Embedded Systems

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Input & Output

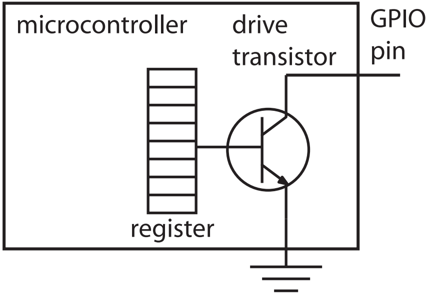
Things to consider

- **Mechanical and electrical properties of the interfaces are important**
- **Drawing too much current may result in malfunction**
- **In physical world most of the things run in parallel, software is sequential**
- **Incorrect interaction between sequential code and concurrent event in physical world may lead to catastrophe**

Interfaces

- Pulse width modulation (PWM)
  - Used to deliver variable power
    - Speed of motor, brightness of LED
  - Duty cycle is one of the key parameters
  - Typically operates using memory-mapped register
- General purpose digital I/O (GPIO)
  - A number of general purpose I/O pins are available in most microcontrollers
  - Voltage level in the pins are read/written to represent logic 0 or 1
  - Active high vs active low logic
  - External physical devices can be connected
    - Need to check current level
    - May require power amplifier
  - Electrical isolation
  - Schmitt triggered, Tristate

Connection



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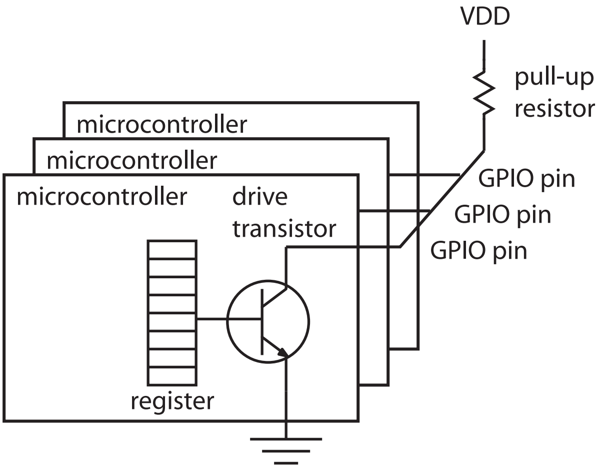
Connection



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Serial interface

- Embedded processor requires physical small package and low power consumption
  - Number of pins need to be reduced
- Send information serially as sequence of bits
- RS232 - one of the popular standard
  - Sender and receiver first agree on transmission rate
  - Sender initiates transmission of byte with a start bit that alerts receiver
  - Sender sends the data with agreed upon rate
  - There will be one or two stop bits
  - Receiver reset upon receiving start bit and samples the data using agreed upon rate
- USB-3.0 — 4.8 GBits/sec
- I^2C, SPI, PCI express

Parallel interface

- It uses multiple lines to simultaneously send data
  - Each line is a serial interface
- Printer port (IEEE-1284)
- GPIO pins can be used to realize parallel interface
- Challenges are to maintain synchrony

Buses

- Interface shared among multiple devices
  - USB - serial bus
  - SCSI - parallel bus
- ISA bus, PCI
- Architecture must include media access control (MAC)
  - MAC has single master that connect with slaves
  - Time triggered bus, token ring

Interrupt and exception

- Interrupt - pausing of execution of whatever processor is currently doing and start executing predefined code sequence
  - Interrupt service routine (ISR)
  - Can be triggered by software or external hardware
- Exception is triggered by internal hardware that detects a fault
- For hardware or software interrupt program resumes its normal execution after completion of ISR
- Exception has the highest priority

Example

```
volatile uint timerCount=0;
void countDown(void){
   if (timerCount != 0){
     timerCount- -;
   }
}
```

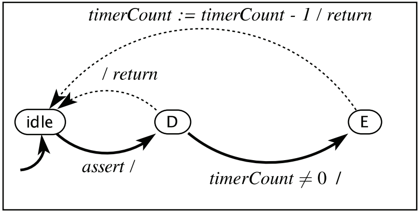
```
SysTickPeriodSet(SysCtlClockGet()/1000);
SysTickIntReg(&countDown);
SysTickEnable();
SysTickIntEnable();
```

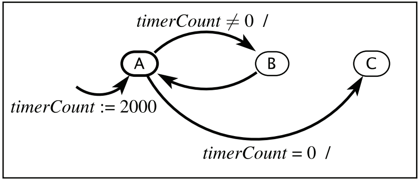
```
int main(){
  timerCount = 2000;
  ...
  while(timerCount != 0){
    ...  code run for 2 sec...
  }
}
```

