

# USB Port Battery Charging



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**AirVenture 2018**

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# Introduction



## USB: Universal Serial Bus

It **IS** a serial communication interface.

It was **NOT** designed to charge batteries!

Repeat:

USB was **NOT** designed to charge batteries!

# My Project History

- The need: 2010 conversation with a pilot who needed to charge iPhone and iPad during flight from 12 volt electrical system in his homebuilt aircraft.
- He handed me two Apple chargers, one for an iPhone, one for an iPad-3:

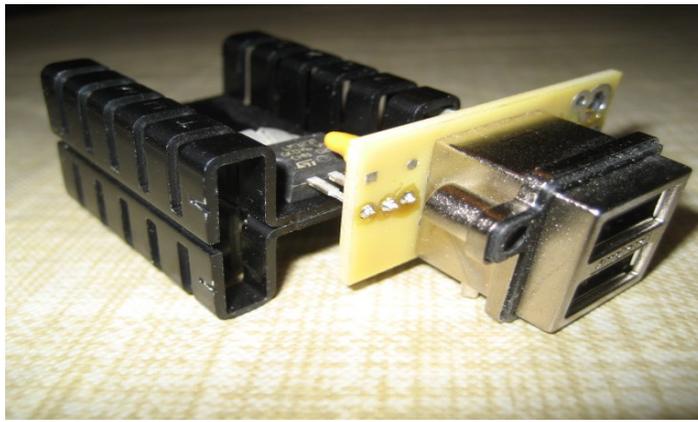


**Apple 5 Watt Charger for iPhone**



**Apple 10 Watt Charger for iPad**

- Seemed like a simple project.
- The 10 watt charger put out 5.1 V @ 2.1 A max.

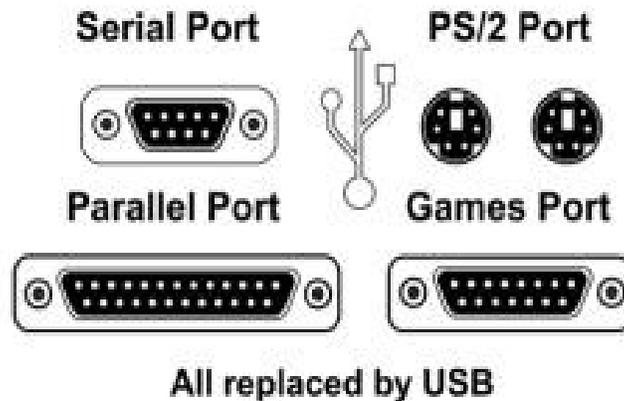


- I designed a 5V - 3A prototype charger with off the shelf linear regulator.
- Result: **DID NOT** *Rapid* charge Apple devices!
- My Internet search in 2010 discovered:
  - No OEM documentation about Apple USB chargers.
  - There was reverse engineering info about Apple chargers.
  - Charging using USB port is neither proprietary nor a trade secret primarily because of use of the USB standard connector.
  - Discovered two modes of charging: “*Trickle*” and “*Rapid*”
    - Charging rate is controlled ***by the device*** by sensing voltage signals on the Data + and Data – pins of the charger USB Port.
    - This system was developed to protect the computer USB Port.

# Where did the USB Port come from?

## Why was it designed in the first place?

- Standard I/O ports on the IBM PC model PS/2:



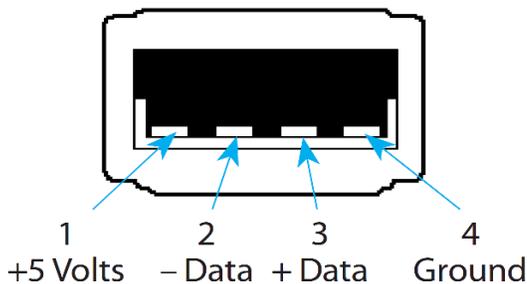
- Myriad of DB type connectors for low speed I/O devices, all were serial except parallel port which was usually for a printer.
- One thing in common: all the functions represented could be handled by a serial interface, if it is fast enough.
- The PS/2 ports had 5V to power keyboard and mouse.
- DB connectors are expensive and large; few of the pins are used.
- DB connectors are unsuitable for portable devices, like laptops, cellphones and tablets because of size.

# What Is A USB Interface?

- In simplest terms, 4 wire interface:
  - Common ground pin
  - Transmit data pin or + Data pin
  - Receive data lead or – Data pin
  - Data pins can be half duplex twisted pair data circuit.
  - Power pin (5 V).
- Standards development started in 1994 by seven companies: Compaq, DEC, IBM, Intel, Microsoft, NEC and Nortel.

## Note absence of Apple

- Voila, USB 1.0:



**USB Socket Schematic    USB-A Socket    USB-A Plug**

- **USB 1.0 / 1.1: Data rate: 1.5 – 12 Mbits/sec (January 1996)**
  - Simple: 4 pins, inexpensive connectors.
  - Keyed, plug only fits one way.
  - Power leads longer than data, guaranteed to mate before data leads.
  - Delivered power: 5 V / 0.15 A (0.75 W)

