use Scissors to cut Buttons apart at the center
  - ○ Skinny legged arrow belongs on top
  - ○ If button don't push-on use 3.5mm bit to drill-out

- ✔ Place 3mm LED light into PCB
  - ○ Square-Pad is Negative (short-lead)
  - ○ Do not solder the LED at this point
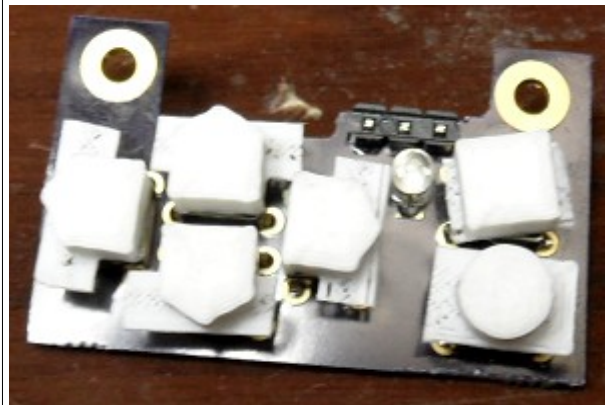
STEP #1 – Install Stickers to Face of Tode-DispKB-Cover.stl

STEP #3 – Fasten Display & Keypad and Solder LED

✔ Place 1.8/1.77-Inch TFT Display in Tode-DispKB-Cover.stl
  ○ Solder the 8P Male Header to Screen if separate

✔ Place the Keypad in Shell over the LCD as shown
  ○ Fasten with Screw Size: M2x0.4 – 8mm long
  ○ Suggest using Phillips flat head but Pan-head okay.

✔ Use LED pins to position LED in Shell Hole for LED
  ○ Solder and cut LED pins to PCB

✔ On Manufactured Keypad PCBs a proper fit may require
    cutting, sanding above the 3P Connection Header.
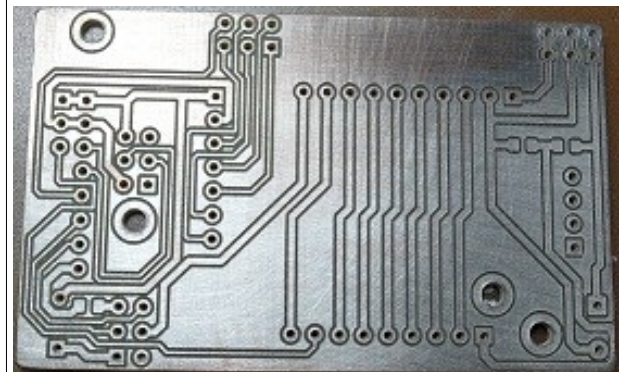


2.3 Backplane AMPE32T30

2.3.1 PCB Assembly

STEP #1 – Obtain (Purchase/Make) the AMPE32T30 – PCB

✔ Design File
  ○ FOLDER = /kicad/AMPE32T30/output/
  ○ GERBER FILE = AMPE32T30-F_Cu.gbr

✔ CNC Routing
  ○ CNC File = AMPE32T30-F_Cu.gbr.nc
  ○ CNC Settings: Z-Down: -0.045, Speed: 45mm/s
  ○ CNC Isolation Bit = Pyramid 0.2mm Tip 45-deg
 ○ Hole Sizes = 0.8mm, 2.7mm

**STEP #2** – Attach Female Dupont Headers

✔ Plug the following Female Headers onto the Mega-Pro Pins
   ○ J1 [PWR]   = 2x3P Female Header (Very Top left)
   ○ J2 [ICSP]   = 2x3P Female Header (ICSP 6-Pin Port)
   ○ J3 [D44...]   = 2x3P Female Header (Bottom-Right Corner)
   ○ J7 [D18...]   = 2x3P Female Header (4-Pin Rows Up on Left)
   ○ J8 [A1...]   = 1x9P Female Header (Top Inner on Right)

✔ Refer to Schematic & Layout to place Pin-Headers
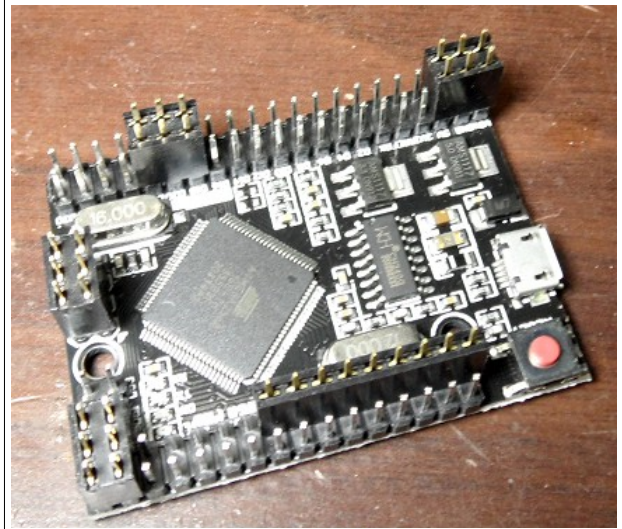
STEP #3 – Solder Female Headers to the PCB

