linux + sensor + device-tree + shell = IoT ?

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@dpavlin

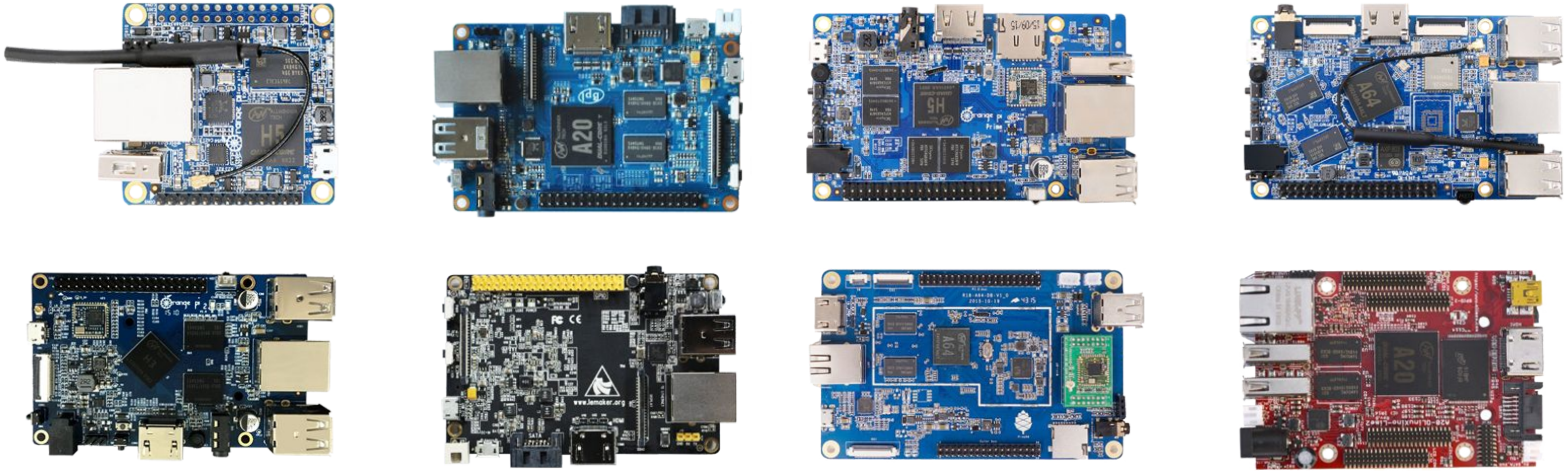
linux+sensor+device-tree+shell=IoT ?

You have one of those fruity *Pi arm boards and cheep sensor from China?

Some buttons and LEDs?

Do I really need to learn whole new scripting language and few web technologies to read my temperature, blink a led or toggle a relay?

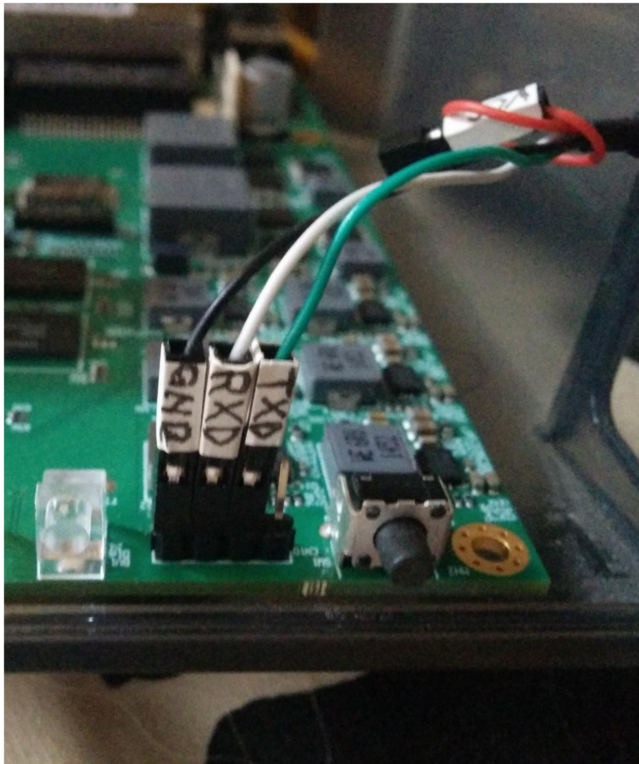
No, because your Linux kernel already has drivers for them and all you need is device tree and cat.



This talk is aimed at people who

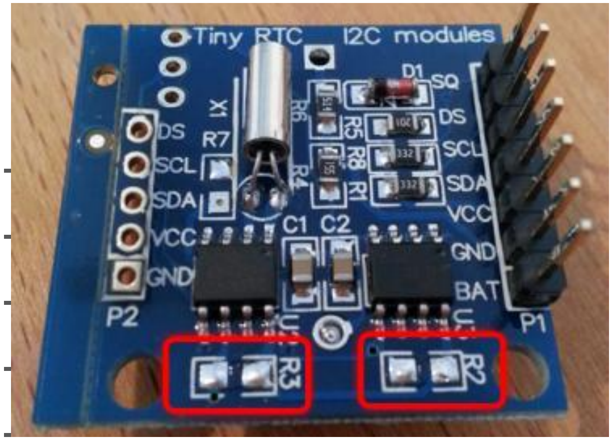
- have arm board with gpio headers (sunxi/Allwinner, bcm/Raspberry Pi)
- found a internet search result with device tree, and it looks like magic
- know how to (cross) compile kernel for arm board if modules are missing
- have cheap sensors from ebay or aliexpress and want to use then from Linux
- a little more than just rx/tx connections....
- but no soldering...

armbian



Arduino i2c modules might be 5V devices!

