Tode-RC

Hardware Development

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

by TGit-Tech [http://www.tgit-tech.com]

Build Version: 21V5 / Last Updated: 2021-11-05

Table of Contents

1. Introduction $35

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

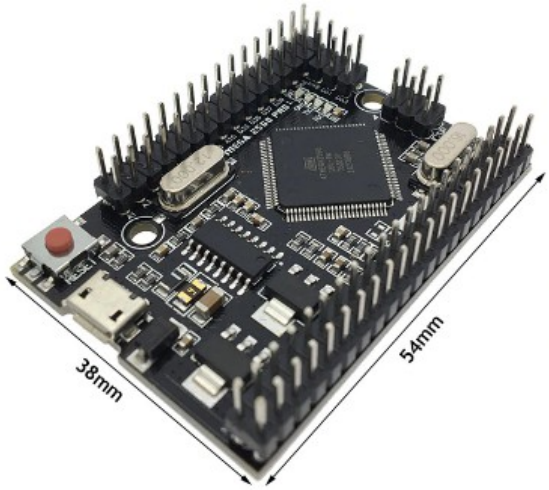
- User Manual Operator Instructions including Setup and Wiring
- Hardware Development How to build the hardware including detailed circuit diagrams
- Firmware Development How to adjust and create firmware for the Tode

2. Tode-RC

2.1 Bill of Materials (BOM)

- ✔ 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.

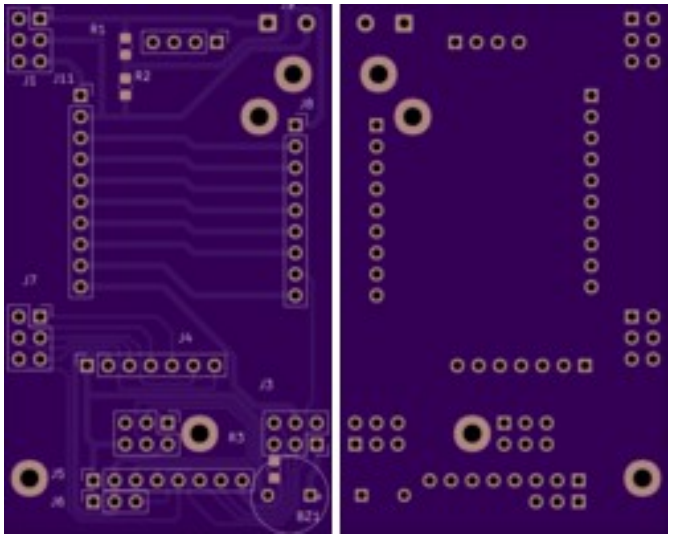
2.1.1 Parts $31



- ✔ 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

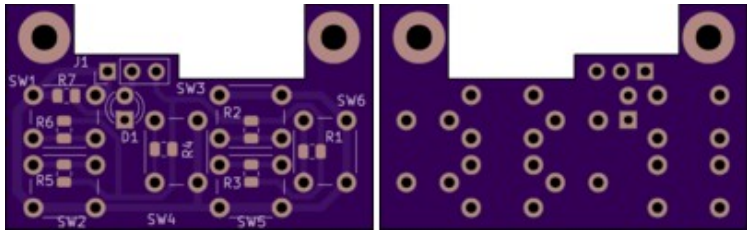
- ✔ Ebyte E32433T30D
  - ○ Power In: 3.3Vdc to 5.2Vdc (+ = Damage)
  - ○ Load Amps: Tx @ 106mA, Rx @ 15mA
  - ○ Data Rate: 0.3Kbps to 19.2Kbps
  - ○ Antenna Plg: SMA-K
  - ○ Frequency: 410MHz to 441MHz
  - ○ RF: Tx @ 30dBm, Rx @ -147dBm
  - ○ Pricing: ~ $10/each
  - ○ Web @ https://www.ebyte.com/en/index.aspx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

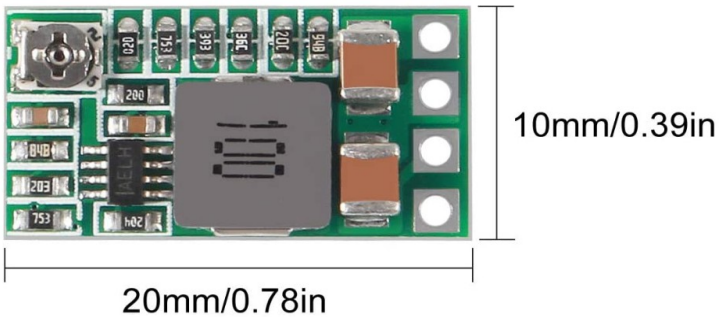


- ✔ Tode #EMPE32T30 PCB
  - ○ Manufacturer: Oshpark.com
  - ○ Pricing: $3.84

- 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

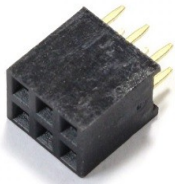
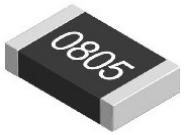
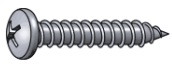


✔ Tode Buttons PCB
- Manufacturer: Oshpark.com
- Pricing Each: $1.41
- Batch Price: $112.80 per 80