✔ Place the Arduino Mega Pro and Headers into proper place on PCB
✔ Solder the Female Pin-Headers from Step #3 to the PCB board.
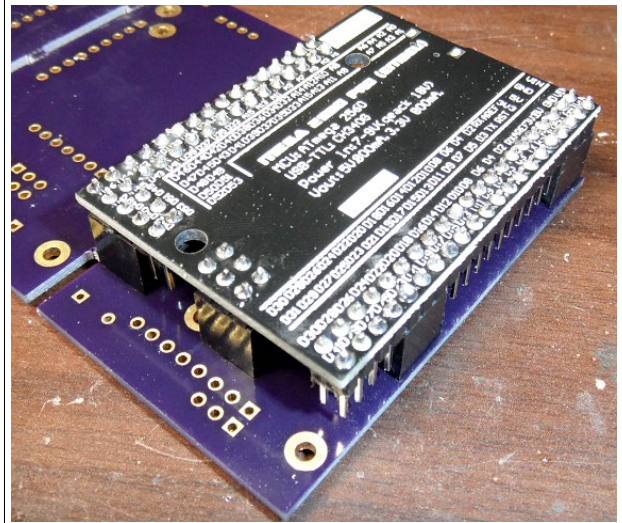
WARNING: Never solder-on E32 Radio before STEP #4.

STEP #4 – Attach & Solder **J11** 1x10P [SideIO] Female Header

   1. Unplug the Arduino Mega Pro from PCB
   2. Press header pins on a flat surface; bend to 90-deg
   3. **J11** [IO] = 1x10P Female Header w/bent pins
   4. Insert as shown. Be sure face is parallel with edge of board
   5. Use a Clip to hold in place while soldering the pins to the PCB.

✔ Refer to Schematic & Layout
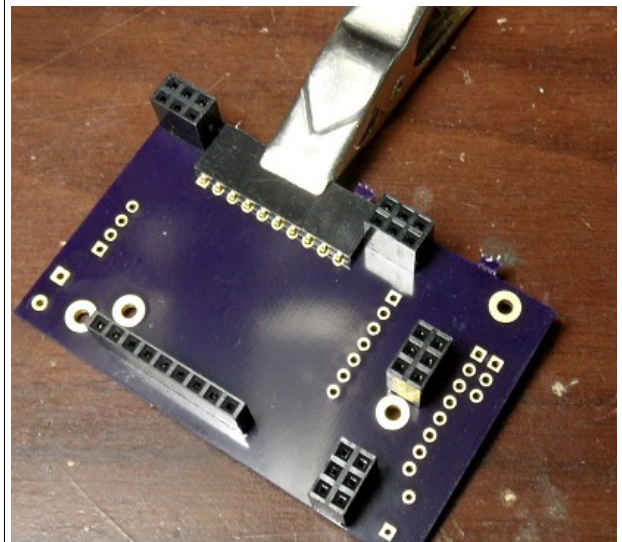
STEP #5A – *BUZZER OPTION* (OPTIONAL) Buzzer Resistor

✔ Using Schematic & Layout Solder-Paste SMT Resistors
   ○ R1 = 910KΩ SMT 0805 Resistor
   ○ R2 = 470KΩ SMT 0805 Resistor
   ○ R3 = 39Ω SMT 0805 Resistor

✔ Bake the PCB in Reflow Oven

SKIP THIS STEP – The battery monitor is no longer relevant due to the required external 3A Power Supply.

If a Buzzer Feature is desired - Manually solder the R3 = 39Ω SMT Resistor.

|	
STEP #5B – ***BUZZER OPTION*** (OPTIONAL) Attach Buzzer ✔ Insert Ultra-Thin 5Vdc Piezo Buzzer into Bottom-Left ✔ Solder the Piezo Buzzer leads and snip to board level.	