- Keyboards, mouse, audio, printers started using serial port capabilities of USB 1. Windows 95 supported USB.
- Totally obsolete now. **NOT** shipped on new equipment.
- Beware: easily damaged electrically.
- **USB 2.0: Faster is better (April 2000)**
  - Data rate: 480 Mbits/sec.
  - Power: 5 V / 0.50 A (2.5 W).
  - Added a plethora of mini connectors (all 5 pin).
  - Besides interfacing peripherals like keyboard and mouse, began to be used to charge batteries in external devices, if they needed no more than 0.5 A (2.5 W).
  - It is the most ubiquitous version, still being shipped.
  - Harder to damage electrically, most just shut down.
- **USB 3.0: Even faster / even better (November 2008)**
  - Full interface incorporates 9 pins. (Backward compatible with USB-A socket.)
  - Data rate: 5 Gbits/sec
  - 9 pin socket **NOT USED** by chargers ... yet.
  - Power: Can supply 5 V / 0.90 Amp (4.5 W)
- **USB 3.1: Blindingly fast / stupendously capable: (July 2013)**
  - Various new plugs and sockets.
  - Data rate: 10 Gbits/sec
  - USB Power supply spec released; intelligent / complex.
  - A variation used by iPad Pro 10.5 and 12 tablets as an option.
- **Data rates are meaningless for battery charging.**

- **USB 2.0 Standard Downstream Port (SDP) data pin definition.**
  - **Device can recognize a SDP with hardware by detecting that the USB data lines, D+ and D-, are separately grounded through 15k $\Omega$ , but needs to enumerate (handshake) to be USB compliant.**
  - **Max load current: 2.5mA when suspended, 100mA when connected and not suspended, and 500mA when configured for that current.**
  - **In USB 2.0, it is not strictly legal to draw power without enumerating, although much of present-day hardware does just that; in violation of the spec.**
  - **Enumeration occurs when you plug into socket.**

# Charge A Battery From A USB Port

## Who's Lame Idea Was That?

- **Misconception: USB port was originally designed with the capability to charge batteries.**
  - The USB Port **WAS NOT** designed to charge batteries!
- **It is a ubiquitous battery charger today because it's a very flexible, inexpensive serial communication specification that just happened to supply some power in its original incarnation because of the PS/2 ports it replaced.**
- **Most of our devices not only need to charge batteries, but also communicate with computers to exchange data: phones, cameras, tablets, music players, etc. But not all devices need serial capability: GPS receivers, ADDS-B boxes, etc. with batteries.**
- **In 2009, basic battery charging protocol defined: BC1.1 (BC1.2 in 2010) Primarily pushed by Chinese and European cell phone manufacturers for smartphones.**
  - **Apple had developed their own charger protocol before 2009.**
  - **Few other vendors follow BC, and then not consistently.**
  - **A Dedicated Charging Port (DCP) ties the two data lines together with any resistance from 0 to 200 ohms. (Usually 0 ohm: short pins together.)**
  - **A DCP charger can supply up to 1.5 A, but **does not** have to. Many only supply 1 A.**

- **In Version 3.1 of the USB port specification, there is a detailed, complex specification for battery charging and peripheral power.**
  - **Not used for most chargers; further discussion in latest iPad section.**

# Voltage / Current / Power

- **POWER** is the **KEY** to battery charging.
- Battery charging is controlled by the **DEVICE! NOT The CHARGER.** The charging smarts are in the device.
  - Charger provides power and has a **MAX** power limit.
  - **Every** charger informs you of voltage and current supplied, thus max power capability, **ON A LABEL.**
  - Discharged battery in device has a slightly lower voltage than when it is fully charged.
  - Fully charged device battery is **always** less than 5 V. (3.5 V common)
  - During battery charging, power demanded is not constant; peak at the beginning of the charging cycle, then decreases.
  - Every OEM USB **charger** signals what kind of charger it is on data pins.
  - Myriad of battery charger signal protocols on data pins. (Standards are pretty meaningless.)
- Universal voltage for charging: 5 V; may be as high as 5.4 V.
- Power, in watts, is simply: Volts x Amps (current).
- Any device with battery requiring more than 2.5 watts to charge its battery must be able to protect USB computer port if it connects to the port for data exchange.
  - The **DEVICE**, not the charger, will have a ***Trickle*** charge mode and a ***Rapid*** charge mode.

- ***Trickle*** charge rate will be no more than 500 ma.
- ***Rapid*** charge rate will be within limit of OEM charger.

# USB Specifications Are Only A Suggestion

- **USB A connector power pin specification: 1.5 A max.**
  - Considering pin size, USB A connector is obviously a low current connector.
  - No charger supplying more than 7.5 watts is within the maximum current specification of USB A connector.
  - Every 10 - 12+ watt USB charger exceeds the maximum current specification for the USB A connector.
- **Battery charging is a dynamic process.** (Thank goodness.)
  - Max charging power, thus highest current demand, lasts for a short period of time at the beginning of the charge cycle of weak or dead battery. (If device turned off.)
  - Most USB battery chargers are not designed for full output, full time. NOT a power supply; they are a charger.
  - NOT advisable to use a USB Charger to supply continuous power to a device that needs more than 7.5 watts. It may get very HOT.
  - Not advisable to use a USB charger for any application for which it was not designed.
- **Apple 10 watt charger provides current at 5.1 V, not 5 V.**
  - USB 1.x and 2.0 maximum voltage spec is 5.25 V. (Chargers often exceed this.)
  - **Voltage has NO affect** on pins in USB connector.