✔ 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 $3

	QTY: 1 @ $0.10/ea = $0.10 1x10P Female Pin Header Dupont 2.54mm-Pitch Used in Step#3 as a Relay Plug-in		QTY: 4 @ $0.10/ea = $0.40 1x2P Screw Terminal 5.08mm Pitch Step #4 and #5
	QTY: 1 @ $0.10/ea = $0.10 1x9P Female Pin Header Dupont 2.54mm-Pitch Used in Step #3 as Tode-IO Plug-in		QTY: 1 @ $0.10 = $0.10 1x3P LONG-Lead Female Pin Header Dupont 2.54mm-Pitch Used in Step #3 as Tode-IO Plug-in
	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 Used in Step #3 as Tode-IO Plug-in		QTY: 1 @ $0.10 = $0.10 1x8P LONG-Lead Female Pin Header Dupont 2.54mm-Pitch Used in Step #3 as Tode-IO Plug-in
	QTY: 1 @ $0.50 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 5.5x2.1mm DC Barrel Jack Female Panel Mount 2-Terminal with Nut		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: 4 @ $0.10/screw-nut-pair = $0.40 (2) M2.5x0.45 x 6mm Screw + Nut for AMP 2.4 AMPE32T30 | Final Assembly | Step #1 (2) M2x0.4 x 8mm Screw + Nut pair for Keypad 2.2.2 Display | Hardware Assembly | Step #1,3 *Temporary use of M2x0.4 x 20mm Long.
	QTY: 1 @ $0.05/ea = $0.05 3mm Green LED		QTY: 4 @ $0.10/ea #2 x 3/8" long pan-head machine screws Used to Attach DispKB to Tode 2.4 Final Assembly | Step #7

2.1.3 3D-Prints $2

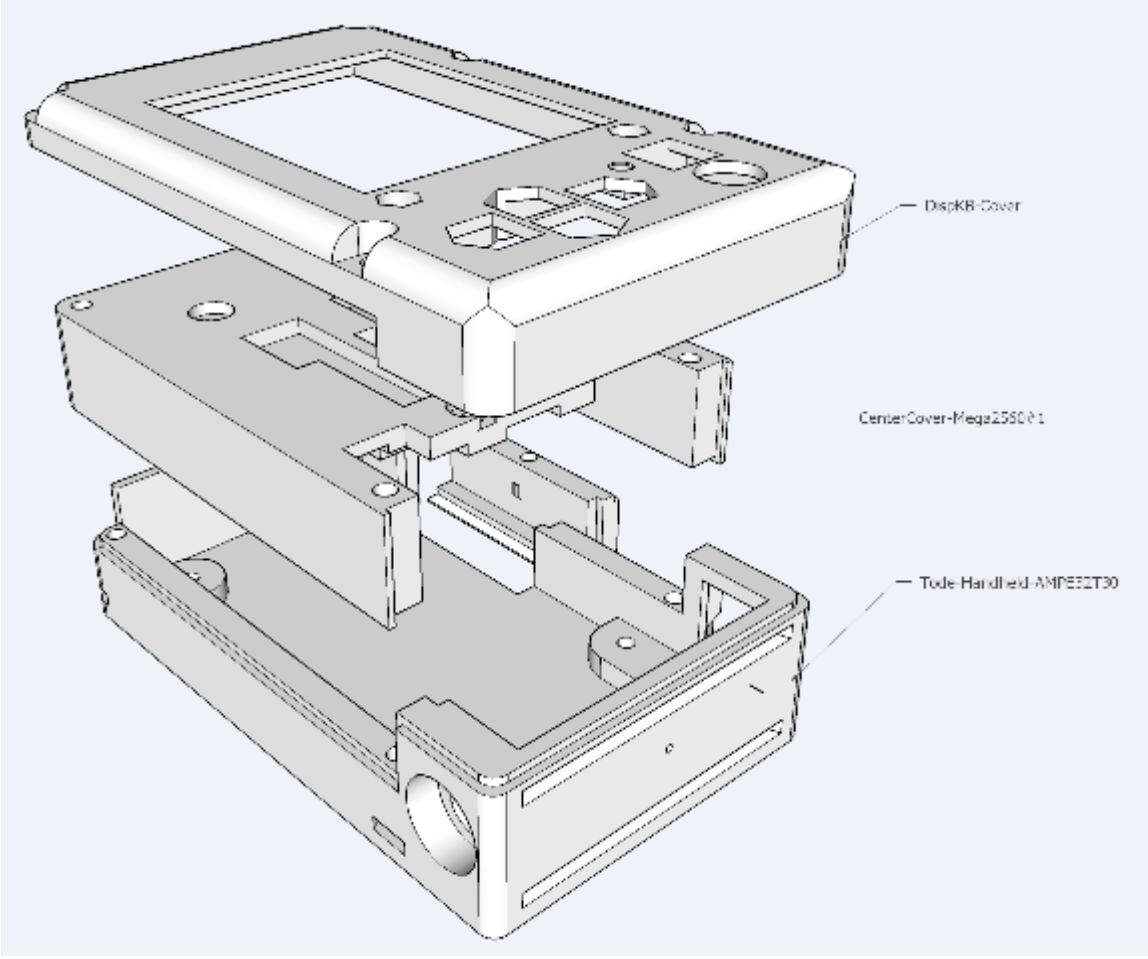
✔ 3D Print the Following Casing (Order according to Assembly Needed)
- Files in Folder: /3DPrints/