STEP #6 – Solder the Ebyte E32 Radio to the PCB
 	
    1. Cut a 4P Male Header and Insert at the top for alignment
       a) The red circle in the picture
 	
    2. Insert Ebyte E32 RF Module into the AMPE32T30 PCB (as shown)
 	
    3. Solder Pins that attach to the PCB
       a) No need to solder the 4P top alignment pins to E32 Module	

STEP #7 – Prepare 5V 3A Power Module ✔ Using Razor Knife cut the Top Trace (label ADJ) ✔ Jump a Solder bridge where 5V is labeled ✔ Do a Continuity Test verifying changes	
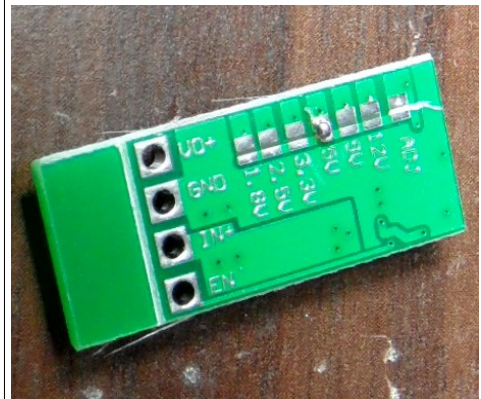
STEP #8 – Wire 5V 3A Power Supply(PS) Ground
 	
✔ With 22awg **Black** stranded wire
  ○ Solder GND hole of **P.S.** by twisted together the ends of….
    ▪ 4″ long piece
    ▪ 1-1/2″ long piece
  ○ Solder GND hole of **PCB** board by twisting together the ends of…
    ▪ The other end of the 4″-long wire above from P.S.
    ▪ 3-1/2″ long piece
 	
✔ NOTE – *It was found that the Mega-Pro on board power regulator couldn't feed the radio while set to high-power (30dbm) and would cause the Mega-Pro to reset during transmission.*
  ○ The Solution is an external 3A Power Module feeding directly into the Radio but GND must also feed to PCB/Mega.	
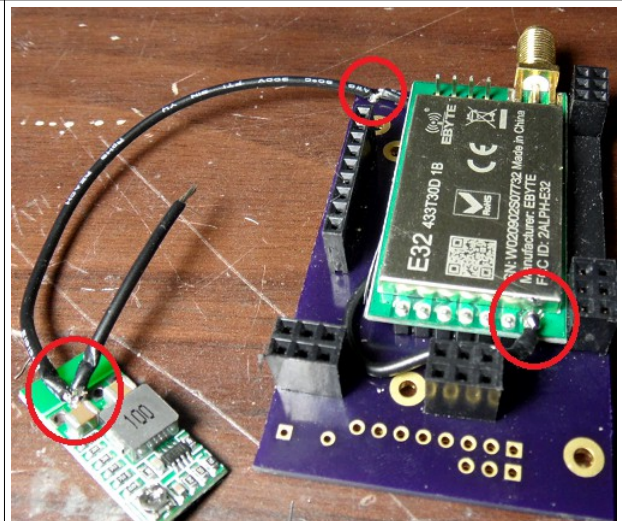
STEP #9 – Wire 5V 3A Power Supply Power
 	
✔ With 22awg **Red** stranded wire
  ○ Solder 1-1/2″ long piece
    ▪ Power Supply VO+(5Vdc) → E32-VCC Pin
  ○ Solder 1-1/2″ long piece in P.S. VI+ (In) hole.	