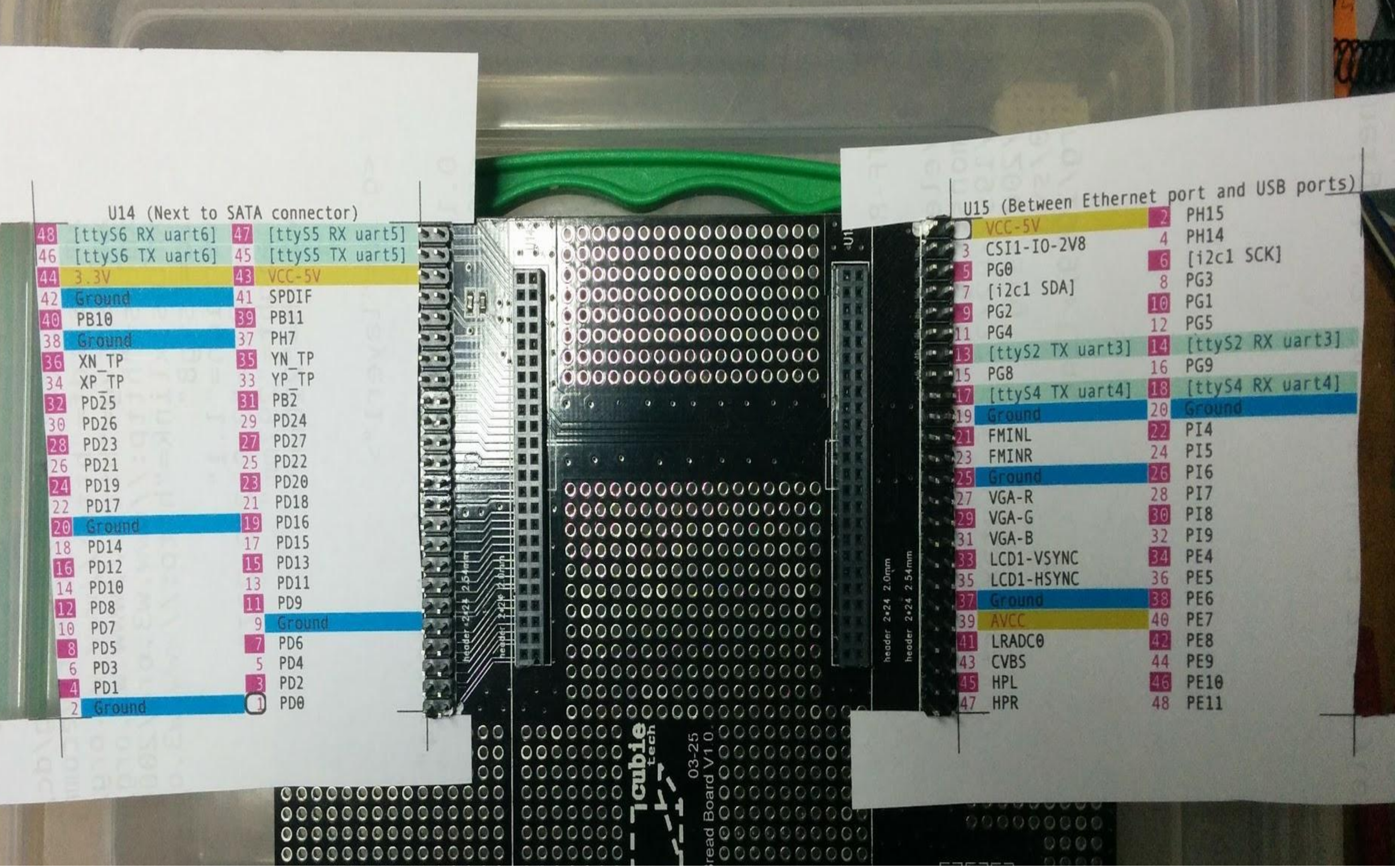
```
root@raspberrypi:/home/pi# apt-get install i2c-tools

root@raspberrypi:/home/pi# modprobe i2c-dev

root@raspberrypi:/home/pi# i2cdetect -y 1
     0  1  2  3  4  5  6  7  8  9  a  b  c  d
00:          -- -- -- -- -- -- -- -- -- -- -- -
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -
40: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -
50: 50 -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- 68 -- -- -- -- -- --
70: -- -- -- -- -- -- -- --

root@raspberrypi:/home/pi# modprobe rtc-ds1307
```



remove i2c pull-up to 5V

if module has 5V VCC check SDA and SCL levels with multimeter!

https://electronics.stackexchange.com/questions/98361/how-to-modify-ds1307-rtc-to-use-3-3v-for-raspberry-pi



U14 (Next to SATA connector)

48	[ttyS6 RX uart6]	47	[ttyS5 RX uart5]
46	[ttyS6 TX uart6]	45	[ttyS5 TX uart5]
44	3.3V	43	VCC-5V
42	Ground	41	SPDIF
40	PB10	39	PB11
38	Ground	37	PH7
36	XN_TP	35	YN_TP
34	XP_TP	33	YP_TP
32	PD25	31	PB2
30	PD26	29	PD24
28	PD23	27	PD27
26	PD21	25	PD22
24	PD19	23	PD20
22	PD17	21	PD18
20	Ground	19	PD16
18	PD14	17	PD15
16	PD12	15	PD13
14	PD10	13	PD11
12	PD8	11	PD9
10	PD7	9	Ground
8	PD5	7	PD6
6	PD3	5	PD4
4	PD1	3	PD2
2	Ground	1	PD0

U15 (Between Ethernet port and USB ports)

	VCC-5V	2	PH15
3	CSI1-IO-2V8	4	PH14
5	PG0	6	[i2c1 SCK]
7	[i2c1 SDA]	8	PG3
9	PG2	10	PG1
11	PG4	12	PG5
13	[ttyS2 TX uart3]	14	[ttyS2 RX uart3]
15	PG8	16	PG9
17	[ttyS4 TX uart4]	18	[ttyS4 RX uart4]
19	Ground	20	Ground
21	FMINL	22	PI4
23	FMINR	24	PI5
25	Ground	26	PI6
27	VGA-R	28	PI7
29	VGA-G	30	PI8
31	VGA-B	32	PI9
33	LCD1-VSYNC	34	PE4
35	LCD1-HSYNC	36	PE5
37	Ground	38	PE6
39	AVCC	40	PE7
41	LRADC0	42	PE8
43	CVBS	44	PE9
45	HPL	46	PE10
47	HPR	48	PE11

Would it be nice if all boards came with 2.54mm pinouts? (in svg, bw or color)
https://github.com/dpavlin/linux-gpio-pinout
with ability to flip horizontally or vertically depending on board orientation?

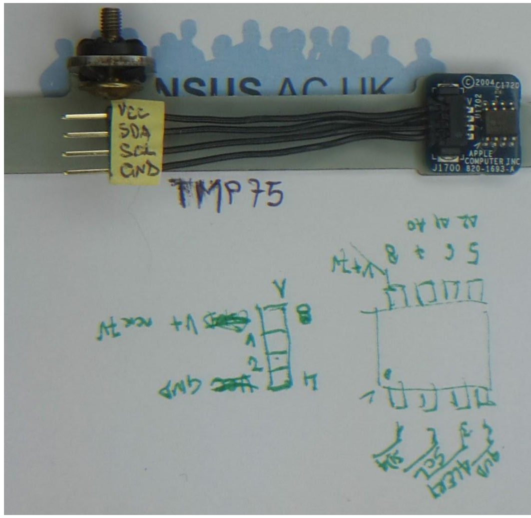
output friendly to grep in terminal with [kernel info]

```
dpavlin@cubieboard:~/linux-gpio-pinout$ sudo ./gpio.pl 2>/dev/null | egrep '(^#|\[)'
## U14 (Next to SATA connector)
###     SPI0
48 PI13 2 0 1 [spi0 MISO]      47 PI11 2 0 1 [spi0 CLK]
46 PI12 2 0 1 [spi0 MOSI]      45 PI10 2 0 1 [spi0 CS]
###     LCD
32 PD25 0 0 1 0                31 PB2 2 0 1 [pwm pwm]
## U15 (Between Ethernet port and USB ports)
### CSI1/TS
 5 PG0 0 0 1 0                  6 PB18 2 0 1 [i2c1 SCK]
 7 PB19 2 0 1 [i2c1 SDA]        8 PG3 0 1 1 1 "E-mail" in hi [gpio-3-buttons gpio_in]
 9 PG2 0 0 1 0                 10 PG1 0 1 1 1 "Connect" in hi [gpio-3-buttons gpio_in]
11 PG4 0 0 1 0                 12 PG5 0 1 1 1 "Print" in hi [gpio-3-buttons gpio_in]
13 PG6 4 0 1 [ttyS3 TX uart3]  14 PG7 4 0 1 [ttyS3 RX uart3]
17 PG10 4 0 1 [ttyS4 TX uart4] 18 PG11 4 0 1 [ttyS4 RX uart4]
###     Analog SDIO3
###     CSI0/TS
## DEBUG serial (middle of board)
 4 PB22 2 0 1 [ttyS0 TX uart0]
 3 PB23 2 1 1 [ttyS0 RX uart0]
```

and again with horizontal or vertical flip depending on board orientation (top, bottom, rotation...)