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

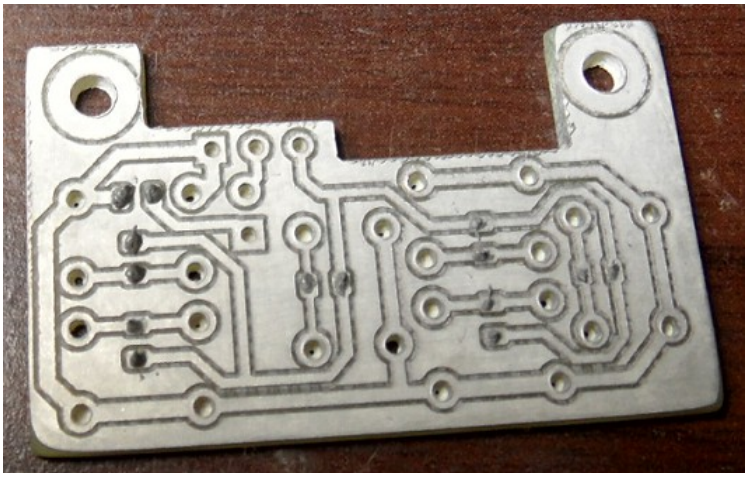
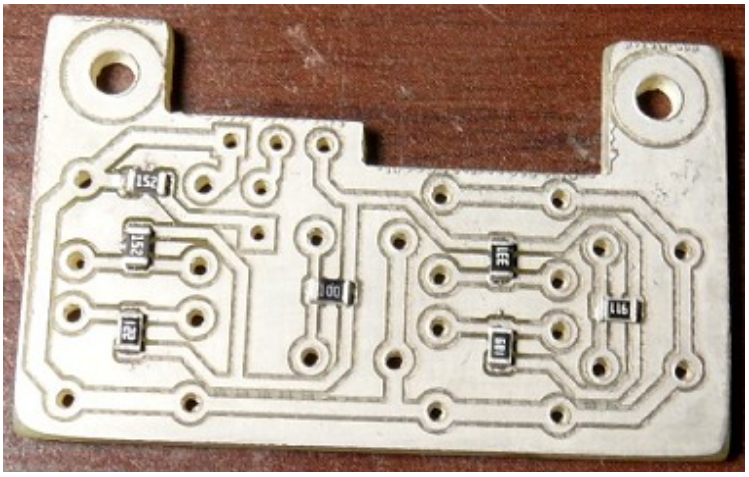


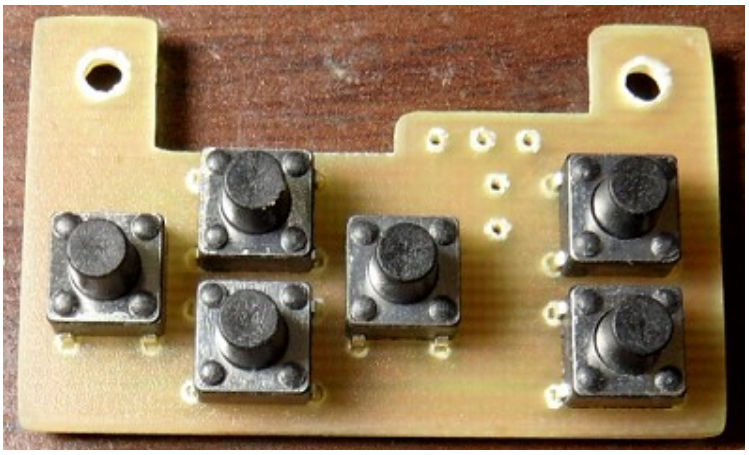
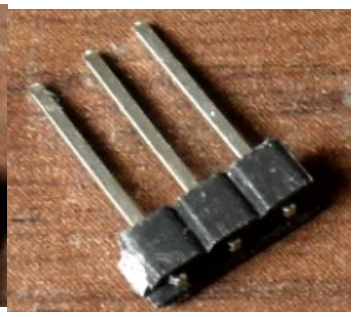
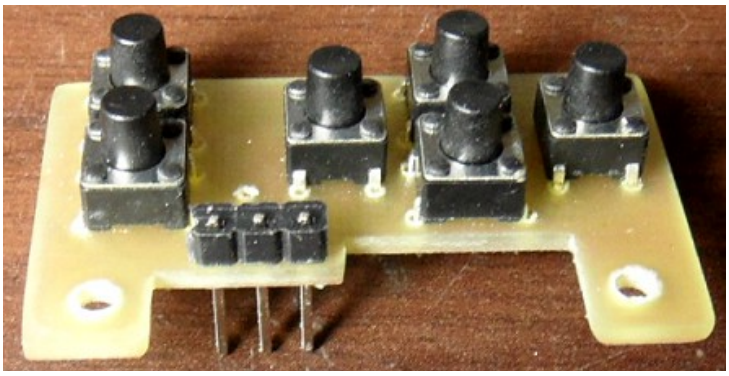
2.2 Display Assembly

2.2.1 PCB Assembly

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

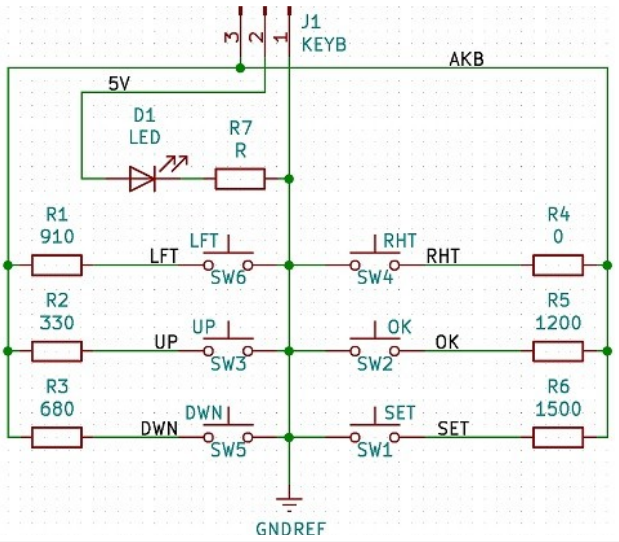
- ✔ Custom Manufactured PCB
  - Benefits - Custom PCB manufacturing is by far the better approach.
    - Copper through holes provide better connection
    - A Silk Sscreen for better corrosion resistance
    - Far easier to solder
  - Common Custom Manufacturing Businesses
    - https://oshpark.com/
    - 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.

