ECE 471 – Embedded Systems
Lecture 23

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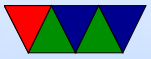
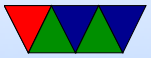
Announcements

- HW7 was due
- HW8 will be posted
- Project topics due next Friday

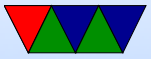


One-Wire Bus

- From Dallas Semiconductor (bought by Maxim in 2001)
- One data wire plus ground (how do you get power?)
  - Open collector, data line pulled high
  - Devices have capacitor to provide power when data line low "parasite power"
  - Low speed data and power over one wire (you also need ground)
- One controller
- Can have many devices

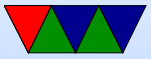


- 16.3kbit/s
- Up to 300m twisted pair (phone or Ethernet wire)



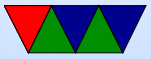
One-Wire Bus users

- Temp probes
- Apple magsafe connector
- eeproms
- Java rings?



One-Wire Protocol

- Each device has unique 64-bit ID; 8-bits of type, 48 bit ID, 8-bit CRC
- Typically 8-bit command followed by 8-bit data chunks



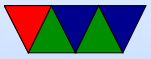
One-Wire Protocol – Detailed

1. Open Collector (BJT equivalent of MOSFET Open Drain)

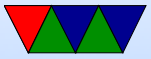
2. Write 1 – Controller pull bus low for 1-15us

3. Write 0 – Controller pull bus low for 60-120us

4. Read – Controller pull bus low for 15us (checks after another 15us). Device does nothing if it's a 1. If it's a 0 it pulls the bus low for another 45us.

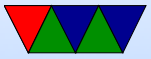


5. Reset/Presence – controller pulls bus low for 480us. If a device is present it pulls bus low for 60us starting within 60us after the reset pulse.



Enumerating BUS (ROM commands)

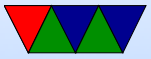
- How can you probe all 2^{64} possible addresses? `https://www.maximintegrated.com/en/app-notes/index.mvp/id/187`
- send a READ ROM request, returns 64-bit address. If multiple devices, then and of all of them. (How do you detect this? Invalid CRC).
- SKIP ROM request sends command to all devices
- MATCH ROM request sends 64-bit address and only matched device responds



- SEARCH ROM –
  - Read first address bit from all devices on bus. Devices send their bit, followed by complement.

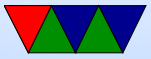
1	1	nothing there
0	1	all devices have 0 there
1	0	all devices have 1 there
0	0	conflict, you will have to probe both ways

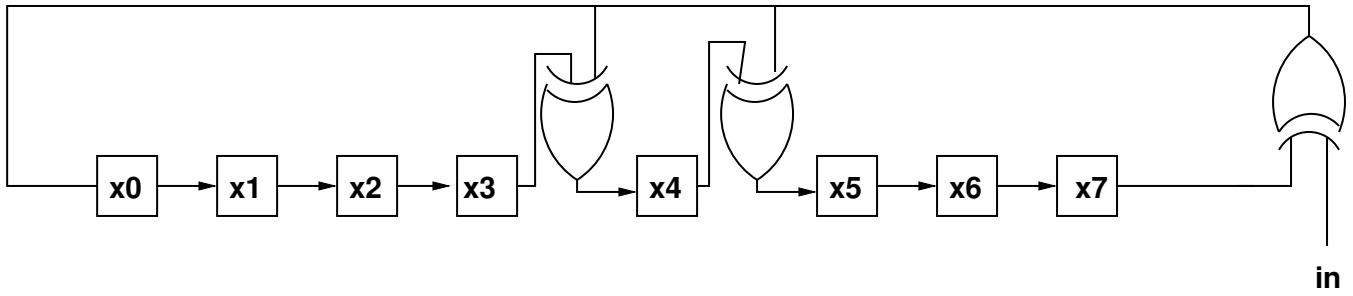
  - Then it does a binary search to enumerate all devices on bus.
  - Faster than probing all 2^{64} possible.

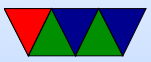


CRC check

- Can detect all double-bit errors, any overall odd number of errors, any cluster within an 8-bit window
- if CRCs with itself gets 0 at the end, how hardware detects correct address.
- $X^8 + X^5 + X^4 + X^1$
- Fill with zero, shift values in.