does kernel have support for my sensor?

```
dpavlin@klin:/klin/linux$ git grep tmp75
Documentation/hwmon/lm75:    Prefixes: 'tmp100', 'tmp101', 'tmp105', 'tmp112', 'tmp175', 'tmp75', 'tmp75c',
'tmp275'
Documentation/hwmon/lm75:               http://www.ti.com/product/tmp75
Documentation/hwmon/lm75:               http://www.ti.com/product/tmp75c
drivers/hwmon/lm75.c:   tmp75,
drivers/hwmon/lm75.c:   tmp75c,
drivers/hwmon/lm75.c:   case tmp75:
drivers/hwmon/lm75.c:   case tmp75c:
drivers/hwmon/lm75.c:   { "tmp75", tmp75, },
drivers/hwmon/lm75.c:   { "tmp75c", tmp75c, },
drivers/hwmon/lm75.c:           .compatible = "ti,tmp75",
drivers/hwmon/lm75.c:           .data = (void *)tmp75
drivers/hwmon/lm75.c:           .compatible = "ti,tmp75c",
drivers/hwmon/lm75.c:           .data = (void *)tmp75c

root@cubieboard2:~# echo lm75 0x49 > /sys/bus/i2c/devices/i2c-1/new_device

dpavlin@cubieboard2:~$ sensors tmp75-i2c-1-49
tmp75-i2c-1-49
Adapter: mv64xxx_i2c adapter
temp1:        +23.5°C  (high = +80.0°C, hyst = +75.0°C)

dpavlin@cubieboard2:~$ cat /sys/devices/platform/soc@01c00000/1c2b000.i2c/i2c-1/1-0049/hwmon/hwmon0/temp1_input
23500
```



device tree for i2c sensor

```
dpavlin@cubieboard2:~/linux-gpio-pinout$ cat device-tree/i2c-tmp75.dts
/dts-v1/;
/plugin/;

/ {
        compatible = "allwinner,sun4i-a10", "allwinner,sun7i-a20", "allwinner,sun50i-a64", "allwinner,sun50i-h5";

        fragment@0 {
                target = <&i2c1>;
                __overlay__ {
                        #address-cells = <1>;
                        #size-cells = <0>;
                        tmp75@49 {
                                compatible = "ti,tmp75";
                                reg = <0x49>;
                                status = "okay";
                        };
                };
        };
};
```

device tree overlay debugging - configfs

You don't need to reboot your board to test device tree! (on sunxi at least)

```
dpavlin@cubieboard2:~/linux-gpio-pinout$ cat overlay-load.sh
#!/bin/sh -xe

dtb=$1
test -f "$dtb" || ( echo "Usage: $0 overlay.dtb" ; exit 1 )
config=`mount -t configfs | awk '{ print $3 }'`
name=`basename $1`
dir=$config/device-tree/overlays/$name
test -d $dir && rmdir $dir
mkdir $dir
cat $dtb > $dir/dtbo
cat $dir/status
```

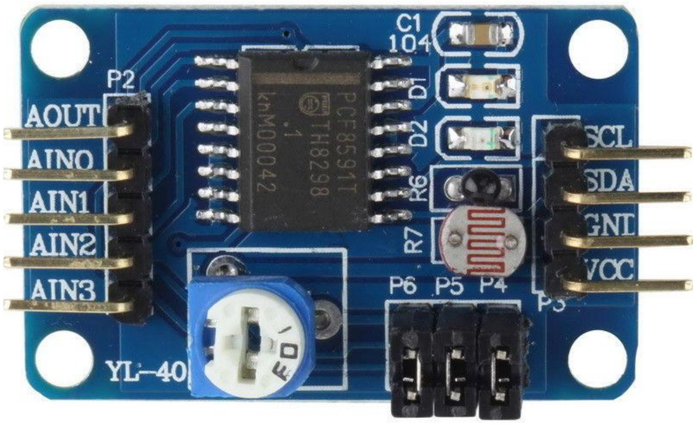
i2c debugging - alternative to logic analyzer

```
dpavlin@cubieboard2:~/linux-gpio-pinout$ cat i2c-tracing.sh
#!/bin/sh

if [ -z "$1" ] ; then
        echo "Usage: $0 0|1 - disable/enable i2c tracking"
        exit 1
fi

echo $1 > /sys/kernel/debug/tracing/events/i2c/enable
# echo adapter_nr==1 >/sys/kernel/debug/tracing/events/i2c/filter
cat /sys/kernel/debug/tracing/trace
```

add ADC to board without it on the chep - pcf8591

```
echo pcf8591 0x48 > /sys/bus/i2c/devices/i2c-1/new_device
```

```
dpavlin@cubieboard:~$ sensors pcf8591-i2c-1-48
pcf8591-i2c-1-48
Adapter: mv64xxx_i2c adapter
in0:          +2.50 V
in1:          +2.55 V
in2:          +0.01 V
in3:          +1.32 V
```