A. Schematic & Layout

SCHEMATIC
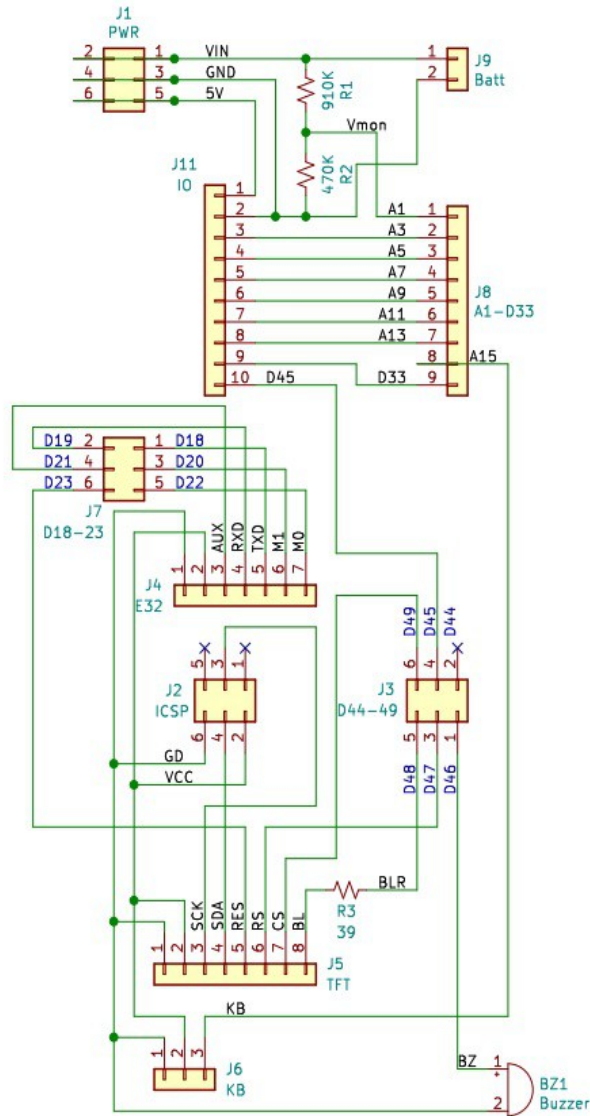
LAYOUT
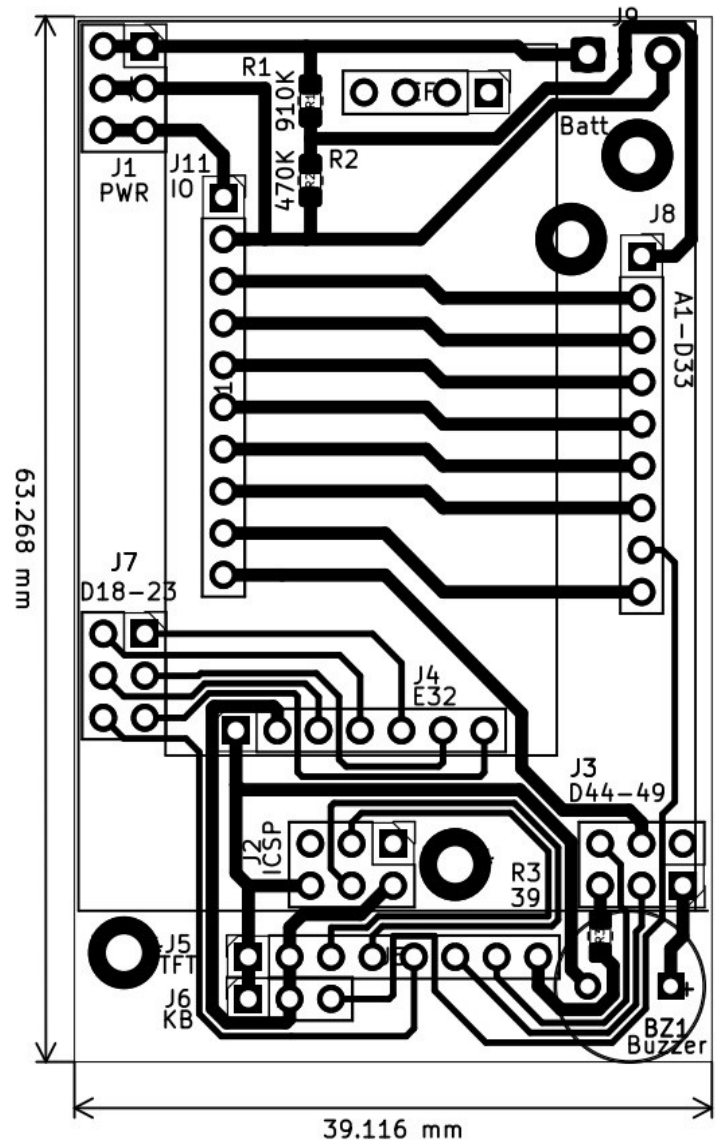
✔ Female Dupont 2.54mm pitch Connectors

J1	PWR	2x3P Female Header
J2	ICSP	2x3P Female Header
J3	D44-	2x3P Female Header
J4	E32	E32 Radio Module (Direct Solder)
J5	TFT	1x8P Female Header (TFT) Display
J6	KB	Keypad PCB
J7	D18	2x3P Female Header
J8	A1-10	1x9P Female Header
J10	SideIO	1x10P Female Header

✔ J4(E32)   Direct Solder

✔ Battery Monitor Resistors
   ○ R1 – 910Kohm 0805 SMD (No longer used)
   ○ R2 – 470Kohm 0805 SMD (No longer used)
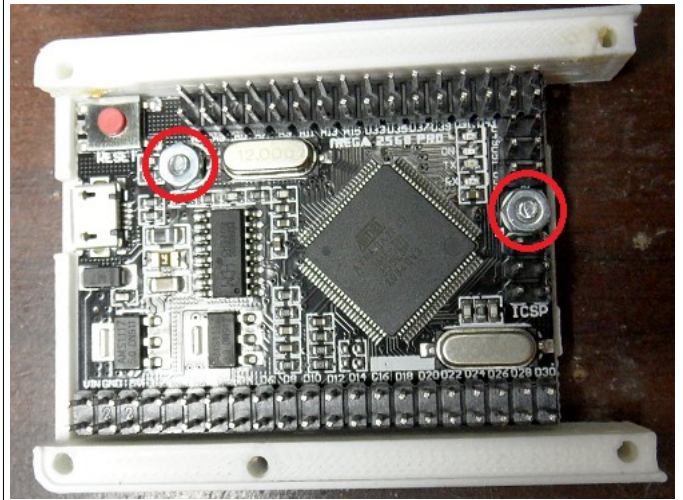   ○ **Due to the external 3A power regulator the battery monitor feature design is no longer used.**