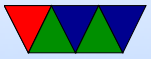

x0
x1
x2
x3
x4
x5
x6
x7
in



Hardware Interface

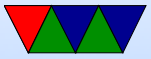
Possible ways to implement this:

- Use a GPIO and a pull-up resistor
- Use a serial UART. Needs extra circuitry to hook both TXD and RXD to bus
- USB/i2c/network connected
- Dedicated hardware?



Linux Interface

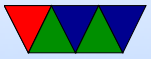
- "w1" driver merged in 3.6 kernel (fairly recently)
  - Driver for various interfaces, including bit-banging over GPIO (w1-gpio)
  - `/sys/bus/w1/devices/22-0000001d84f2/w1_slave`
  - read value and get ASCII dump of transaction
- OWFS – another driver, not in main kernel. Lets you export one-wire devices as a filesystem



One-Wire on Raspberry Pi

- The recommended way to enable things is to use `raspi-config`, interface options, 1-wire, enable on boot and reboot.

- Otherwise you can manually `sudo modprobe w1-gpio` and `sudo modprobe w1-therm` but on device tree systems (meaning, most recent Raspbian distributions) this might not be enough to make sure GPIO4 gets set up properly.

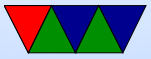


Temperature Interface w1_therm

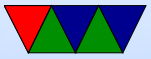
- `cd /sys/bus/w1/devices/`
- `ls`
- `cd 28-000005aaf7ed` The serial number will differ (each unique)
- `cat w1-slave`

```
82 01 4b 46 7f ff 0e 10 70 : crc=70 YES
82 01 4b 46 7f ff 0e 10 70 t=24125
```

- Valid if the last value in first line is YES (passes CRC)

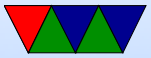


- second line has temperature in mili-degrees Celsius



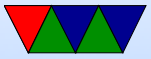
DS18B20

- -55 to 125C
- +/- 0.5C from -10 to 85C
- 9 to 12 bit resolution (configurable)
  Takes longer to convert more bits
- Converts temp in 93ms - 750ms
- Can set alarm (if go over a temp, a high bit set in result)



- small EEPROM can store alarm, config (number of bits) etc

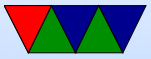
- Getting the result:
  - Controller resets
  - Controller listens for device to see it is present
  - Controller sends MATCH ROM (0x55) then sends the 64-bit ID of the device it wants to talk to
  - Controller sends a CONVERT T (0x44)
  - Controller holds line high during conversion so the device has enough power to do the calculations



- Controller sends reset
- Controller listens for response
- Controller sends MATCH ROM (0x55) then the 64-bit ID
- Controller sends READ SCRATCHPAD (0xbe)
- Controller reads 8 bytes from device and CRC. If CRC wrong, tries again.

- 9 bytes from device:

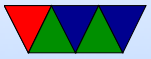
```
82 01 4b 46 7f ff 0e 10 70 :  crc=70 YES
```



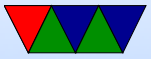
Byte 0/Byte1 = LSB/MSB Temperature = 0x0182
Byte 2 = TH register (high temp alarm, 8-bit)
Byte 3 = TL register (low temp alarm, 8-bit)
Byte 4 = config register 7f = 12 bit
Byte 5,6,7 reserved (5=0xff, 7=0x10)
Byte 8 = CRC

- Temperature is signed fixed point...

```
0x0182 = SSSS S654 3210 -1-2-3-4
         0000 0001 1000  0 0 1 0
```



$$2^4 + 2^3 + 2^{-3} = 16 + 8 + \frac{1}{8} = 24.125^oC = 75F$$

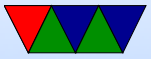


C string review

String manipulation is famously horrible in C. There are many ways to get the "YES" and "t=24125" values out of the text file. Any you choose is fine.

- If you trust the Linux kernel developers to keep a "stable ABI" then you can just read in the entire line into a string (array of chars) with `fgets()` and index into the string array to look for 'Y'

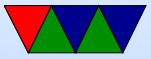
- Alternately you can use `fscanf()` to read the file. Again



you have to trust the format won't change and that the YES always happens the same number of values into the file. One helpful hint, putting a '*' in a conversion (like `%*s` tells scanf to read in the value but ignore it.

- Converting string to decimal or floating point
  `atoi()`, `atof()`, `strtod()`

- Comparing strings. Can you just use ==? NO!
  Be careful using `strcmp()` (or even better, `strncmp()`, has unusual return value
  less than, 0 or greater than depending. 0 means match



- If you had a string that was "V=YES" how could you start a string compare starting with the 2nd byte? Pointer math? Use `string+2` or even `&string[2]`.