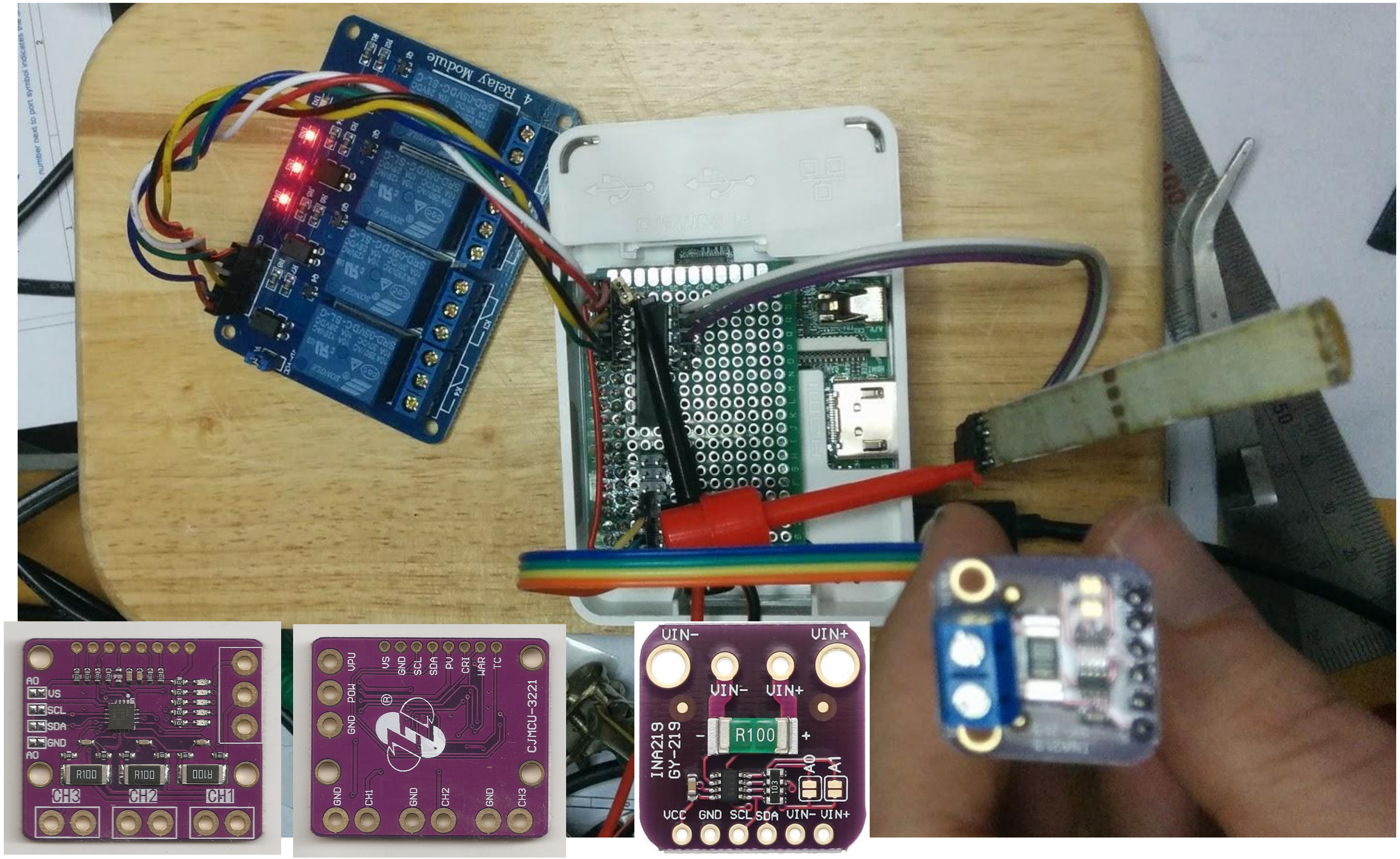


```
root@cubieboard:~# cd /sys/devices/platform/soc@01c00000/1c2b000.i2c/i2c-1/1-0048/
root@cubieboard:/sys/devices/platform/soc@01c00000/1c2b000.i2c/i2c-1/1-0048# ls
driver   in0_input  in2_input  modalias  out0_enable  power      uevent
hwmon    in1_input  in3_input  name      out0_output  subsystem
```

Current monitoring usina ina219 or ina3221

Current monitoring of your arm boards or anything is internet ready!

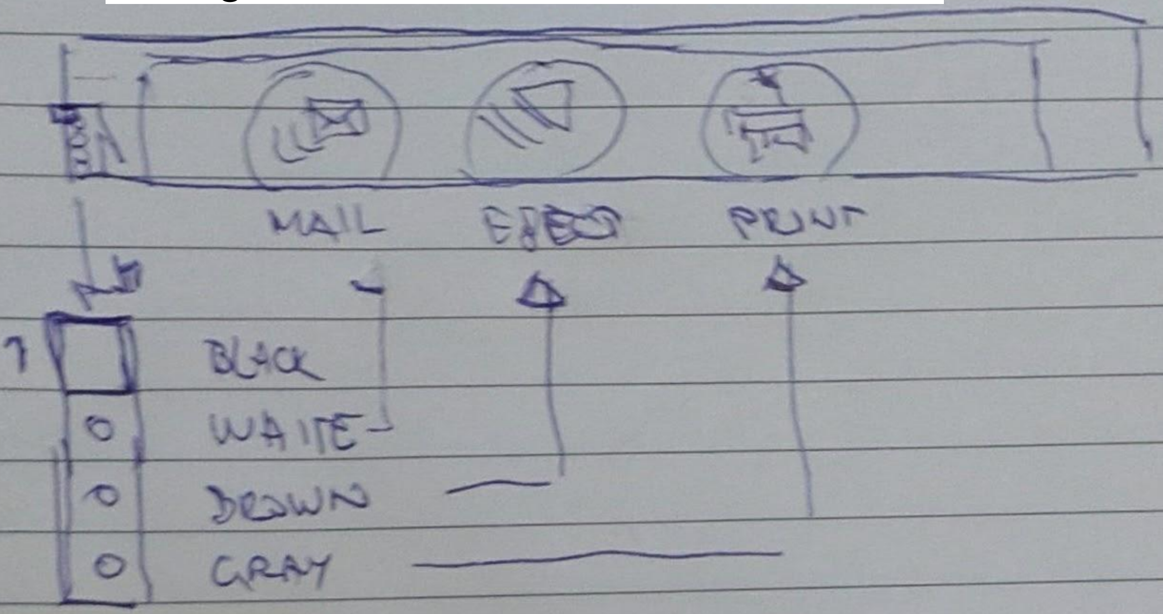
```
cat /sys/devices/platform/soc@01c00000/1c2b000.i2c/i2c-1/1-0040/hwmon/hwmon0/curr1_input
```

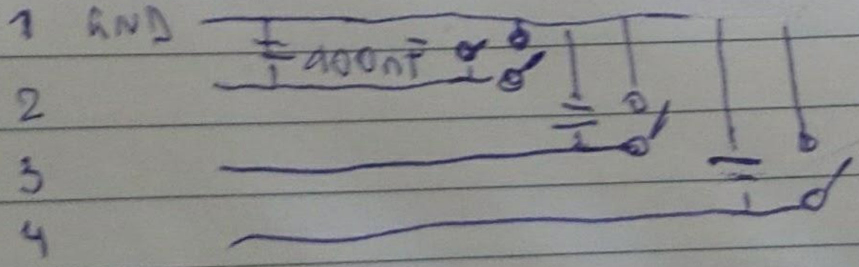


But, you
promised IoT!
OK, let's make
MQTT button

2017-12-02

salvage some buttons from old scanner





hardware debounce

device tree defines pins and keys

```
/dts-v1/;
/plugin/;

/ {
        compatible = "allwinner,sun4i-a10", "allwinner,sun7i-a20", "allwinner,sun50i-a64", "allwinner,sun50i-h5";

        /*
         * This fragment is needed only for the internal pull-up activation,
         * external pull-up resistor is highly recommended if using long wires
         */

        fragment@0 {
                target = <&pio>;
                __overlay__ {
                        gpio_button_0: gpio_button_0 {
                                pins = "PG3","PG1","PG5";
                                function = "gpio_in";
                                bias-pull-up;
                        };
                };
        };

        fragment@1 {
                target-path = "/";
                __overlay__ {
                        gpio-3-buttons {
                                /*
                                 * Use "gpio-keys" for EINT capable pins, "gpio-keys-polled" for other pins
                                 * add "poll-interval" property if using "gpio-keys-polled"
                                 */
                                compatible = "gpio-keys-polled";
                                poll-interval = <100>;
                                autorepeat;

                                pinctrl-names = "default";
                                pinctrl-0 = <&gpio_button_0>;

                                email {
                                        label = "E-mail";
                                        linux,code = <215>; /* KEY_EMAIL, see include/uapi/linux/input-event-codes.h */
                                        gpios = <&pio 6 3 1>; /* PG3 GPIO_ACTIVE_LOW */
                                };

                                connect {
                                        label = "Connect";
                                        linux,code = <218>; /* KEY_CONNECT, see include/uapi/linux/input-event-codes.h */
                                        gpios = <&pio 6 1 1>; /* PG1 GPIO_ACTIVE_LOW */
                                };

                                print {
                                        label = "Print";
                                        linux,code = <210>; /* KEY_PRINT, see include/uapi/linux/input-event-codes.h */
                                        gpios = <&pio 6 5 1>; /* PG5 GPIO_ACTIVE_LOW */
                                };
                        };
                };
        };
};
```