✔ Buzzer Feature (If a buzzer feature is desired)
   ○ R3 – 39ohm 0805 SMD
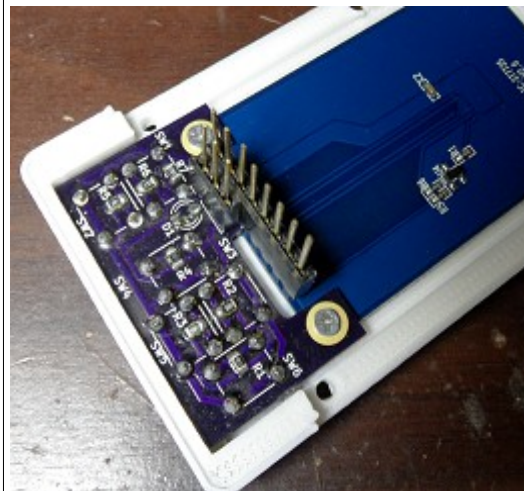   ○ BZ1   Direct Solder

2.4 Final Assembly

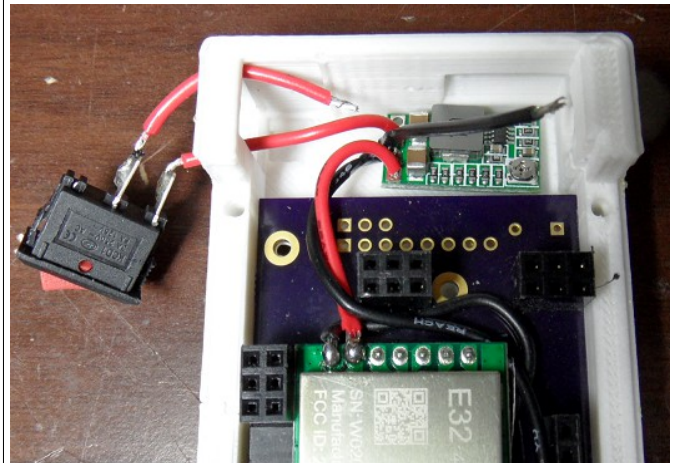|	
STEP #1 – Fasten Mega 2560-Pro Board to AMPCenter ✔ 3D-Print File: Tode-Handheld-AMPCenter.stl ✔ Pan-head Screw Size: M2.5x0.45 – 6mm long	

STEP #2 – Plug on Long-Leg 3P Female and 8P Female
 	
✔ On the Display Assembly
  ○ Plug in a Long-Legged 8P Female Header to Screen
  ○ Plug in a Long-Legged 3P Female Header on Keypad	

Step #3 – Plug on Back-plane Assembly with Screen
 	
✔ Carefully Align the Mega-Pro Pins [from Step#1] with the AMPE32T30 back-plane PCB as well as the Screen and Keypad pins
 	
✔ Compress the assembly verifying all plugs are seated.
  ○ Lift Plugs on Display & Keypad just a hair.
 	
✔ Solder the Display and Keypad Plug Pins to the PCB.
  ○ Cut off excessive leads	

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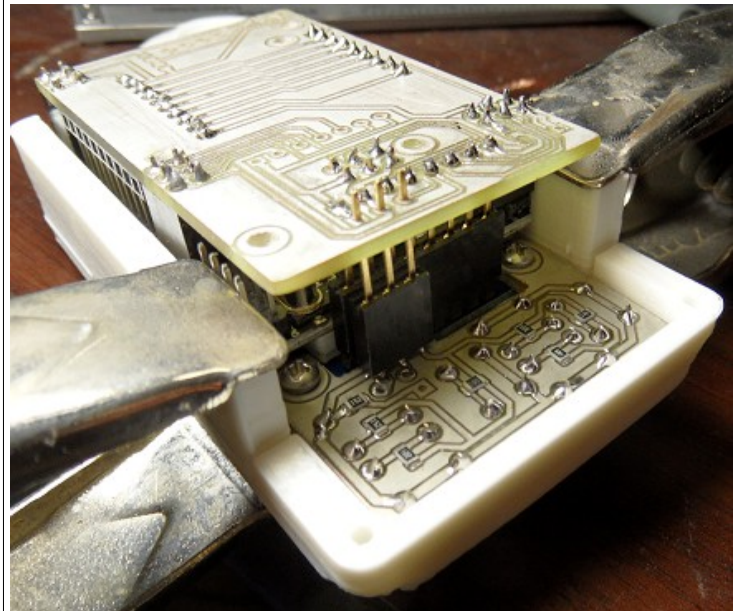
Step #4 – Insert and Fasten the AMPE32T30 Back-plane PCB.
 	
