IEEE-Madison ECN Meeting
Packaging SoCs

How to Package These Tiny but Powerful Linux Devices

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What is A SoC?

A System on a Chip (SoC) is a method of placing all necessary electronics for running a computer on a single chip. Instead of having an individual chip for the CPU, GPU, USB controller, RAM, Northbridge, Southbridge, etc., everything is compressed down into one tidy package --- Raspberrypi.org
Raspberry Pi Family

- Model B
- Model A
- Compute Module
- CM-3
- Model B+
- Model A+
- 2 Model B
- Zero
- 3 Model B
- 3 Model B+
Raspberry Pi 3B+

- Quad Core BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC @ 1.4GHz
- 1GB LPDDR2 SDRAM
- 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE
- 40-pin extended GPIO
- 4 USB 2 ports
- 4 Pole stereo output and composite video port
- Full size HDMI
- CSI camera port for connecting a Raspberry Pi camera
- DSI display port for connecting a Raspberry Pi touchscreen display
- Micro SD port for loading your operating system and storing data
- Upgraded switched Micro USB power source up to 2.5A
- PoE Capable with PoE Hat
- Gigabit Ethernet over USB 2.0 (maximum throughput 300 Mbps)

$35!!!
Raspberry Pi Zero W

- Dimensions: 65mm × 30mm × 5mm
- SoC: Broadcom BCM2835
- CPU: ARM11 running at 1GHz
- RAM: 512MB
- Wireless: 2.4GHz 802.11n wireless LAN
- Bluetooth: Bluetooth Classic 4.1 and Bluetooth LE
- Power: 5V, supplied via micro USB connector
- Video & Audio: 1080P HD video & stereo audio via mini-HDMI connector
- Storage: MicroSD card
- Output: Micro USB
- GPIO: 40-pin GPIO, unpopulated
- Pins: Run mode, unpopulated; RCA composite, unpopulated
- Camera Serial Interface (CSI)

$10
Minimum System

Raspberry Pi 3 or Pi Zero W

- 5V Power Supply
- WiFi Switch/Router/Firewall
- Micro SD (8GByte)

Laptop/Desktop with Monitor/Mouse/Keyboard for programming and configuration.

HDMI Monitor, Keyboard/Mouse for initial setup.

Both Also support SSH (Secure Shell) remote access.
Pi Connections

Max 3A/pin Female Connector (Limited)

50-100 mA. Max

2.5 Amp Max

= Ground/Power Return (up to 3A/pin)

Note:

Clearance issues for Ethernet, USB, Audio, HDMI and Micro SD

Also:

WiFi and Bluetooth have no antenna connections

June 20th, 2019

ECN: Packaging SoCs
Pi Hats -- More Connectors!

All 24bit ADC up to 192kHz Sampling

Pi Zero

Ultra

GPS

Packing GPS units:

Internal Antenna or External Antenna?

Signal interference for Pi or other Processor could be a problem.
Basic Supply

Typically, a Wall Wart is used via the micro-USB connector.

It is limited to 2.5 Amps by the connector.

Use a high-quality cable with a good connector.

Typically they are 2.5 Amps.
Power-Over-Ethernet (PoE)

- 802.3af PoE
- Fully isolated switched-mode power supply
- 37–57V DC, Class 2 device
- 5V/2.5A DC output
- 25mm x 25mm brushless fan for processor cooling
- Fan control

* Only Pi 3B+
* Full Bandwidth
Power-Over-Ethernet (PoE) cont.

- IEEE 802.3af compliant
- Supports 10/100M data transmission (not for Gigabit ethernet)
- Supports 48V Unsolicited Power Over Ethernet PoE Switches/Hubs/Adapters with a 44V-57V power voltage input
- Operation temperature: 20°C - 45°C
- Storage temperature: -30°C - 70°C
- Isolation: 2.5kV
- Power Input: 44~57V DC
- Power Output: 5V DC 2.4A
Power-Over-Ethernet (PoE) cont.

- IEEE 802.3af compliant
- Supports 10/100M data transmission (not for Gigabit ethernet)
- Supports 48V Unsolicited Power Over Ethernet PoE Switches/Hubs/Adapters with a 44V-57V power voltage input
- Operation temperature: -30°C - +80°C
- Storage temperature: -20°C - +85°C
- Isolation: 2.5kV
- Power Input: 44~57V DC
- Power Output: 5V DC 1.8A

1. Connect pins 1 and 2 to Ethernet wires 4 and 5
2. Connect pins 3 and 4 to Ethernet wires 7 and 8
3. Pin labeled (-) is ground output
4. Pin labeled (+) is 5V out
“Fake” or Passive PoE

- Passive – Voltage in is Voltage Out minus Drop
- 10/100 MBit Ethernet Only
- Inexpensive for single sites
- Up to 1 Volt drop per 10 Meters Cat 5/6
- Requires Pi End regulator for longer runs over temperature
- See Example Power loss below for 10W at Pi

<table>
<thead>
<tr>
<th>Voltage at source end = 12 Volts</th>
<th>Current = 0.92 Amps</th>
<th>delivering 10 watts remotely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>50 (ft)</td>
<td></td>
</tr>
<tr>
<td>Resistance</td>
<td>1.28 (Ohms)</td>
<td>2 Pair</td>
</tr>
<tr>
<td>Line Loss</td>
<td>1.09 Watts per device</td>
<td></td>
</tr>
</tbody>
</table>
Passive PoE Plus Regulator

- Switching Regulator First Stage (or Only one)
- Linear Low-Drop-Out Regulator Second Stage
- Third Stage for low-noise Analog
- Advantages: Power Efficient Switching Plus Lower Ripple/Noise Output
- Possible: Battery Power 12 or 24 Volt.