Does my pin has irq support? /sys/kernel/debug/

```
root@rpi:~# grep Hardware /proc/cpuinfo
Hardware        : BCM2835

root@rpi:~# grep -r irq /sys/kernel/debug/pinctrl/ | head
/sys/kernel/debug/pinctrl/20200000.gpio/pins:pin 0 (gpio0) function alt0 in hi; irq 160 (none)
/sys/kernel/debug/pinctrl/20200000.gpio/pins:pin 1 (gpio1) function alt0 in hi; irq 161 (none)
/sys/kernel/debug/pinctrl/20200000.gpio/pins:pin 2 (gpio2) function alt0 in hi; irq 162 (none)
/sys/kernel/debug/pinctrl/20200000.gpio/pins:pin 3 (gpio3) function alt0 in hi; irq 163 (none)
/sys/kernel/debug/pinctrl/20200000.gpio/pins:pin 4 (gpio4) function gpio_in in hi; irq 164 (none)
/sys/kernel/debug/pinctrl/20200000.gpio/pins:pin 5 (gpio5) function gpio_out in lo; irq 165 (none)
/sys/kernel/debug/pinctrl/20200000.gpio/pins:pin 6 (gpio6) function gpio_out in hi; irq 166 (none)
/sys/kernel/debug/pinctrl/20200000.gpio/pins:pin 7 (gpio7) function gpio_in in hi; irq 167 (none)
/sys/kernel/debug/pinctrl/20200000.gpio/pins:pin 8 (gpio8) function gpio_in in hi; irq 168 (none)
/sys/kernel/debug/pinctrl/20200000.gpio/pins:pin 9 (gpio9) function gpio_in in lo; irq 169 (none)

root@cubieboard:~# grep Hardware /proc/cpuinfo
Hardware        : Allwinner sun4i/sun5i Families

root@cubieboard:~# grep -r irq /sys/kernel/debug/pinctrl/
/sys/kernel/debug/pinctrl/1c20800.pinctrl/pinmux-functions:function: irq, groups = [ PH0 PH1 PH2 PH3 PH4 PH5 PH6 PH7
PH8 PH9 PH10 PH11 PH12 PH13 PH14 PH15 PH16 PH17 PH18 PH19 PH20 PH21 PI10 PI11 PI12 PI13 PI14 PI15 PI16 PI17 PI18 PI19 ]
```

Different on different hardware, but still kernel knows!

Test new input events using evtest

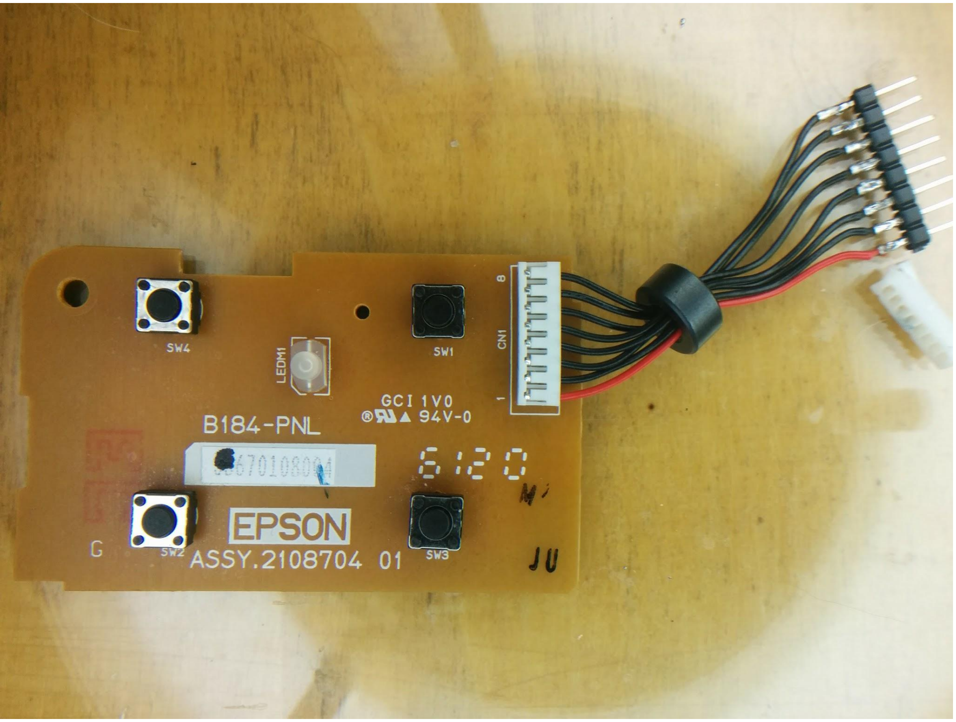
```
root@cubieboard:~# evtest
No device specified, trying to scan all of /dev/input/event*
Available devices:
/dev/input/event0:      axp20x-pek
/dev/input/event1:      gpio-3-buttons
/dev/input/event2:      sunxi-ir
Select the device event number [0-2]: 1
Input driver version is 1.0.1
Input device ID: bus 0x19 vendor 0x1 product 0x1 version 0x100
Input device name: "gpio-3-buttons"
Supported events:
  Event type 0 (EV_SYN)
  Event type 1 (EV_KEY)
    Event code 210 (KEY_PRINT)
    Event code 215 (KEY_EMAIL)
    Event code 218 (KEY_CONNECT)
Key repeat handling:
  Repeat type 20 (EV_REP)
    Repeat code 0 (REP_DELAY)
      Value    250
    Repeat code 1 (REP_PERIOD)
      Value     33
```