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	

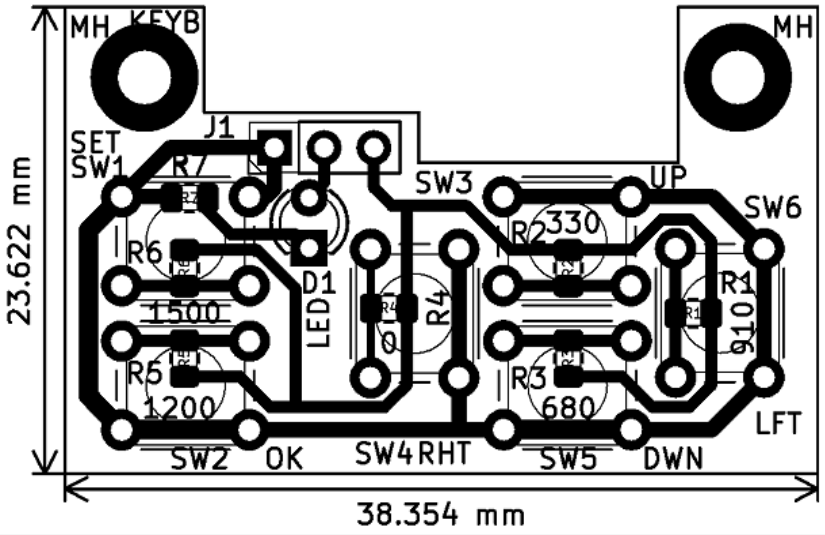
STEP #4 - Install and Solder Buttons Set the board asside and proceed to Assembly Instructions. NOTICE: The 3P Male Header and Power LED will be installed to fit during assembly.	
STEP #5 – Keypad Connection ✔ Push the pins of a 3P Male Header flush with Top	 
Step #6 – Insert and Solder 3P Male Header ✔ Solder from the bottom-side instead of top	

A. Schematic & Layout

SCHEMATIC



LAYOUT



- ✔ 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

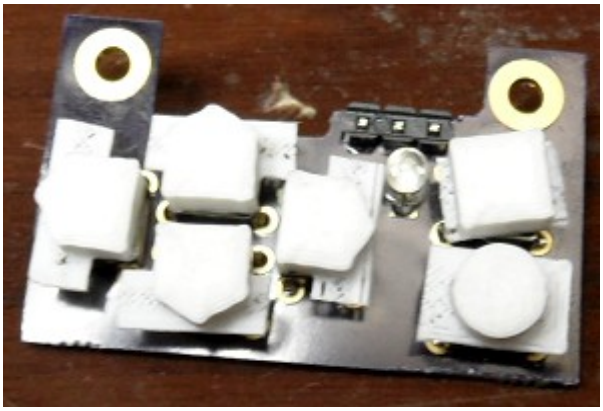
2.2.2 Hardware Assembly

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

- ✔ Holding a long M2 Screw and nut with pliers
- ✔ Heat the Nut using a heat gun
- ✔ Press the nut with edges lined up to shell flush with top

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

- ✔ Using Paper Scissors Cut each Button apart at center
- ✔ Place each button in it's appropriate shell location
  - On the Push Button Switch Itself
- ✔ If Buttons do not set onto Push Switches
  - Using a variable speed drill and approx 3.5mm bit
  - Drill Back-Side of Each Button till face plastic notches
  - Do not attempt to hold by hand – use pliers



STEP #3 – Install Display, Keypad and Solder LED

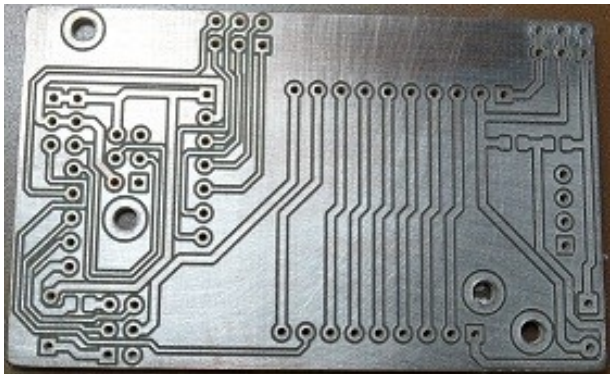
- ✔ In the Tode-DispKB-Cover.stl
  - ○ Solder the 8P Male Header to Screen if separate
  - ○ Place the 1.8 / 1.77 -Inch TFT LCD Screen in shell
  - ○ Insert the 3mm LED into Keypad PCB
    - ▪ Square-Pad is Negative (short-LED-lead)
    - ▪ Bend one lead slightly to hold in place
    - ▪ *NOTE – LED pins in picture are missing*
  - ○ Place the Keypad in Shell over the LCD as shown
  - ○ Fasten with Screw Size: M2x0.4 – 8mm long
  - ○ Use LED pins to position LED in Shell Hole for LED
  - ○ Solder and cut LED pins to PCB
- ✔ Suggest using Phillips flat head but Pan-head will do.
- ✔ 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

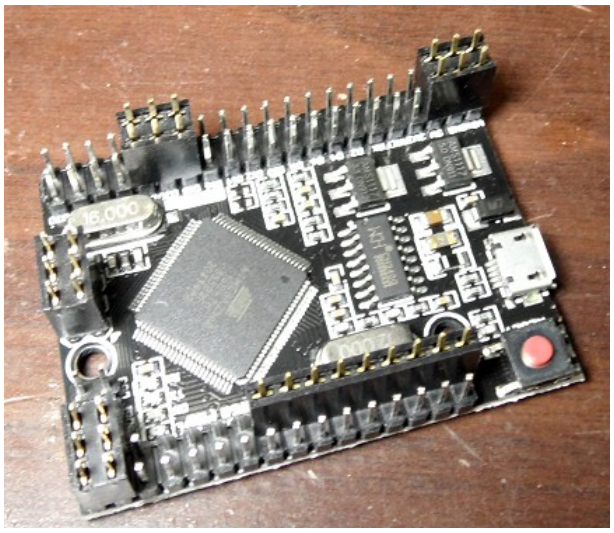
STEP #1 – Obtain (Purchase/Make) the AMPE32T30 – PCB