- **Apple 12 watt charger is rated at 5.2 V and 2.4 A max.**
  - **So it is actually a 12.48 watt charger. (Do the math)**
  - **Optimistically, max current will flow for a brief time since it exceeds USB max current spec by 60%.**
- **Many non-Apple chargers present 5.1 – 5.4 V.**
- **New USB-C chargers may supply 9 – 14+ volts.**

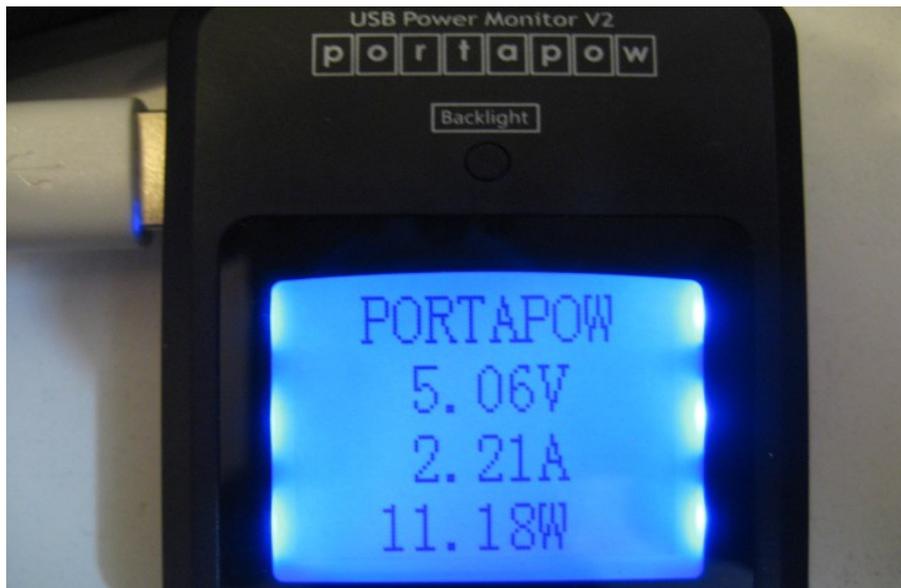
# Diagnosing USB Charging Status

- Minimally, you need a USB Port volt / ammeter:



Simple USB meter: voltage and current simultaneously

- Some USB meters will also compute the power:



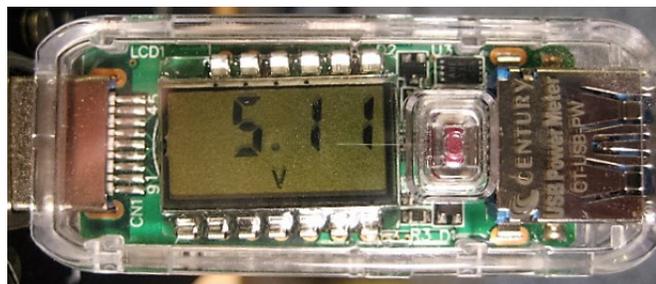
- Zillion different kinds at Amazon and eBay:



Example above displays voltage and current alternately.

- Most in the \$10 range.
- Quality varies immensely.

Lousy and expensive:



- Buyer beware!

- Sophisticated meter from YZXstudio will display data pin voltage levels and charging protocols.

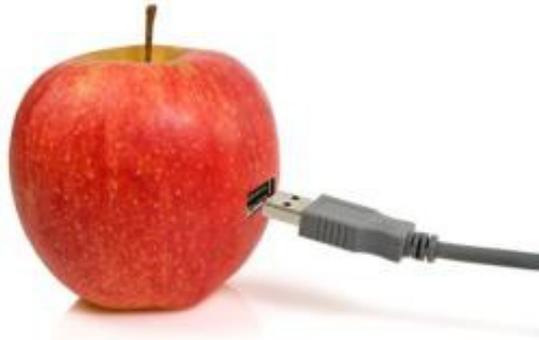


- Also does power data logging:



- Find on eBay, shipped from China. In the \$30 range. (Sometimes at Amazon.)

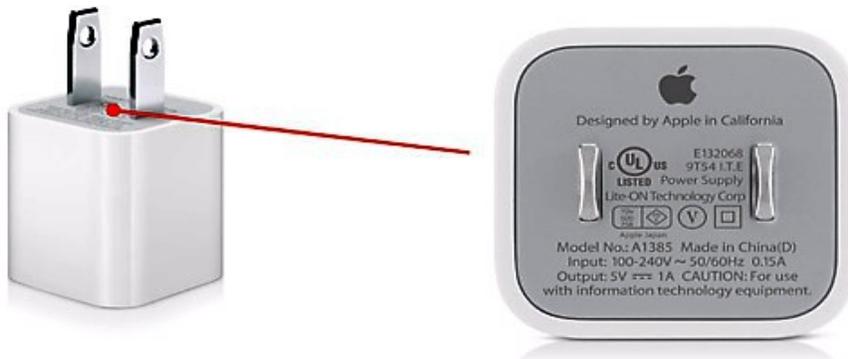
# Apple Started It



- In the beginning: USB 2.0 ports on computers charged some external device batteries at  $5\text{ V} \times 0.5\text{ A} = 2.5\text{ watts}$  (USB 2.0 spec)



- Apple iPod 4<sup>th</sup> generation (2005) needed 5 watts to charge battery and iPhones (2008) needed a 5 watt charger:

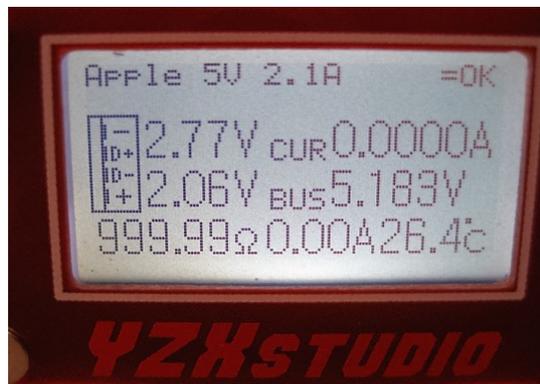


- How does Apple device tell if it is plugged into a charger or a computer? (**Apple users, pay attention.**)
  - Power protocol is signaled on the data pins.
  - Pins 2 (D-) & 3 (D+).
  - Each charger has a different voltage on the D- and D+ pins.