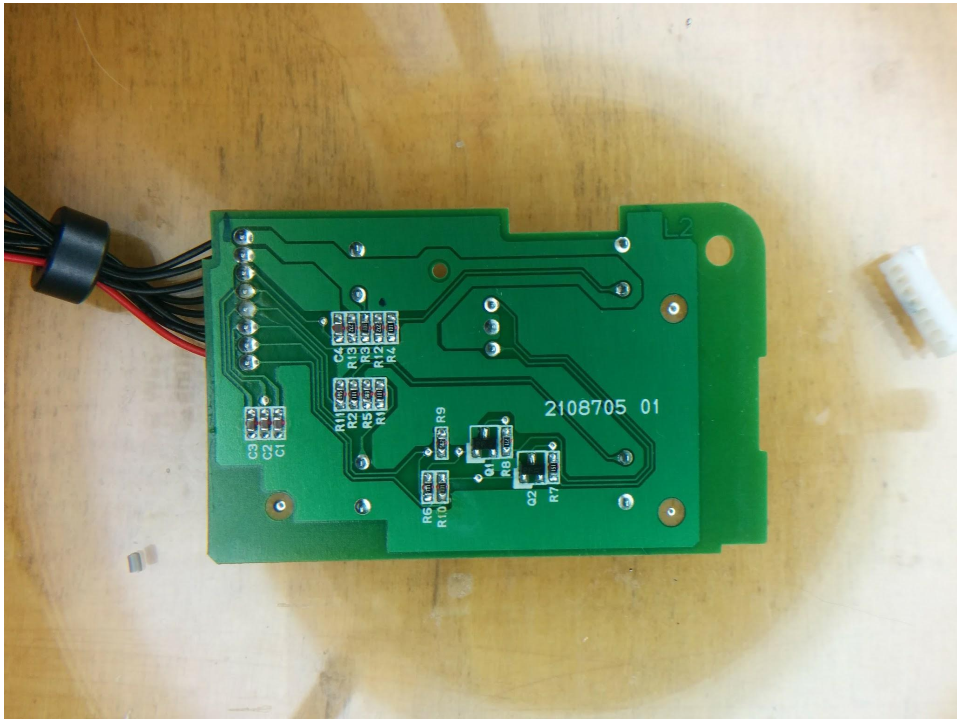
Bind something to keypress using thd

```
root@cubieboard:~# grep -v '^#' /etc/triggerhappy/triggers.d/mqtt.conf
KEY_EMAIL   1 /usr/bin/mosquitto_pub -h rpi2 -t cubieboard/gpio-3-buttons -m email
KEY_CONNECT 1 /usr/bin/mosquitto_pub -h rpi2 -t cubieboard/gpio-3-buttons -m connect
KEY_PRINT   1 /usr/bin/mosquitto_pub -h rpi2 -t cubieboard/gpio-3-buttons -m print
```

IoT is easy: mqtt buttons without a line of new code, lust config!
Don't deploy local IoT devices which require internet to operate :-\

Use any old button board - old Epson matrix printer

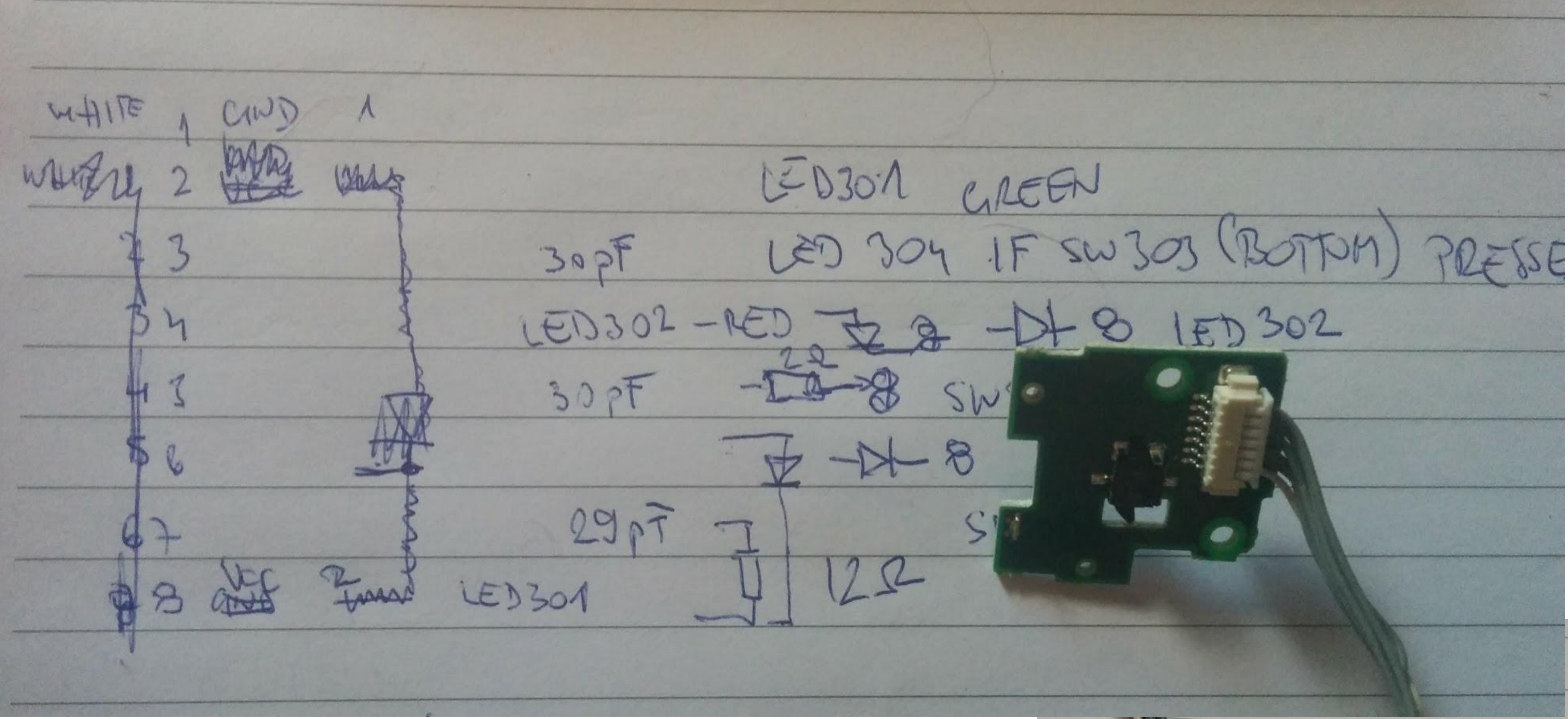




https://github.com/dpavlin/linux-gpio-pinout/blob/master/device-tree/EPSON-B184.dts
keys are active high, pull-downs are on board
led is connected directly to pin, but expects 5V to light up

LEDs? Can leds show cpu and mmc activity?

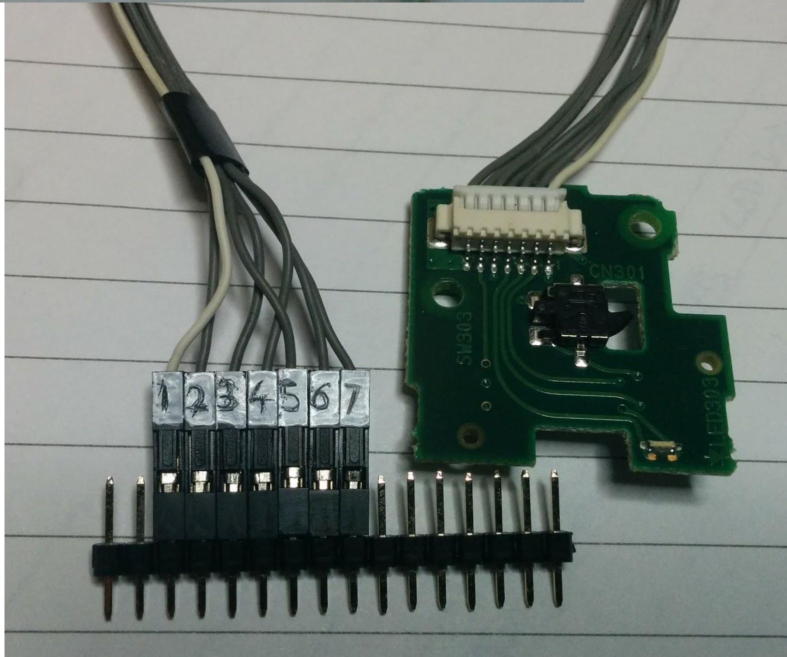
```
/dts-v1/;
/plugin/;

/ {
        compatible = "allwinner,sun4i-a10", "allwinner,sun7i-a20", "allwinner,sun50i-a64", "allwinner,sun50i-h5";

        /* Documentation/devicetree/bindings/leds/leds-gpio.txt */
        fragment@0 {
                target-path = "/";

                __overlay__ {
                        user-leds {
                                compatible = "gpio-leds";

                                leds@0 {
                                        label = "gpio:red-top";
                                        gpios = <&pio 8 20 0>; /* PI20 GPIO_ACTIVE_HIGH */
                                        linux,default-trigger = "mmc0";
                                };

                                leds@1 {
                                        label = "gpio:green-bottom";
                                        gpios = <&pio 8 21 0>; /* PI21 GPIO_ACTIVE_HIGH */
                                        linux,default-trigger = "cpu";
                                };
                        };
                };
        };
};
```



this board from old thinkpad dock adds leds with cpu and mmc activity and buttons to arm sbc