Interrupt modeling

```
     volatile uint timerCount = 0;
     void ISR(void) {
         … disable interrupts
D→       if(timerCount != 0) {
E→           timerCount--;
         }
         … enable interrupts
     }
     int main(void) {
         // initialization code
         SysTickIntRegister(&ISR);
         … // other init
         timerCount = 2000;
A→       while(timerCount != 0) {
B→          … code to run for 2 seconds
         }
     }
C→   … whatever comes next
```

variables: *timerCount*: `uint`
input: *assert*: pure
output: *return*: pure





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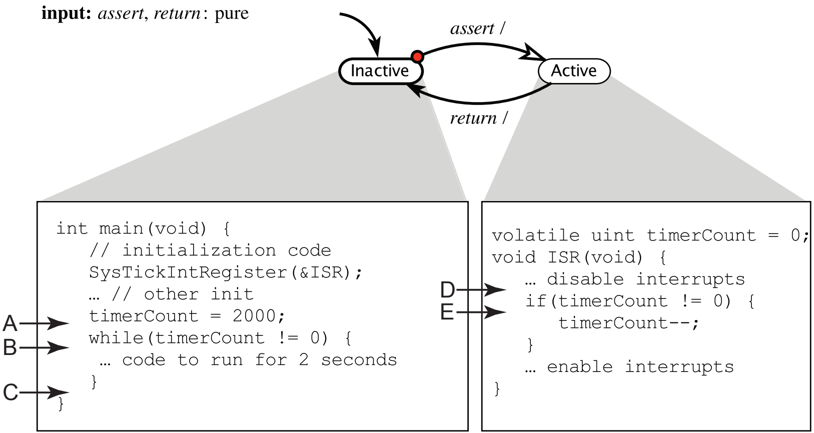
Interrupt modeling



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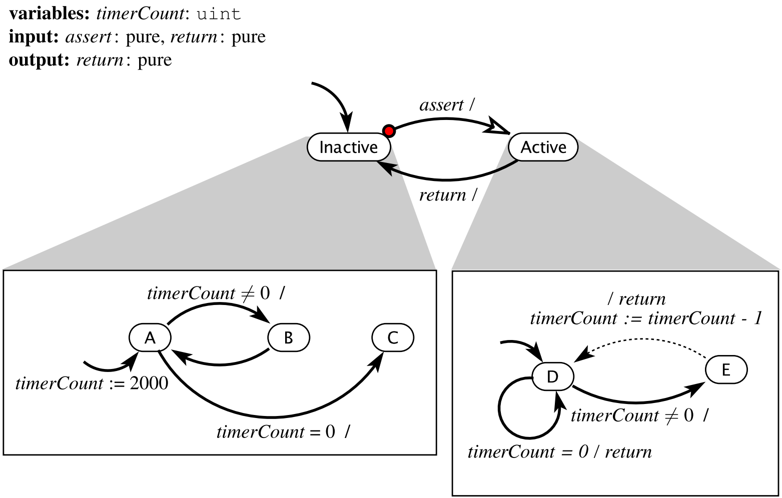
Interrupt modeling



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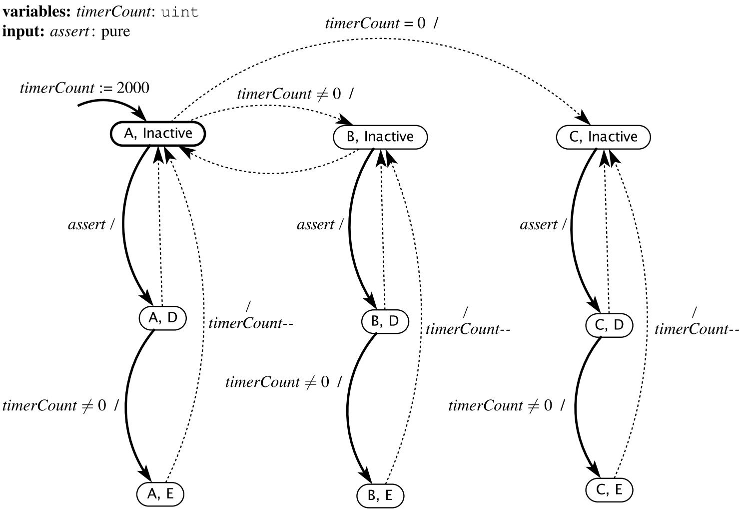
Interrupt modeling



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