### Apple 5 watt charger presents:



### Apple 10 watt charger presents:



### Apple 12 watt charger presents:



# Apple 29 Watt MacBook USB-C Charger

- Physically bigger and connector is not USB-A:



- For use with iPads, requires USB-C to Lightning cable.
- Note: it has **TWO** output power specifications:



- Will Rapid charge any iPad / iPhone.
- 14.5V – 2.0A spec only works with iPad Pro 10.5 & 12

# What About Everyone Else?



- **Android devices (phones and tablets), eReaders, navigation units, etc.**
- **Most varied and ubiquitous devices and they have a wide variety of charger protocols, some standard, some not.**
- **Many device chargers follow BC1.2 spec.**
- **Some devices completely ignore data leads.**
  - **It is possible to damage USB port on computer trying to charge an oddball device that doesn't use USB to communicate if it needs more than 0.5 A.**
  - **Most modern USB 2.0 ports will protect themselves by dropping voltage and limiting current to not more than 0.5 A; NOT GUARANTEED.**
- **Some devices will not rapid charge on computer port or another manufacturer's charger. Must use OEM charger.**

# Samsung non-standard charger protocol:

- 10+ watt charging system: 5+ V, 2 A.

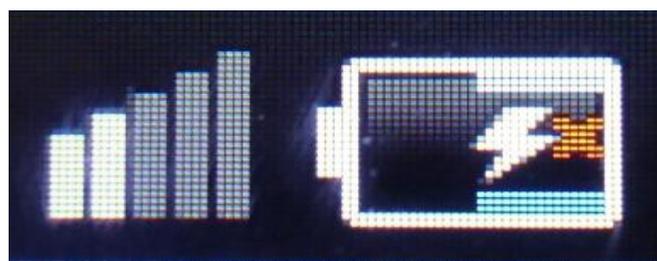


Presents approximately 1.2 volts on both data pins.

- When Samsung tablet is *Rapid* charging, lightning bolt appears and level in the background is animated, eventually filling entire battery icon as the battery reaches full charge:



- When Samsung tablet is *Trickle* charging:



# Mobile USB Battery Charging

## The Universal Mobile Power Interface



Many devices, have optional *car chargers*:



- Will probably work with specific device if OEM. If third party, NO guarantee.

## Aircraft Alternative: use a USB Charger converter in the 12 volt power outlet:



### Total crap-shoot. Buyer beware!

- May only have +5 V and Gnd with no protocol signal on data pins.
- Data pins may be shorted or open.
- Packaging often misleading:



Unit is actually a 1A (5 watt) charger in **both** sockets

- Many cause RFI in aircraft radios.
  - Most manufacturers pay no attention to RFI for car chargers.
  - Leave filtering components out to reduce cost.
- May overheat under prolonged full load and act strangely.

# Universal Charger Dongle

- Change dumb charger into an OEM charger or use one manufacturer's charger to *Rapid* charge a competitor's device:
  - Charger must supply power required, i.e. 5+ V at 2+ A
  - Best advice: Always carry 12 watt charger(s).



**Targeted Single Manufacturer *Rapid* Charge Dongle:  
Apple 10 W protocol only.**



**Sabrent *Smart* Dongle (up to a point: Apple 10 watt protocol)**

- Often advertised as ***Turbo Boosters***.

**DO NOT PLUG THESE DEVICES INTO A COMPUTER USB PORT!**

# Smart Chargers

- Companies like TI make ICs that can sense charging device and supply correct protocol signal voltages on data pins.
- Uses *Charging Downstream Port (CDP)* handshake protocol.
- These ICs are appearing in charging devices and dongles:



Detects your device.  
Delivers the fastest charge.

**Anker 40W 5-Port USB Desktop Charger**  
(Knows Apple 12 watt protocol)



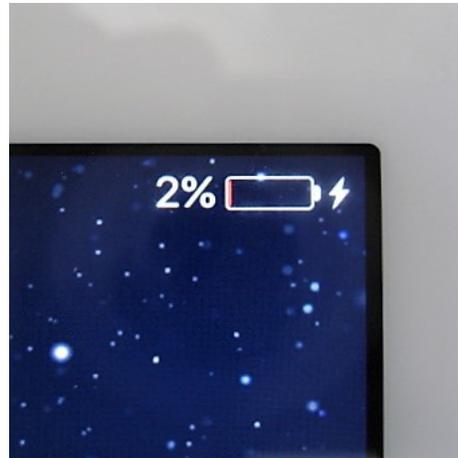
**CommitLift Hi-IQ Charger (Non-TSO)    Smart Dongle**

**Charger and Dongle know Apple 12 watt protocol.**

**Buyer beware: some chargers claim to be smart, but they are **NOT!****

# Apple iPad Charging Example

One rather discharged iPad-4:



Universal symbol for Apple charging:  **Unfortunately, does NOT indicate charge rate.**

Charging on Apple 12 watt charger:



- Voltages on data pins are same: ~2.7 V
- Data pin voltages are affected by device. (Makes no difference.)
- iPad-4 is charging at 11.6 watts.

## How will iPad-4 charge on Apple 10 watt charger?



- Voltage on data pins unequal: 2.7 V on D+, 2 V on D-
- Data pin voltages are affected by device.
- iPad-4 is charging at 10 watts.

## How will iPad-4 charge on Apple 5 watt charger?



- Voltage on data pins unequal: 2 V on D+, 2.7 V on D-
- iPad-4 is charging at 5 watts.