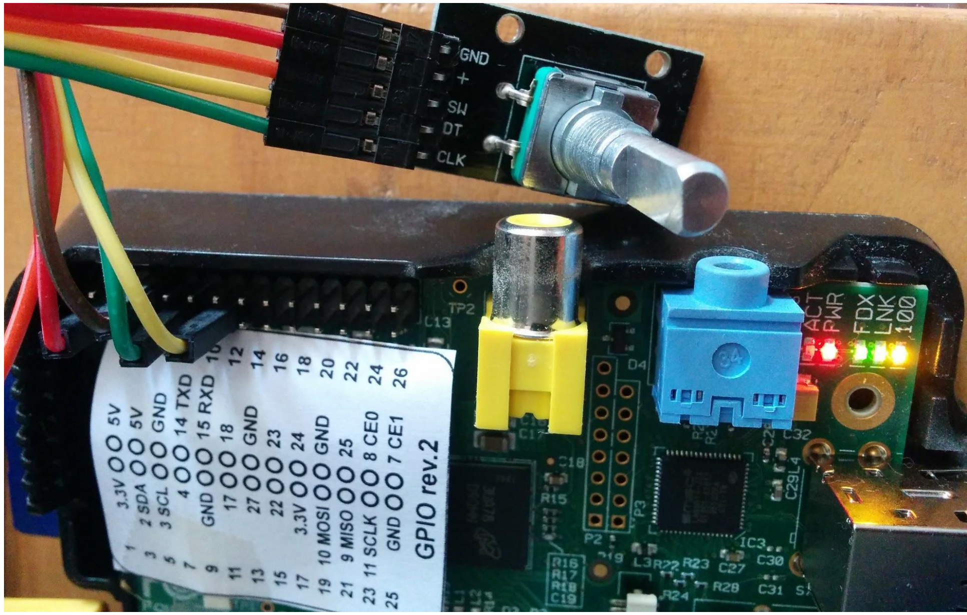
first step is to test all pins with transistor tester and figure out connections from board layout

good reason to horde old parts :-)
[and number pins, compare with notes]



rotary encoder from /boot/overlays/README

```
root@ntpi:~# dmesg | grep rotary
[   10.370238] rotary-encoder rotary@0: gray
[   10.393505] input: rotary@0 as /devices/platform/rotary@0/input/input0

root@ntpi:~# grep rotary /boot/config.txt
dtoverlay=rotary-encoder,rollover,steps=20

root@ntpi:~# evtest /dev/input/event0
Input device name: "rotary@0"
Supported events:
  Event type 0 (EV_SYN)
  Event type 3 (EV_ABS)
    Event code 0 (ABS_X)
      Value      0
      Min        0
      Max       20
      Flat       1
Properties:
Testing ... (interrupt to exit)
Event: time 1523107078.786053, type 3 (EV_ABS), code 0 (ABS_X), value 1
Event: time 1523107078.786053, -------------- SYN_REPORT ------------
Event: time 1523107080.280269, type 3 (EV_ABS), code 0 (ABS_X), value 2
Event: time 1523107080.280269, -------------- SYN_REPORT ------------
```



Relays as leds in Linux kernel?

We want to take control of GPIO pins as soon as possible after power on

On Raspberry Pi it seems that configfs loading of overlays doesn't work

https://github.com/dpavlin/linux-gpio-pinout/blob/master/device-tree/relay-leds.dts

```
pi@rpi3:~ $ grep -C 1 dtdebug /boot/config.txt
dtoverlay=relay-leds
dtdebug=on
# sudo vcdbg log msg

pi@rpi3:~ $ ls /sys/class/leds/
led0  led1  relay1  relay2  relay3  relay4
pi@rpi3:~ $ sudo sh -c 'echo 1 >
/sys/class/leds/relay1/brightness'
pi@rpi3:~ $ cat /sys/class/leds/relay1/brightness
255
```

Raspberry Pi pull-up/down ?!

you specified active low/high in your device tree and default-state it doesn't work

```
pi@rpi3:~ $ raspi-gpio funcs 21
GPIO, DEFAULT PULL, ALT0, ALT1, ALT2, ALT3, ALT4, ALT5
21, DOWN, PCM_DOUT, SD13, DPI_D17, I2CSL_CE_N, SPI1_SCLK, GPCLK1
```

does this but pins have hardware pull-up if one of alternative functions is spi clock? See forum post GPIO Port Behaviour @ Power-up/Reboot

Please use device tree configuration instead of user-land (python) code...

...or Arduino over serial port
...or WiringPi

You will eventually need to put device tree overlay in i2c eeprom on rpi!

What did we learn?

- Linux kernel has device tree as configuration mechanism
  - different on different architectures, sill in state of flux, especially overlays
- integrating your sensors, buttons or leds into linux kernel
  - easy way to create input devices for Linux kernel
- debugging i2c messages using tracing