✔ Slide PCB from bottom to top and E32 Antenna plug through hole
 	
✔ Using (2) #2-56 x 1/4" Machine Screws and Nuts fasten the PCB
  ○ Use the hole in the very Bottom-Right (as shown)
  ○ Use the hole in the very Top-Left (next to wires)
  ○ Use a longer screw to pull nuts into the plastic	

Step #5 – Solder Switch ✔ Thread the 1-1/2" long piece in P.S. VI+ (In) hole (from Step #9) through the switch hole and solder to the bottom leg of the switch as shown. ✔ Cut 1-1/2" long piece and solder to switch top leg and thread it through the switch hole as shown.	
Step #6 – Finish Wiring ✔ Wire Power Supply GND to Barrel Plug (long-leg) ○ Thread wire through Barrel NUT BEFORE soldering. ✔ Tighten barrel jack with Nut ✔ Wire Switch top-leg to Barrel Plug (short-leg) ✔ Insert Switch fully and arrange wires 	
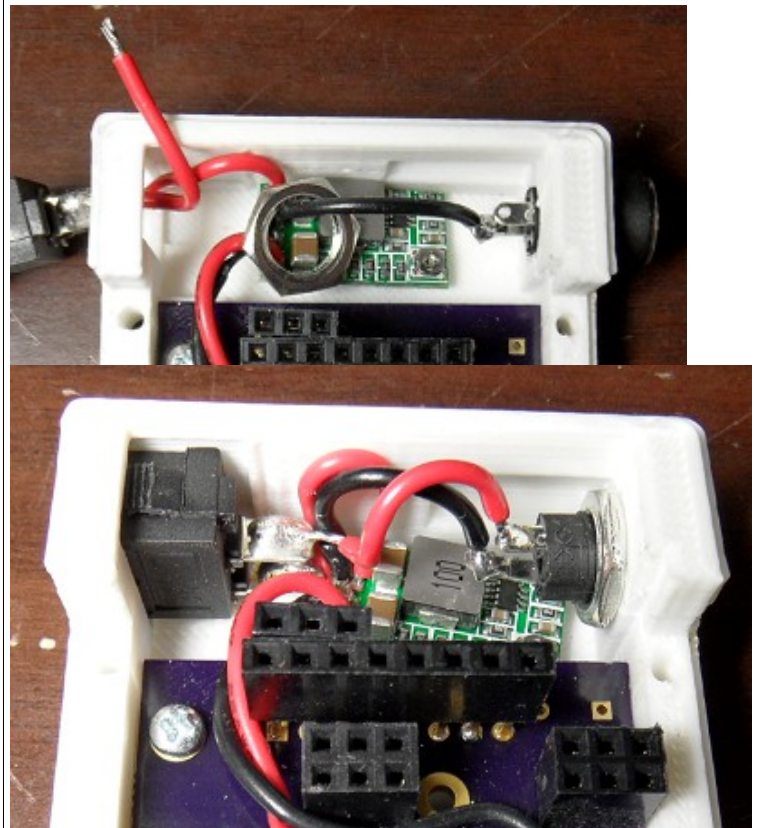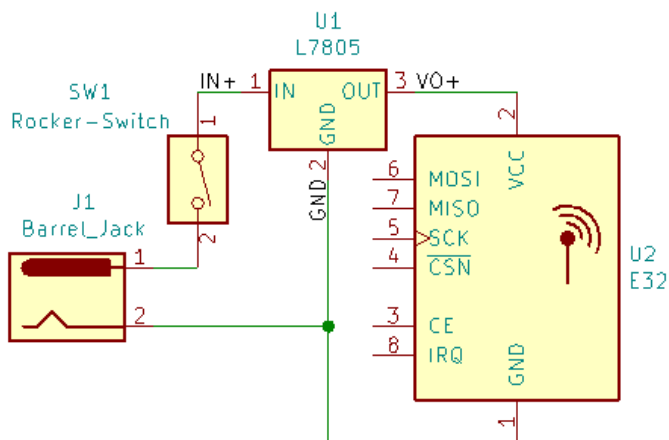
STEP #7 – Final Assembly and Functional Test

- ✔ Plug the Mega-Pro Into the AMPE32T30 Backplane

- ✔ Plug the DiskKB on top.
  - ○ Fasten using (4) #2 x 3/8" long pan-head SMS.

