ECE 471 – Embedded Systems Lecture 8

Vince Weaver

http://web.eece.maine.edu/~vweaver

vincent.weaver@maine.edu

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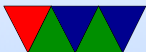
Announcements

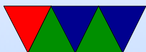
- HW#4 will be posted soon
- Will require an LED, a breadboard, and some jumper wires. I handed out some GPIO wires in class.



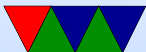
Coding Directly for the Hardware

One way of developing embedded systems is coding to the raw hardware, as you did with the STM Discovery Boards in ECE271.

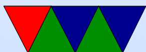
- Compile code
- Prepare for upload (hexbin?)
- Upload into FLASH
- Boots to offset



- Setup, flat memory (usually), stack at top, code near bottom, IRQ vectors
- Handle Interrupts
- Must do I/O directly (no drivers)
  Although if lucky, can find existing code.
- **Code is specific to the hardware you are on**

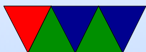


Instead, one can use an Operating System

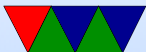


Why Use an Operating System?

- Provides Layers of Abstraction
  - Abstract hardware: hide hardware differences. same hardware interface for classes of hardware (things like video cameras, disks, keyboards, etc) despite differing implementation details
  - Abstract software: with VM get linear address space, same system calls on all systems
  - Abstraction comes at a cost. Higher overhead, unknown timing

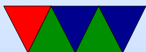


- Multi-tasking / Multi-user
- Security, permissions (Linus dial out onto /dev/hda)
- Common code in kernel and libraries, no need to re-invent



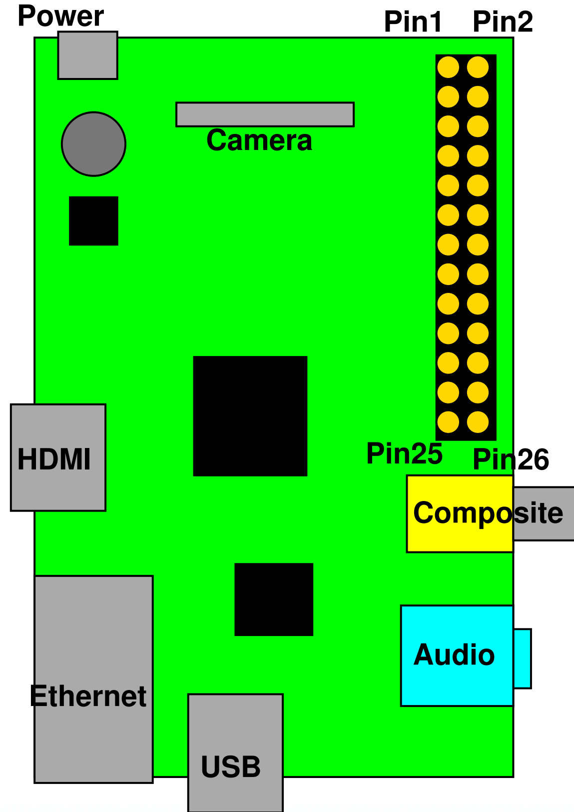
What's included with an OS

- kernel / drivers – Linux definition
- also system libraries – Solaris definition
- low-level utils / software / GUI – Windows definition
  Web Browser included?
- Linux usually makes distinction between the OS Kernel and distribution. OSX/Windows usually doesn't.

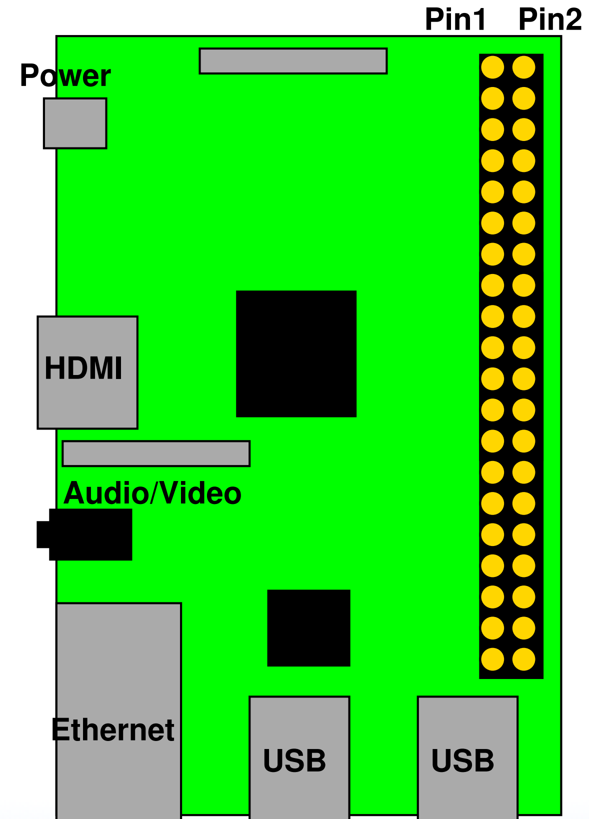


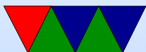
Brief Overview of the Raspberry Pi Board

Model B



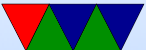
Model B+





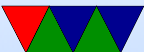
Rasp-pi Header

- Model B has 17 GPIOs (out of 26 pins), B+ has 9 more (out of 40)
- 3.3V signaling logic. Need level shifter if want 5V or 1.8V
- Linux by default configures some for other purposes (serial, i2c, SPI)