- ✔ 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



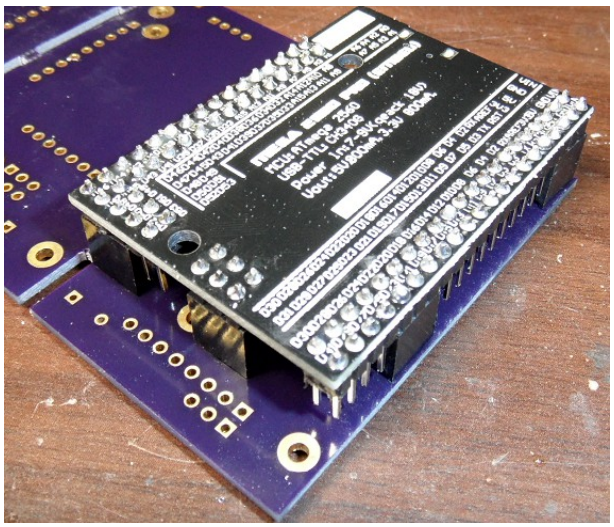
STEP #2 – Attach Female Dupont Headers

- ✔ 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.

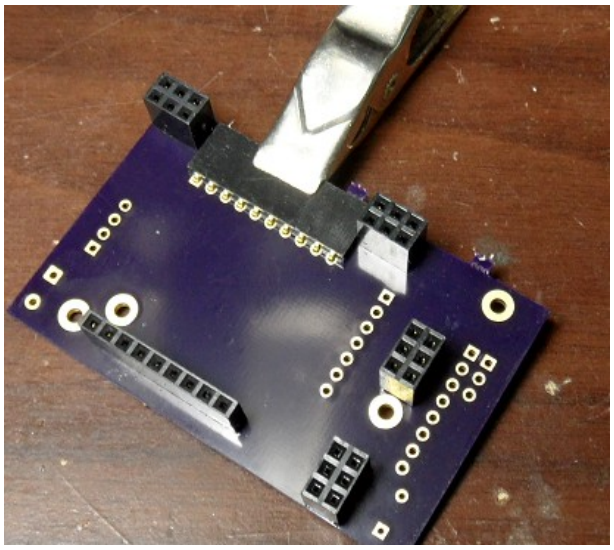


WARNING: Never solder-on E32 Radio before STEP #4.

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

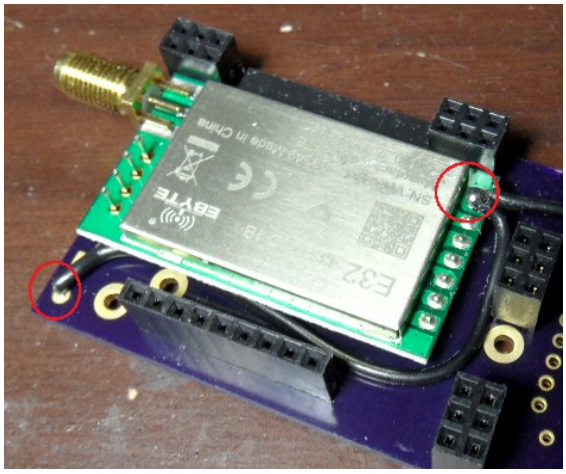
2. Insert Ebyte E32 RF Module into the AMPE32T30 PCB (as shown)

3. Solder Pins that attach to the PCB
   a) No need to solder the 4P top alignment pins to E32 Module

STEP #7 – Solder Ground Wire from Board to E32-Radio

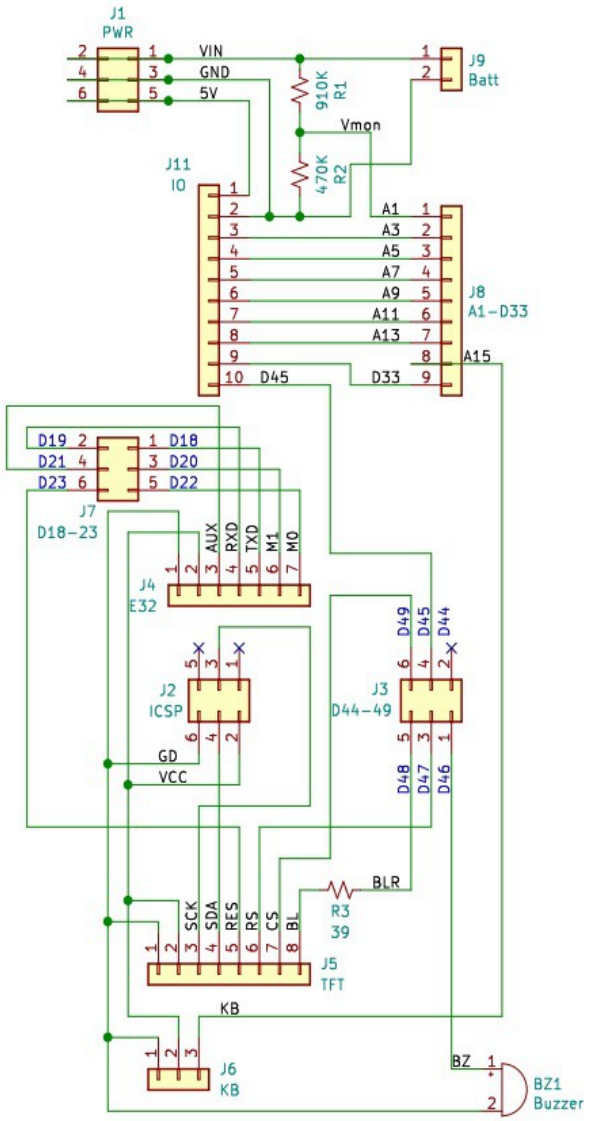
- ✔ Using Black 22AWG stranded wire 6-inches long
  - ○ Solder one end to Top-Left PCB (round-pad GND)
  - ○ … either cut or center-strip …
  - ○ Solder other end to E32-Radio GND (far-right pin)
  - ○ Leaving approximately 2-Inches (goes to Power Module)

- ✔ 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 jump is still required to prevent reset.