- ✔ Fasten from the backside
  - ○ Use (4) #2 – 5/8" long Pan-head Sheet Metal Screws

- ✔ Side-IO Cover Install
  - ○ Insert a #2-56 nut into side of cover
  - ○ Use #2-56 x 3/4" long screw to tighten

- ✔ Plug the Tode-RC into Computer via Top-USB
- ✔ Upload the firmware and test button/screen operation

3. Battery Tray

3.1 Bill of Materials (BOM) $4
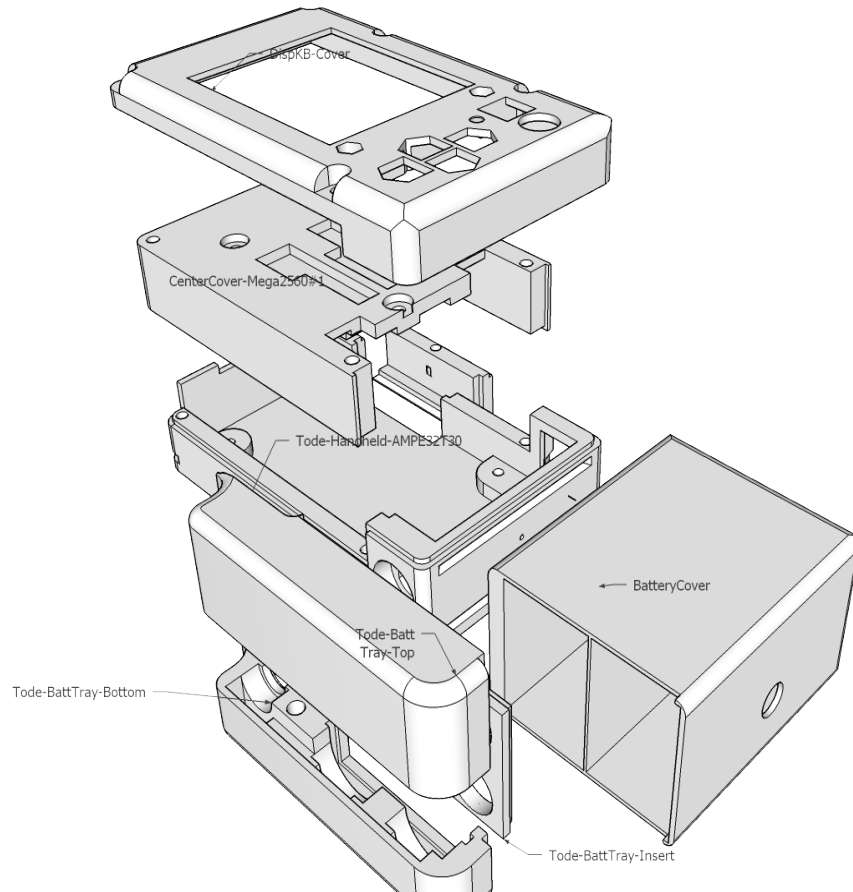
3.1.1 Supplies $3

QTY: 1 @ $1.75/ea 5.5x2.1mm DC Barrel Plug Female Panel Mount 2-Terminal with Nut	QTY: 2 @ $0.35/ea = $0.90 Hard Plastic Side-Exit Wires 9V Battery Connector Clip *Wires must exit from a side / must be hard plastic.
Pan-Head Screws @ $0.10/ea (1) #2 x 1/4" Long. (1) #4 x 3/4" Long.	

3.1.2 3D-Prints $1

- ✔ 3D Print the Following Casing (Order according to Assembly Needed)
  - ○ Files in Folder: /3DPrints/

File Name	Grams	Plastic Cost $0.02/g	Time	Power + Machine Use $0.01/hr	Total Cost	Supports
Tode-BattTray-Top.stl	7-grams	$0.14	1h 43m	$0.02	$0.16	NO
Tode-BattTray-Bottom.stl	4-grams	$0.08	1h 0m	$0.01	$0.09	NO
Tode-BattTray-Insert.stl	2-grams	$0.04	0h 20m	$0.01	$0.05	NO
Tode-BattTray-Cover.stl	14-gram	$0.28	2h 54m	$0.03	$0.31	NO