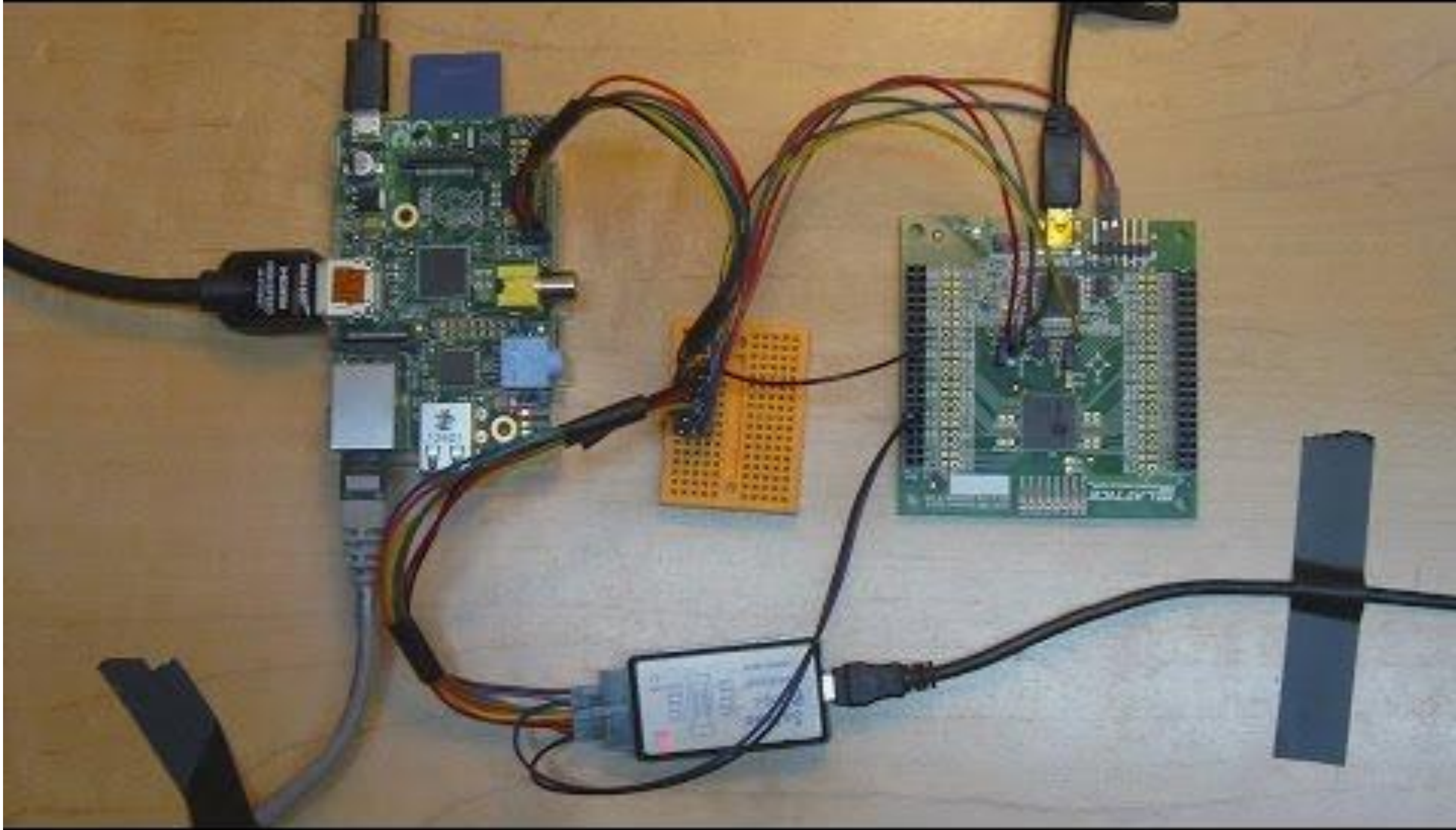
Useful links

- more about device trees
  - https://github.com/dpavlin/linux-gpio-pinout
  - https://github.com/armbian/sunxi-DT-overlays
  - https://www.raspberrypi.org/documentation/configuration/device-tree.md
- kernel building
  - https://www.raspberrypi.org/documentation/linux/kernel/building.md
  - https://docs.armbian.com/Developer-Guide_Build-Preparation/

Question? Comments?

Videos about device tree

OpenTechLab[002] Testing the Linux Kernel driver for the Lattice iCE40 FPGA

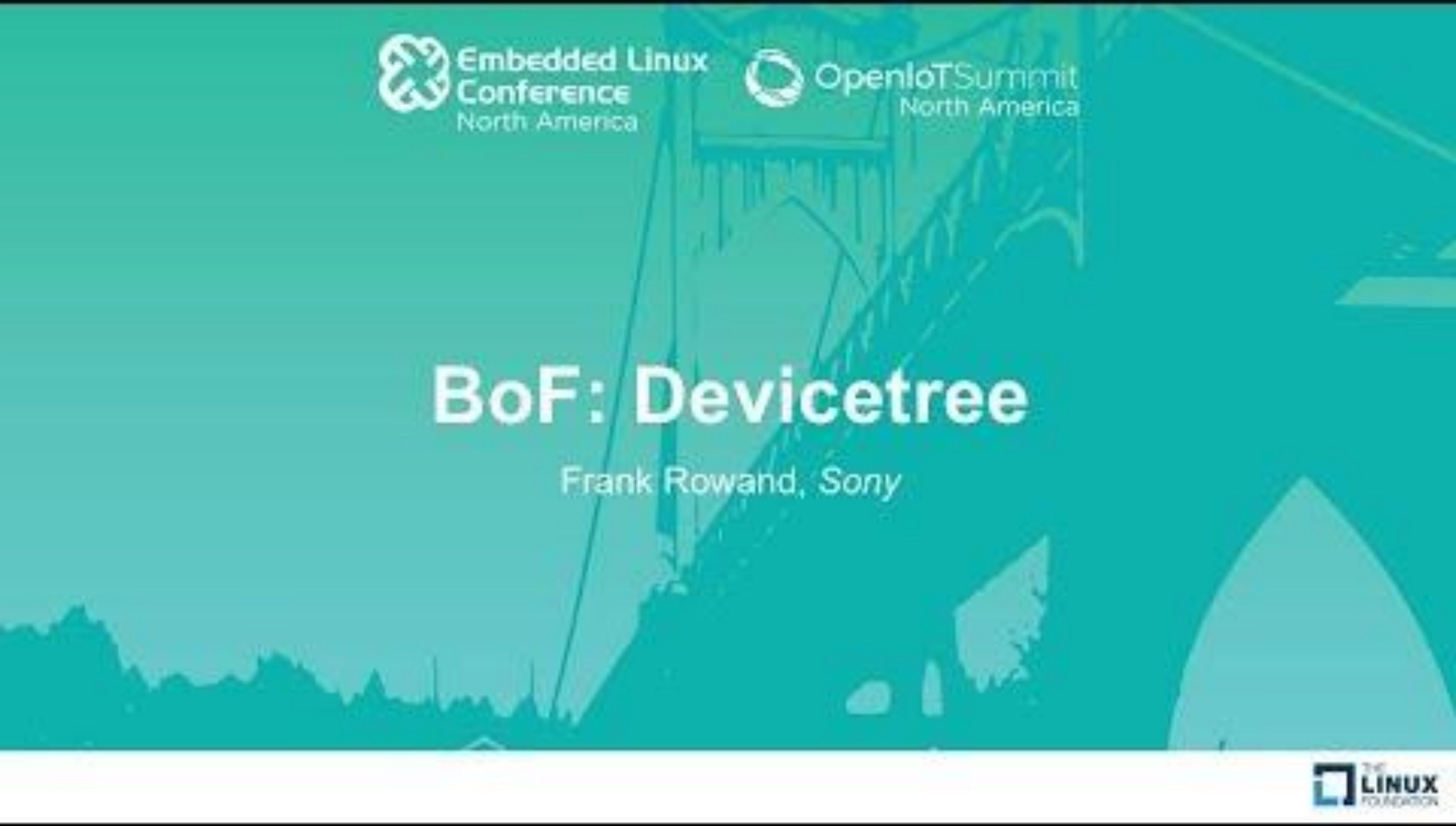


https://opentechlab.org.uk/videos:002:notes good device-tree introduction

LCA2018 Device Tree: Past, Present, and Future

https://www.youtube.com/watch?v=PgQezmlst0w

BoF: Devicetree - Frank Rowand, Sony



Embedded Linux Conference North America

OpenIoTSummit North America

BoF: Devicetree

Frank Rowand, *Sony*

THE LINUX FOUNDATION

https://youtu.be/HYdb5uimPtE what's comming up, overlays, new dtc warnings