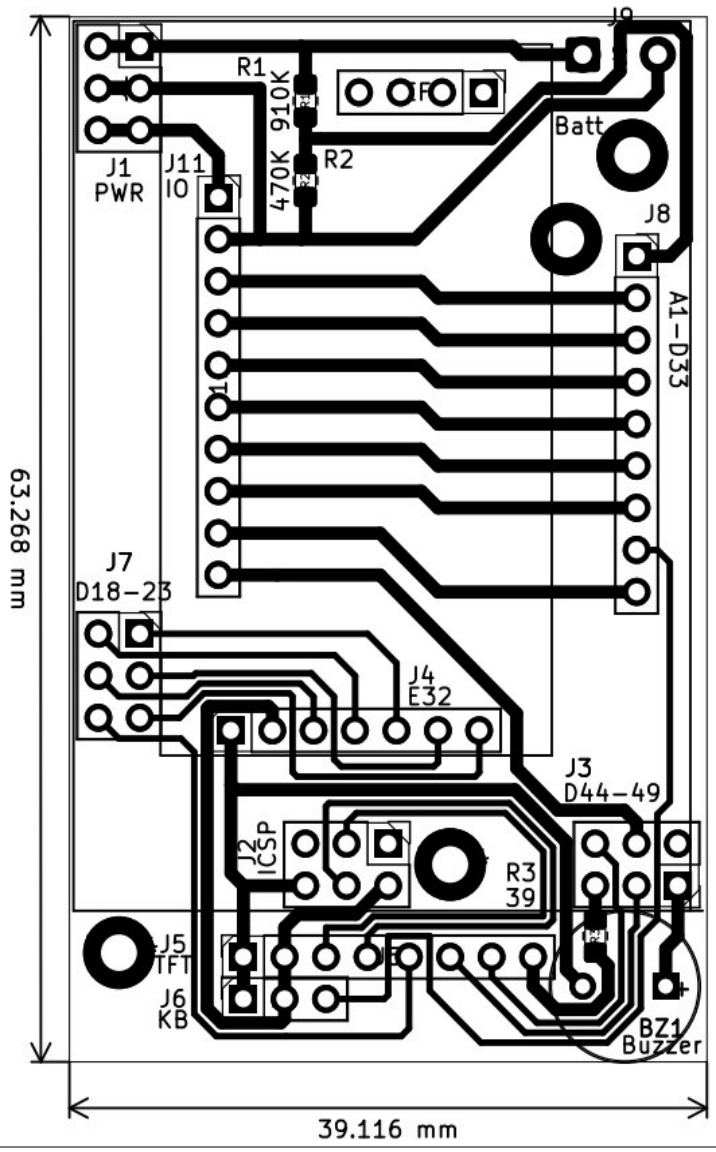


A. Schematic & Layout

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

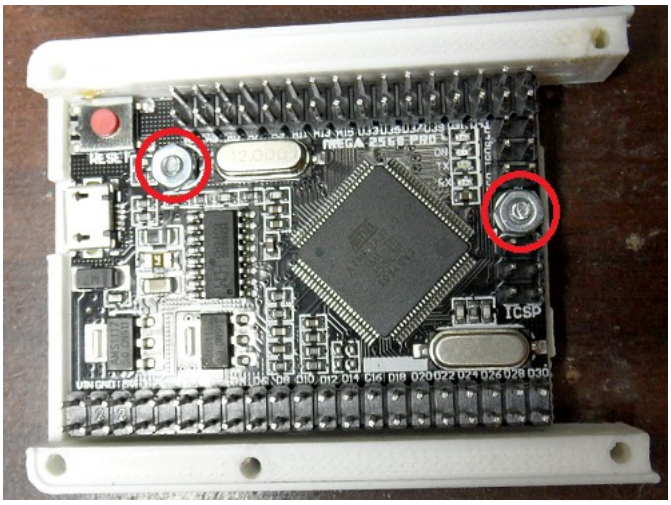
✔ Battery Monitor Resistors
- R1 – 910Kohm 0805 SMD (No longer used)
- R2 – 470Kohm 0805 SMD (No longer used)
- ***Due to the external 3A power regulator the battery monitor feature design is no longer used.***

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

2.4 Final Assembly

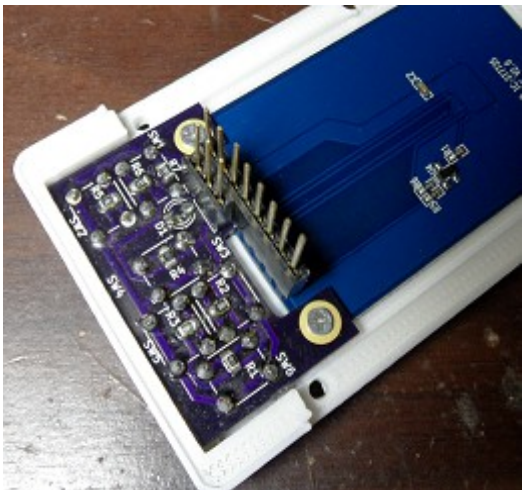
STEP #1 – Fasten Mega 2560-Pro Board to AMPCenter

- ✔ 3D-Print File: Tode-Handheld-AMPCenter.stl
- ✔ Pan-head Screw Size: M2.5x0.45 – 6mm long