- ○ Pricing at $20/per 1KG Roll
- ○ 0.15 Layer Height

DispKB-Cover

CenterCover-Mega2560#1

Tode-Handheld-AMPE32T30

BatteryCover

Tode-Batt Tray-Top

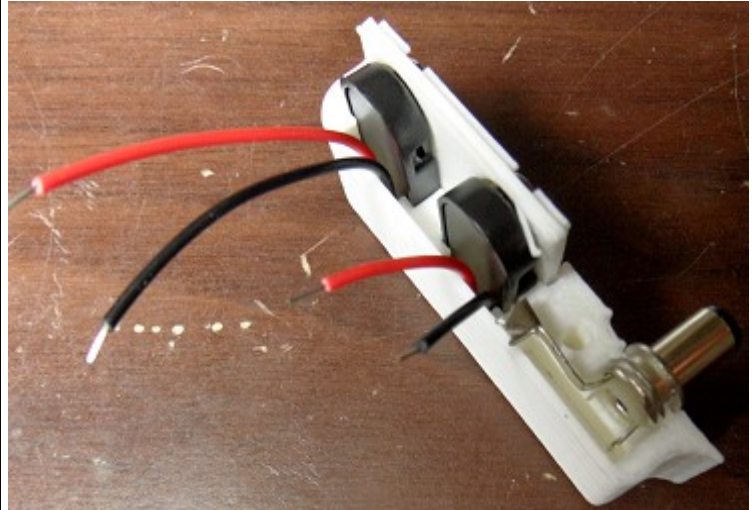Tode-BattTray-Bottom

Tode-BattTray-Insert

3.2 Assembly

STEP #1 – Place Insert and Plugs

- ✔ Place (2) 9V Clips in Tode-BattTray-Insert.stl
- ✔ Bend wires back behind the clip as shown
- ✔ Slide the Insert w/Plugs into the Tode-BattTray-Top.stl
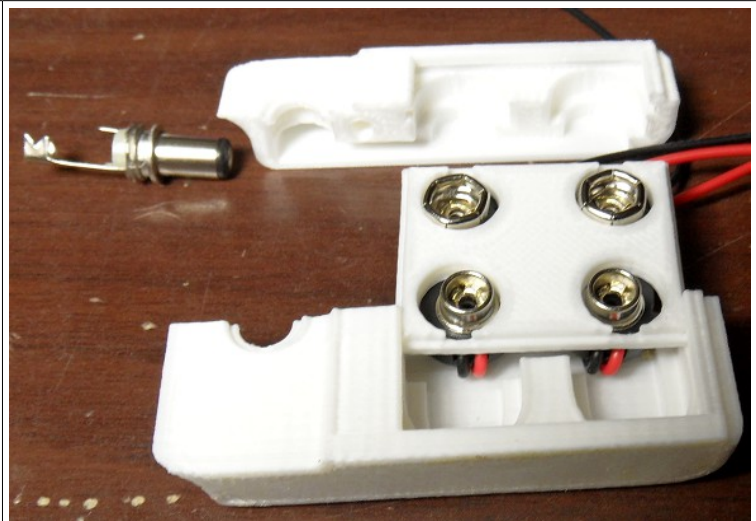
STEP #2 – Cut-to-fit wires and strip

- ✔ Pull the wires together to the edge of the model
- ✔ Snip the wires and strip their ends

- ✔ Bend the long DC-Barrel Plug Lead over to fit in model
- ✔ Cut the wire holding part off with dikes

STEP #3 – Solder wires to DC-Barrel Plug

- ✔ Twist the two red wires together and solder to short lead on DC-Barrel plug
- ✔ Twist the two black wires together and solder them to the longer (cut-off & bent) lead.
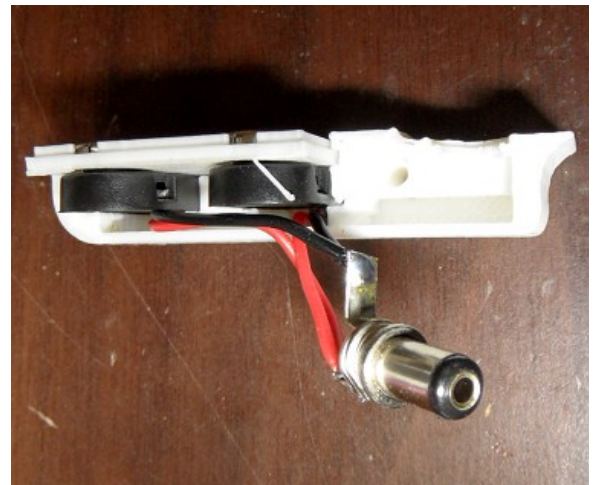
STEP #4 – Assemble the Tode-BattTray-Bottom.stl

- ✔ Slide the Bottom down over the top
- ✔ Make sure wires don't get trapped in the joint
- ✔ Use #4 – 3/4" long screw to tighten/hold assembly

STEP #5 – Attach Tode-BattTray-Cover.stl to Tode-RC Unit

- ✔ Place a #2 – 1/4" Long Screw on a screwdriver
- ✔ Run the screw up through the holes in the Tray Cover
- ✔ Hold the screw up and place Tode-RC on top
  - ○ Where the Grooves mesh together
- ✔ Tighten the Screw with the screwdriver

STEP #6 – Loading / Replacing Batteries

- ✔ Plug (2) 9V Batteries onto battery clips
- ✔ Slide the assembly right into battery cover
- ✔ The DC-Barrel jack will align correctly with Tode-RC