**iPad adjusts to charger's max power capability.**

## Will iPad-4 charge on a computer USB port?



- No voltage on data pins.
- Charges at 2.5 watt maximum USB 2.0 power rate.

## Will iPad-4 charge on a Samsung charger?



- Samsung protocol voltage on data pins.
- iPad-4 thinks it's plugged into a computer USB port.
- Charges at 2.5 watt rate.

In summary: Apple iPad-4 and later tablets are **SMART**.

(So are new iPhones)

# My Free Charging Hints

- For fastest recharge: turn device off, so display is off. The display uses the most power. (Most likely the way you normally recharge device.)
  - **WARNING:** when a phone or tablet is OFF, **it is still ON!**
  - For faster recharge, turn wi-fi, location (GPS) and Bluetooth off. (Or put in *Airplane Mode*.) All these services consume power even when device off.
  - For very fastest recharge, power device down.
- **The charger that came with your device may NOT be the most efficient charger. (Blasphemy!)**
- Use Apple 12 watt charger to charge **ALL** Apple devices.
- Want to minimize number of chargers when you travel? Take 12 watt charger and an intelligent dongle:



## USB Chargers at airport and in hotel rooms:

- Rarely intelligent. (Did find one recently in new hotel.)
  - Lucky if they present Apple 5 watt protocol.
  - Usually same as a computer USB port. (5 V if you are lucky and 0.5 A = 2.5 watts.)
- Using an Intelligent Dongle probably won't make any difference with airport or hotel room chargers. They are usually 5 watt / port chargers.
- There are USB chargers with oddball charging protocols but they are all backward compatible to 5 V chargers.
  - Qualcomm Quickcharge 2.0
  - Samsung *Adaptive Fast Charging* (9 V @ 1.6 A = ~14 watts) used for telephones.
  - Apple USB-C 29 watt charger for iPad Pro (USB Power Delivery: 14.5V @ 2A).

## Suspect your device is not charging properly?

- Suspect the cable. Cary two Lightning cables. There are electronics at the device end that can fail as well as broken wires.

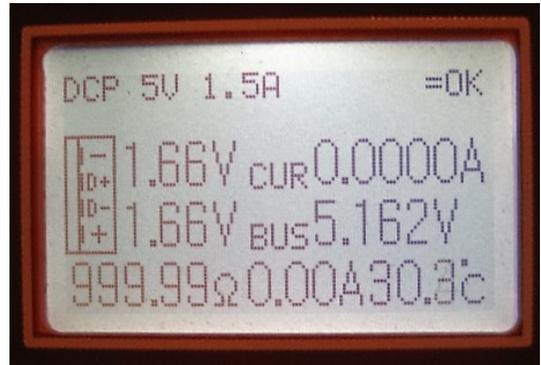


- **Always** plug cable into the charger first. Then, plug the cable into your tablet. Tablets are smart and know three, possibly four, charging protocols. They can get confused and charge at the wrong rate.

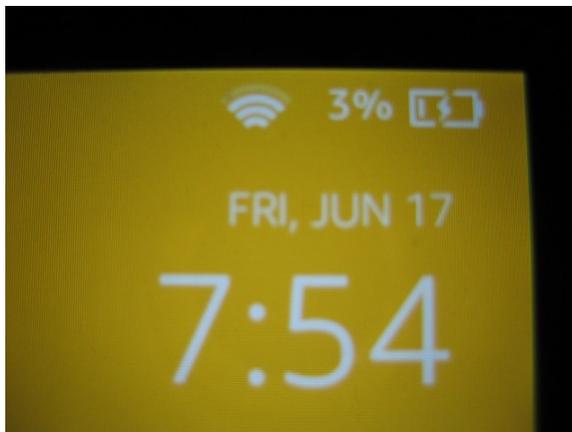
**Example: charging your Kindle on a 10+ watt charger, not the cheap 5 watt charger Amazon sent with it.**



**Amazon OEM Charger**



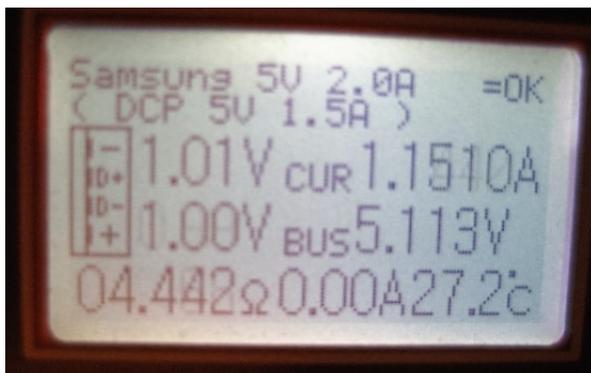
**Charger Presentation**



**Discharged Kindle**



**Charging Setup**

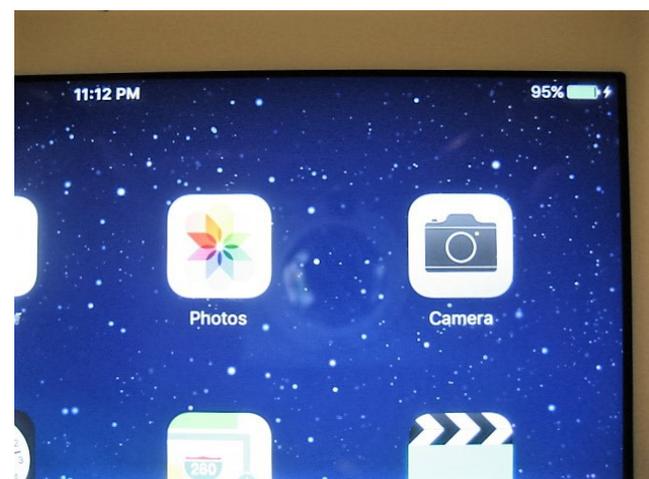


**Charging at ~5 watt rate.**

**Using real Samsung 10 watt charger:**



- **Tablets and phones that communicate over USB port will trickle charge when connected to computer USB port even though they may display message they are not charging. (Old Apple devices did this.)**
- **Apple tablets connected to computer USB port will trickle charge without indicating charge rate:**