Rasp-pi Header

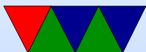
3.3V	1	2	5V
GPIO2 (SDA)	3	4	5V
GPIO3 (SCL)	5	6	GND
GPIO4 (1-wire)	7	8	GPIO14 (UART_TXD)
GND	9	10	GPIO15 (UART_RXD)
GPIO17	11	12	GPIO18 (PCM_CLK)
GPIO27	13	14	GND
GPIO22	15	16	GPIO23
3.3V	17	18	GPIO24
GPIO10 (MOSI)	19	20	GND
GPIO9 (MISO)	21	22	GPIO25
GPIO11 (SCLK)	23	24	GPIO8 (CE0)
GND	25	26	GPIO7 (CE1)
ID_SD (EEPROM)	27	28	ID_SC (EEPROM)
GPIO5	29	30	GND
GPIO6	31	32	GPIO12
GPIO13	33	34	GND
GPIO19	35	36	GPIO16
GPIO26	37	38	GPIO20
GND	39	40	GPIO21



How you enable GPIO on STM32L

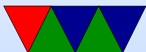
A lot of read/modify/write instructions to read current register values and then to shift/mask to write out updated bitfields.

- Enable GPIO Clock
- Set output mode for GPIO.
- Set GPIO type.
- Set pin clock speed.
- Set pin pull-up/pull-down
- Set or clear GPIO pin.

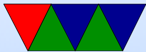


“Bare Metal” on BCM2835 (Rasp-pi)

- Documented in BCM2835 ARM Peripherals Manual
- 53 GPIOs (not all available on board)
- Can use Wiring-Pi or libbcm2835 if you need speed
- Similar to how done on STM32L... but we have an operating system

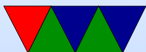


Letting the OS handle it for you

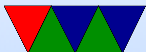


Linux GPIO interface

- `Documentation/gpio/sysfs.txt`
- sysfs and string based



A few low-level Linux Coding Instructions



Enable a GPIO for use

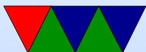
To enable GPIO 17:

write "17" to `/sys/class/gpio/export`

To disable GPIO 17:

write "17" to `/sys/class/gpio/unexport`

```
char buffer[10];
fd=open("/sys/class/gpio/export",O_WRONLY);
if (fd<0) fprintf(stderr,"\tError enabling\n");
strcpy(buffer,"17");
write(fd,buffer,2);
close(fd);
```



Set GPIO Direction

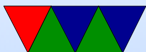
To make GPIO 17 an input:

write "in" to `/sys/class/gpio/gpio17/direction`

To make GPIO 17 an output:

write "out" to `/sys/class/gpio/gpio17/direction`

```
fd=open("/sys/class/gpio/gpio17/direction",O_WRONLY);
if (fd<0) fprintf(stderr,"Error!\n");
write(fd,"in",2);
close(fd);
```

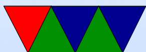


Write GPIO Value

To write value of GPIO 17:

write /sys/class/gpio/gpio17/value

```
fd=open("/sys/class/gpio/gpio17/value",O_WRONLY);
if (fd<0) fprintf(stderr,"Error opening!\n");
write(fd,"1",1);
close(fd);
```



Read GPIO Value

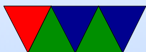
To read value of GPIO 17:

read `/sys/class/gpio/gpio17/value`

```
char buffer[16];
fd=open("/sys/class/gpio/gpio17/value",O_RDONLY);
if (fd<0) fprintf(stderr,"Error opening!\n");
read(fd,buffer,16);
printf("Read %c from GPIO17\n",buffer[0]);
close(fd);
```

Note: the value you read is ASCII, not an integer.

Also Note, if reading and you do not close after read you will have to rewind using `lseek(fd,0,SEEK_SET);` after your read.

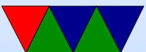


Delay

- Busy delay (like in 271).
  `for(i=0;i<1000000;i++);`
  Harder to do in C. Why?
  Compiler optimizes away.

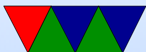
- `usleep()` puts process to sleep for a number of microseconds. But can have issues if want exact delay. Why? OS potentially context switches every 100ms.

- Other ways to implement: Set up PWM? Timers?



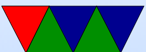
Using fopen instead?

- Need to `fflush()` after writes (linefeed not enough?)
- Need to `frewind()` after reads?



Waiting for Input

- Busy loop. Bad, burns CPU / power
- usleep() in loop. Can delay response time.
- Interrupt when ready! poll()



GPIO Interrupts on Linux

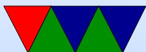
May need a recent version of Raspbian.

First write "rising", "falling", or "both" to `/sys/class/gpio/gpio17/edge`.

Then open and poll `/sys/class/gpio/gpio17/value`.

```
struct pollfd fds;
int result;

fd=open("/sys/class/gpio/gpio18/value",O_RDONLY);
fds.fd=fd;
fds.events=POLLPRI|POLLERR;
while(1) {
    result=poll(&fds,1, -1);
    if (result<0) printf("Error!\n");
    lseek(fd,0,SEEK_SET);
read(fd,buffer,1); }
```



Debouncing!

- Pull-up / Pull-down resistor. Why?
- Noisy switches, have to debounce
- Manual, no built-in debounce like on STM32L