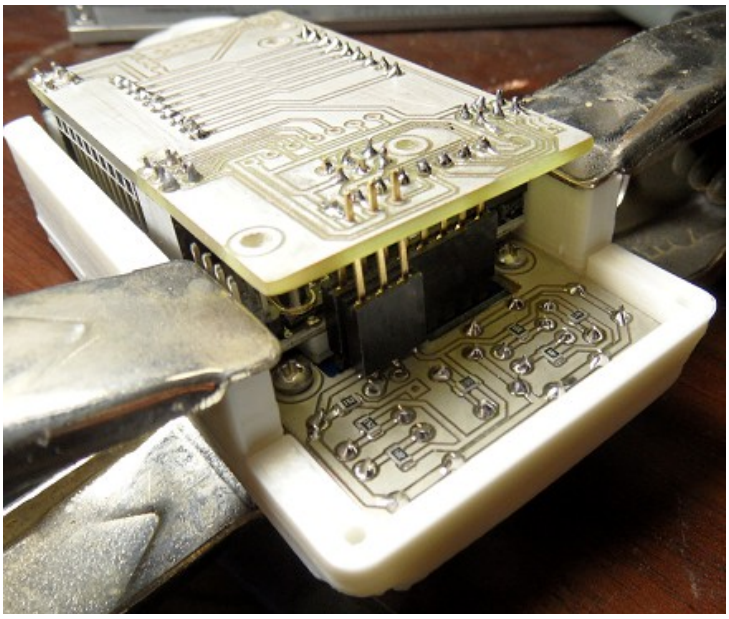
STEP #2 – Plug on Long-Leg 3P Female and 8P Female

- ✔ 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
- ✔ Fully Compress the assembly verifying all plugs are fully seated.
- ✔ Solder the Screen Plug pins and Keypad Plug Pins to the AMPE32T30 back-plane PCB and cut excessive leads.



Step #4 – Insert and Fasten the AMPE32T30 Back-plane PCB.

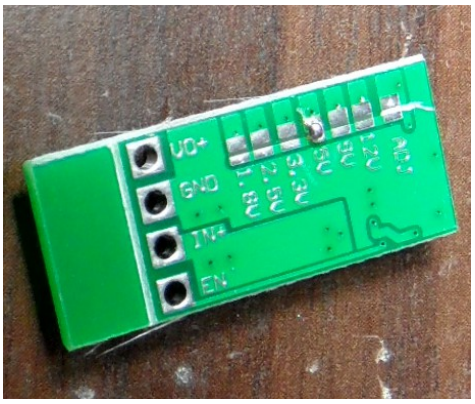
- ✔ Slide PCB from bottom to top and E32 Antenna plug through hole
  - ○ If hole is too tight suggest heating screwdriver with heat gun an opening the hole by melting.

- ✔ 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 plastic

STEP #5 – Prepare 5V 3A Power Module

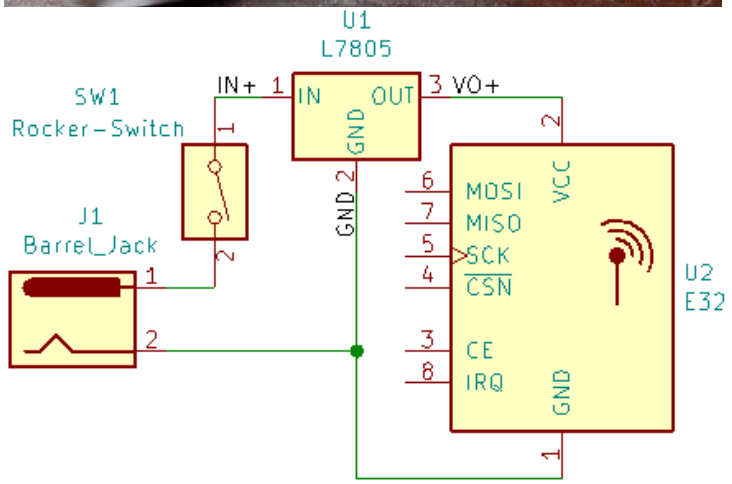
- ✔ Using Razor Knife cut the Top Trace
- ✔ Jump a Solder bridge where 5V is labelled
- ✔ Do a Continuity Test verifying changes

- ✔ Solder 22-AWG stranded wire about 3" long on each.
  - ○ Red Wire on VO+
  - ○ Black Wire on GND
  - ○ Red Wire on IN+



STEP #6 – Install Switch and Barrel Plug; Start wiring

- ✔ DC Barrel Jack
  - ○ Solder about 3-in Red Wire (+) to Short Lead
  - ○ Solder about 3-in Black Wire (-) to Long Lead
  - ○ Insert Wires through Casing Hole and Slide Nut over both wires (DO-BEFORE-MORE WIRING)
- ✔ Cut-to-fit wire from VO+ to E32-VCC (Red Wire 2nd-pin)
- ✔ Cut-to-fit wire from IN+ to the Switch
- ✔ Cut-to-fit red wire from DC Barrel Jack to Switch on terminal opposite of IN+ on previous step.
- ✔ Twist and Solder Together
  - ○ the DC Barrel Jack – black wire
  - ○ the E32 GND black wire
  - ○ the Power Module GND



STEP #7 – Final Assembly and Functional Test

- ✔ Plug the Mega-Pro Into the AMPE32T30 Backplane
- ✔ Plug the DiskKB on top.
  - ○ Fasten using #2 x 3/8" long pan-head machine screws.
- ✔ 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)

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.		