- **You can use this method in emergency, but very slow.**

# TSO'd Charger?

- The only one I know:

**True Blue Power: TA-102:**



- Apple 10 watt protocol only. (spec & verified)
  - List price north of \$400.
  - An Apple iPad 4 or later, that is powered on, may discharge when on this charger.



**New Product: True Blue Power: TA-202:**

- Claims 3 amp / port, but Apple 10 watt protocol.
- Without knowing protocol, 3A capability useless.

# Flying With Your iPad

Consider: You normally turn your device off and charge it.  
We don't do that when flying.

- Fly with an Apple or intelligent 12 watt charging system!
- Fully charge your device(s) before you fly.
- Without a 12 watt charging system, a late model iPad may discharge while on, and plugged into a charger:



iPad-4 charging at 50% depleted: uses 11.4 watts

- If your iPad is discharging while on and plugged into a charger, the charger is NOT an Apple 12 watt protocol charger. Likely a 10 watt charger at best. (Or it's confused.)
- A discharged iPad plugged into a cheap auto converter may run hot and iPad may discharge completely.
- Know your system BEFORE you have to depend on it.
- Problems? Suspect the cable. **Cary two cables.**

# Summary

- USB Port **WAS NOT** designed to charge batteries!
- **DEVICE** determines charging rate! **NOT THE CHARGER.**



- All chargers provide 5+ V at some max power: commonly 5, 10 or 12 watts. Voltage and power rating are always printed on a label on charger.



- Chargers provide charging protocol signal on data pins.
  - Apple and Samsung developed their own protocol before first USB charging standards developed.
  - USB standards are **NOT** necessarily followed.

- Computer USB-2 ports can supply 2.5 watts of power with no charging protocol signals on data pins. USB-3 port **MAY** supply 4.5 watts. Can be used in emergency. **SLOW!**



- **Never** plug “intelligent” or “*Turbo*” dongles into computer USB ports!



- Travel smarter: one 12 Watt charger and a smart dongle:



## Flying with Apple tablet?

- Fully charge your device before takeoff.
- Be sure in-aircraft charger knows Apple 12 Watt protocol.
- Plug cable into charger first, then into tablet.
- **Cary a spare Lightning cable.**

# Apple iPad Charging Matrix Test

## Appendix: Secrets of USB Port Battery Charging

### iPad Mini

CPU: A5

CPU Speed: 1 GHz

CPU Architecture: 32 Bit

CPU Cores: 2

RAM: 512 MB

Storage: 16 GB

Wireless Option: No

Charger Supplied: 5 watt

**This iPad recognizes 10 and 12 watt chargers, and will charge faster on them.**

#### Charging Characteristics While ON

##### 5 Watt Charger:

Battery dead: 1A / 5W, Turns on @2%, charging

Battery 50%: 1A / 5W, charging

Battery 95%: 1A / 5W, charging

Battery 100%: .6A / 3W, maintaining full charge

##### 10 Watt Charger:

Battery dead: 1.8A / 9W, Turns on @2%, charging

Battery 50%: 1.8A / 9W, charging

Battery 95%: 1.3A / 6.5W, charging

Battery 100%: .6A / 3W, maintaining full charge

##### 12 Watt Charger:

Battery dead: 1.8A / 9W, Turns on @2%, charging

Battery 50%: 1.8A / 9W, charging

Battery 95%: 1.3A / 6.5W, charging

Battery 100%: .6A / 3W, maintaining full charge

**Note: It is not charging at 10 or 12 watt rate, but it is charging faster than 5 watt rate.**

# iPad Mini 2

CPU: A7

CPU Speed: 1.3 GHz

CPU Architecture: 64 Bit

CPU Cores: 2

RAM: 1 GB

Storage: 64 GB

Wireless Option: Yes

Charger Supplied: 10 watt

This iPad recognizes 12 watt charger, but charges at 10 watt rate.

## Charging Characteristics While ON

### 5 Watt Charger:

Battery dead: 1A / 5W, Turns on @2%, starts discharging

Battery 50%: 1A / 5W, discharging

Battery 95%: 1A / 5W, discharging

Battery 100%: 1A / 5W, discharging

### 10 Watt Charger:

Battery dead: 2A / 10W, Turns on @2%, charging

Battery 50%: 2A / 10W, charging

Battery 95%: 1.6A / 8W, charging

Battery 100%: .9A / 4.5W, maintaining full charge

### 12 Watt Charger:

Battery dead: 2A / 10W, Turns on @2%, charging

Battery 50%: 2A / 10W, charging

Battery 95%: 1.6A / 8W, charging

Battery 100%: .9A / 4.5W, maintaining full charge

# iPad Mini 3

CPU: A7

CPU Speed: 1.3 GHz

CPU Architecture: 64 Bit

CPU Cores: 2

RAM: 1 GB

Storage: 16 GB

Wireless Option: No

Charger Supplied: 10 watt

This iPad recognizes 12 watt charger, but charges at 10 watt rate.