**MIC29300**
Fixed Output Version

- 5V
- IN
- OUT
- 3.3V @ 3A
- 10μF Tantalum
- GND

**MIC29152**
Adjustable Output Version

- 3.3V
- IN
- EN
- GND
- 10μF Tantalum
- OUT
- ADJ
- * See Minimum Load Current Section
- 2.5VOUT@1.5A

* Image of a Passive PoE Plus Regulator component*
BB01 | BitScope Blade for Raspberry Pi & HAT | Uno Pi

- 40-way socket for Raspberry Pi providing solid 5V power.
- Solid copper GND and 5V power.
- 40-way HAT header to connect Pi HAT boards.
- Dual USB sockets for Raspberry Pi Display and peripherals power.
- 2.5mm DC socket
- Power on LED
- V+ blocking diode prevents shorting power input.
- V+ connect, M3 mounting holes.
- Low ESR Cap for solid 5V supply.
- SMPS 7~48V switching regulator with heatsink.
- Raspberry Pi HAT slot and optional prototyping area.
- Slot powered LED.
- 5V auxiliary power header (reversible).
BitScope Duo

BB02 | BitScope Blade for Raspberry Pi x 2 | Duo Pi

Solid copper GND and 5V power.

40-way sockets for Raspberry Pis providing solid 5V power.

2.5mm DC socket

Power on LED

M2.5 mounting post for Raspberry Pi.

GND connect, M3 mounting holes.

Raspberry Pi Slot 1 exposes HDMI and Audio full access.

Slot powered LED.

Slot power and Pi reset control.

Cutout to reveal Pi LEDs and BCM

V+ blocking diode prevents shorting power input.

V+ connect, M3 mounting holes.

Low ESR Cap for solid 5V supply.

SMPS 7~48V switching regulator with heatsink.

Slot for second Raspberry Pi.
BitScope Hub Connector

- Duo and Uno have rear “Hub” Connector
- Allows separate Card to access Pins
- SPI, I2C, Etc. Available

Issues:
- Only 26 Pins (Older Pi)
- Card can block Camera Slot
Basic Box

- Insulate the circuit cards from shorts
- Provide openings for the connectors
- Plastic Passes WiFi, Blue Tooth
- Does not provide Cooling Vents
- Camera clots may or may not be used
Waterproof Box with Glands

- Insulate the circuit cards from shorts
- Provides some environmental protection
- Plastic Passes WiFi, Blue Tooth
- Does not provide Cooling Vents
- Glands require cable wiring

This Box barely fits a Pi Zero
Metal Box

- Provides good environmental protection
- Metal Blocks WiFi, Blue Tooth
- Does not provide Cooling Vents
- Metal can act as cooling surface

Metal is reasonably easy to work.
IP67 Open IO

- Provides good environmental protection
- Metal Base Plate, Plastic box
- Pases WiFi, Blue Tooth
- Does not provide Cooling Vents
- Metal can act as cooling surface

- Pre-taped holes poorly placed
- Gasket impossible to use
Sonic Boom Monitor

Geographically Distributed Recorders
Stores 1-minute .wav files
Cloud-Based Server
Node.js + Meteor
Linux Cloud Server

- Components mounted on a Aluminum Sheet
- Packaged in Rugged Instrument Box
- Also shipped via Air Freight in the same box
- Not environmentally sealed in operation

Sub-Audio Microphone
ADC
USB Mem
Rpi
Cellular Modem

Linux Cloud Server

48ksps, 24 bit
f_{3db} = 0.7 Hz

Enet
Sonic Boom Monitor (cont).
1. Jackd Digitizes Audio Data
2. Audio Data buffered and written as .wav file in 6000 byte chunks.
3. FFT converts 1-second data to Frequency Spectra
4. 1/3 Octave Power Level Computation
5. 1/3 Octave Power Level data written as .csv file each second
6. Server can start/stop record function
7. Wave file data written on minute boundaries

Calibrated Microphone

AD

48ksp s, 24 bit

3dB

f = 10 Hz

USB MEM

RPi

WiFi or Wired Ethernet
Sound Transit

- 2 Pi-Based cameras 8 fps
- Radar unit
- Inertial Unit
- RFID Reader
- Audio Recorder with Accelerometer
- GPS with PPS for Accurate Time
- Separate MicroChip Processor with RTC integrated
- Deployed in less than 2.5 minutes
Sound Transit (Tests)

- Subaru with Roof Rack
- Cameras and Radar Detail
- Microphone
- System
Sound Transit (Tests)

Speed Bump at 2018-08-14-15:51:18_plus

Lord IMU

Time in Seconds

Acceleration/Angular Rate

Ax
Ay
Az
Gx
Gy
Gz
BBB Raman Spectroscopy

- Package BBB, ADC, Counters, Regulators
- 8X 10MHz counters and 2 High Speed ADCs
- Serial or Ethernet
- “Motherboard” mount
- LabVIEW Remote monitoring