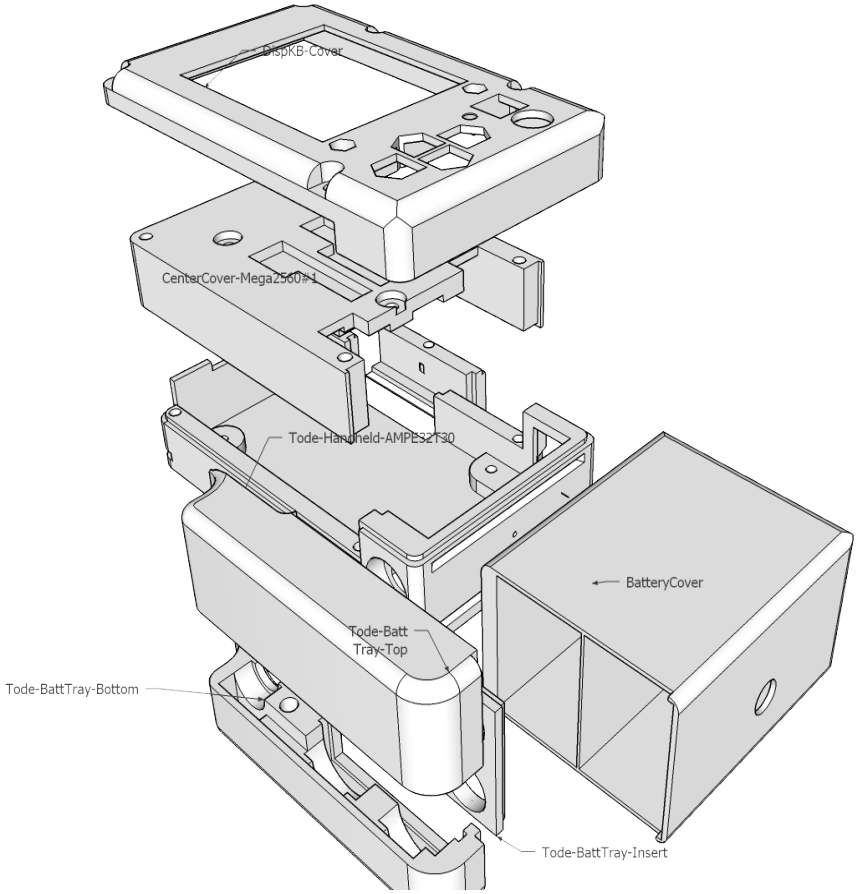
3.1.2 3D-Prints $1

✔ 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

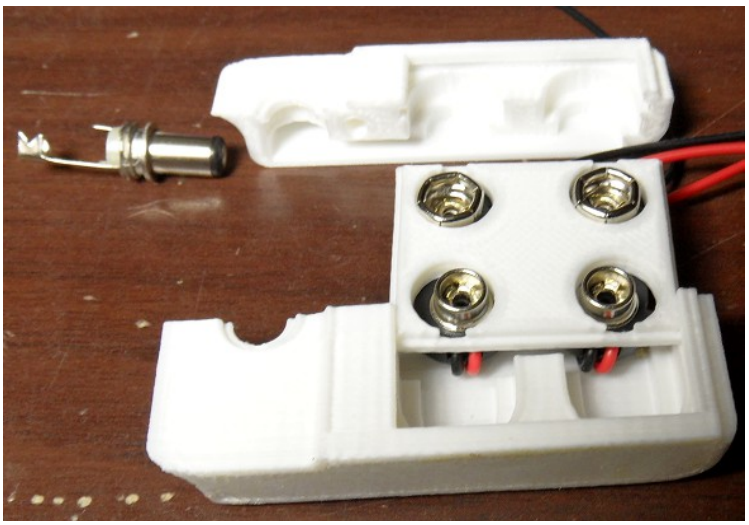
- Pricing at $20/per 1KG Roll
- 0.15 Layer Height



3.2 Assembly

STEP #1 – Place Insert and Plugs

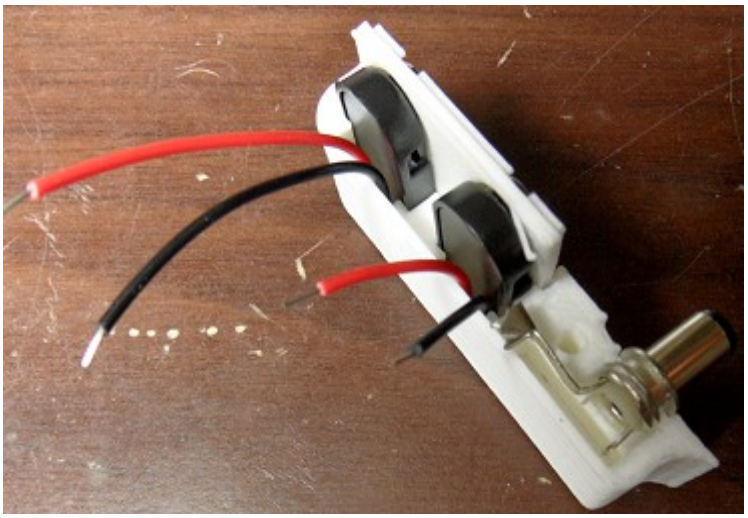
- ✔ Place (2) 9V Clips in Tode-BattTray-Insert.stl
- ✔ Bend wires back behind the clip as shown
- ✔ Slide the Insert w/Plugs into the Tode-BattTray-Top.stl



STEP #2 – Cut-to-fit wires and strip

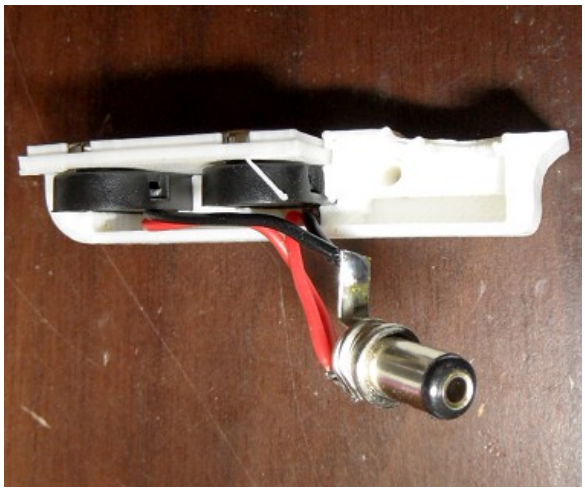
- ✔ Pull the wires together to the edge of the model
- ✔ Snip the wires and strip their ends

- ✔ 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