## Charging Characteristics While ON

### 5 Watt Charger:

Battery dead: 1A / 5W, Turns on @2%, charging slowly

Battery 50%: 1A / 5W, charging slowly

Battery 95%: 1A / 5W, charging slowly

Battery 100%: .6A / 3W, maintaining full charge

### 10 Watt Charger:

Battery dead: 2A / 10W, Turns on @2%, charging

Battery 50%: 2A / 10W, charging

Battery 95%: 1.4A / 6W, charging

Battery 100%: .6A / 3W, maintaining full charge

### 12 Watt Charger:

Battery dead: 2A / 10W, Turns on @2%, charging

Battery 50%: 2A / 10W, charging

Battery 95%: 1.6A / 8W, charging

Battery 100%: .6A / 3W, maintaining full charge

# iPad Mini 4

CPU: A8

CPU Speed: 1.5 GHz

CPU Architecture: 64 Bit

CPU Cores: 2

RAM: 2 GB

Storage: 16 GB

Wireless Option: Yes

Charger Supplied: 10 watt

**This iPad recognizes 12 watt charger, and will charge faster on it.**

## Charging Characteristics While ON

### 5 Watt Charger:

Battery dead: 1A / 5W, Turns on @2%, charging

Battery 50%: 1A / 5W, charging

Battery 95%: 1A / 5W, charging

Battery 100%: 1A / 5W, maintaining full charge

### 10 Watt Charger:

Battery dead: 2.1A / 10.5W, Turns on @2%, charging

Battery 50%: 2A / 10W, charging

Battery 95%: 1.8A / 9W, charging

Battery 100%: .8A / 4W, maintaining full charge

### 12 Watt Charger:

Battery dead: 2.3A / 11.5W, Turns on @2%, charging

Battery 50%: 2.2A / 11W, charging

Battery 95%: 1.5A / 7.5W, charging

Battery 100%: .7A / 3.5W, maintaining full charge

# iPad

CPU: A4

CPU Speed: 1 GHz

CPU Architecture: 32 Bit

CPU Cores: 1

RAM: 256 MB

Storage: 64 GB

Wireless Option: Yes

Charger Supplied: 10 watt

This iPad recognizes 12 watt charger, but charges at the 10 watt rate.

## Charging Characteristics While ON

### 5 Watt Charger:

Battery dead: 1A / 5W, Turns on @2%, charging slowly

Battery 50%: 1A / 5W, charging slowly

Battery 95%: 1A / 5W, charging slowly

Battery 100%: .8A / 4W, maintaining full charge

### 10 Watt Charger:

Battery dead: 2A / 10W, Turns on @2%, charging

Battery 50%: 1.8A / 9W, charging

Battery 95%: 1.5A / 7.5W, charging

Battery 100%: .8A / 4W, maintaining full charge

### 12 Watt Charger:

Battery dead: 2A / 10W, Turns on @2%, charging

Battery 50%: 1.8A / 9W, charging

Battery 95%: 1.6A / 8W, charging

Battery 100%: .8A / 4W, maintaining full charge

# iPad 2

CPU: A5

CPU Speed: 1 GHz

CPU Architecture: 32 Bit

CPU Cores: 2

RAM: 512 MB

Storage: 64 GB

Wireless Option: Yes

Charger Supplied: 10 watt

This iPad recognizes 12 watt charger, but charges at the 10 watt rate.

## Charging Characteristics While ON

### 5 Watt Charger:

Battery dead: 1A / 5W, Turns on @2%, barely maintains charge

Battery 50%: 1A / 5W, charging slowly

Battery 95%: 1A / 5W, charging slowly

Battery 100%: .9A / 4.5W, maintaining full charge

### 10 Watt Charger:

Battery dead: 2A / 10W, Turns on @2%, charging

Battery 50%: 2A / 10W, charging

Battery 95%: 1.6A / 8W, charging

Battery 100%: .9A / 4.5W, maintaining full charge

### 12 Watt Charger:

Battery dead: 2A / 10W, Turns on @2%, charging

Battery 50%: 2A / 10W, charging

Battery 95%: 1.7A / 8.5W, charging

Battery 100%: .9A / 4.5W, maintaining full charge

# iPad 3

CPU: A5X

CPU Speed: 1 GHz

CPU Architecture: 32 Bit

CPU Cores: 2

RAM: 1 GB

Storage: 16 GB

Wireless Option: No

Charger Supplied: 10 watt

**This iPad recognizes 12 watt charger, and will charge faster on it.**

## Charging Characteristics While ON

### 5 Watt Charger:

Battery dead: 1A / 5W, Turns on @2%, starts discharging

Battery 50%: 1A / 5W, maintaining

Battery 95%: 1A / 5W, charging slowly

Battery 100%: .7A / 3.5W, maintaining full charge

### 10 Watt Charger:

Battery dead: 2.1A / 10.5W, Turns on @2%, charging

Battery 50%: 2.1A / 10.5W, charging

Battery 95%: 1.7A / 8.5W, charging

Battery 100%: .8A / 4W, maintaining full charge

### 12 Watt Charger:

Battery dead: 2.4A / 12W, Turns on @2%, charging

Battery 50%: 2.3A / 11.5W, charging

Battery 95%: 1.8A / 9W, charging

Battery 100%: .8A / 4W, maintaining full charge

# iPad 4

CPU: A6

CPU Speed: 1.4 GHz

CPU Architecture: 32 Bit

CPU Cores: 2

RAM: 1 GB

Storage: 16 GB

Wireless Option: No

Charger Supplied: Debut of the 12 watt charger

## Charging Characteristics While ON

### 5 Watt Charger:

Battery dead: 1A / 5W, Turns on @2%, starts discharging

Battery 50%: 1A / 5W, discharging

Battery 95%: 1A / 5W, discharging

Battery 100%: .6A / 3W, discharging

### 10 Watt Charger:

Battery dead: 2A / 10W, Turns on @2%, slowly charging

Battery 50%: 2A / 10W, slowly charging

Battery 95%: 1.9A / 9.5W, charging

Battery 100%: .9A / 4.5W, maintaining full charge

### 12 Watt Charger:

Battery dead: 2.2A / 11W, Turns on @2%, charging

Battery 50%: 2.2A / 11W, charging

Battery 95%: 2A / 10W, charging

Battery 100%: .8A / 4W, maintaining full charge

# iPad Air

CPU: A7

CPU Speed: 1.4 GHz

CPU Architecture: 64 Bit

CPU Cores: 2

RAM: 1 GB

Storage: 32 GB

Wireless Option: Yes

Charger Supplied: 12 watt (First model that really needs it)

## Charging Characteristics While ON

### 5 Watt Charger:

Battery dead: 1A / 5W, Turns on @2%, starts discharging

Battery 50%: 1A / 5W, discharging

Battery 95%: 1A / 5W, discharging

Battery 100%: 1A / 5W, discharging

### 10 Watt Charger:

Battery dead: 2A / 10W, Turns on @2%, slowly charging

Battery 50%: 2A / 10W, slowly charging

Battery 95%: 1.9A / 9.5W, slowly charging

Battery 100%: 1.7A / 8.5W, maintaining full charge

### 12 Watt Charger:

Battery dead: 2.3A / 11.5W, Turns on @2%, charging

Battery 50%: 2.3A / 11.5W, charging

Battery 95%: 1.7A / 8.5W, charging

Battery 100%: 1.7A / 8.5W, maintaining full charge

# iPad Air 2

CPU: A8X

CPU Speed: 1.5 GHz

CPU Architecture: 64 Bit

CPU Cores: 3

RAM: 2 GB

Storage: 64 GB

Wireless Option: Yes

Charger Supplied: 10 watt

**This iPad recognizes 12 watt charger, and will charge faster on it.**

## Charging Characteristics While ON

### 5 Watt Charger:

Battery dead: 1A / 5W, Turns on @2%, start very slow charging

Battery 50%: 1A / 5W, barely charging

Battery 95%: 1A / 5W, barely charging

Battery 100%: 1A / 5W, Maintain full charge barely, intermittent discharge

### 10 Watt Charger:

Battery dead: 2.1A / 10.5W, Turns on @2%, charging

Battery 50%: 2A / 10W, charging

Battery 95%: 1.9A / 9.5W, charging

Battery 100%: ~1A / 5W, maintaining full charge

### 12 Watt Charger:

Battery dead: 2.4A / 12W, Turns on @2%, charging

Battery 50%: 2.4A / 12W, charging

Battery 95%: 2A / 10W, charging

Battery 100%: ~1A / 5W, maintaining full charge

# iPad Pro 9.7

CPU: A9X

CPU Speed: 2.16 GHz

CPU Architecture: 64 Bit

CPU Cores: 2

RAM: 2 GB

Storage: 32 GB

Wireless Option: Yes

Charger Supplied: 10 watt

**This iPad recognizes 12 watt charger, and will charge faster on it.**

## Charging Characteristics While ON

### 5 Watt Charger:

Battery dead: 1A / 5W, Turns on @2%, starts discharging

Battery 50%: 1A / 5W, slowly discharging

Battery 95%: 1A / 5W, slowly discharging

Battery 100%: 1A / W, slowly discharging

### 10 Watt Charger:

Battery dead: 2A / 10W, Turns on @2%, charging

Battery 50%: 2A / 10W, charging

Battery 95%: 1.6A / 8W, charging

Battery 100%: ~1.5A / 7.5W, maintaining full charge

### 12 Watt Charger:

Battery dead: 2.3A / 11.5W, Turns on @2%, charging

Battery 50%: 2.3A / 11.5W, charging

Battery 95%: 1.7A / 8.5W, charging

Battery 100%: ~1.5A / 7.5W, maintaining full charge

# Newer iPad Models I Have Not Tested

New iPad Pro 9.7 versions are iPad “year” models: iPad 2017 and iPad 2018. iPad Pro 9.7 discontinued in 2017.

## iPad (9.7” models)

- **IPad 2017 (Slower than iPad Pro 9.7)**

CPU: A9 (64 Bit, 2 core, 1.85 GHz)

RAM: 2 GB

Storage: 32 or 128 GB

Charger Supplied: 12 watt

- **iPad 2018**

CPU: A10 (64 Bit, 4 core, only 2 used, 2.3 GHz)

RAM: 2 GB

Storage: 32 or 128 GB

Charger Supplied: 12 watt

## iPad Pro 10.5

CPU: A10X (64 Bit, 6 core, 2.39 GHz)

RAM: 4 GB

Storage: 64, 256, 512 GB

Charger Supplied: 12 watt

**Recognizes 29 watt USB-C charger (USB Power Delivery: 14.5V @ 2A).**

## iPad Pro 12 (Two generations)

CPU: A9X (64 Bit, 2 core, 2.26 GHz) and A10X (64 Bit, 6 core, 2.39 GHz)

RAM: 4 GB

Storage: 64, 128, 256, 512 GB

Charger Supplied: 12 watt

**Recognizes 29 watt USB-C charger (USB Power Delivery: 14.5V @ 2A).**

**iPad Pro 12 needs 29 watt charger to remain charged while on.**

