I/O Devices & Debugging

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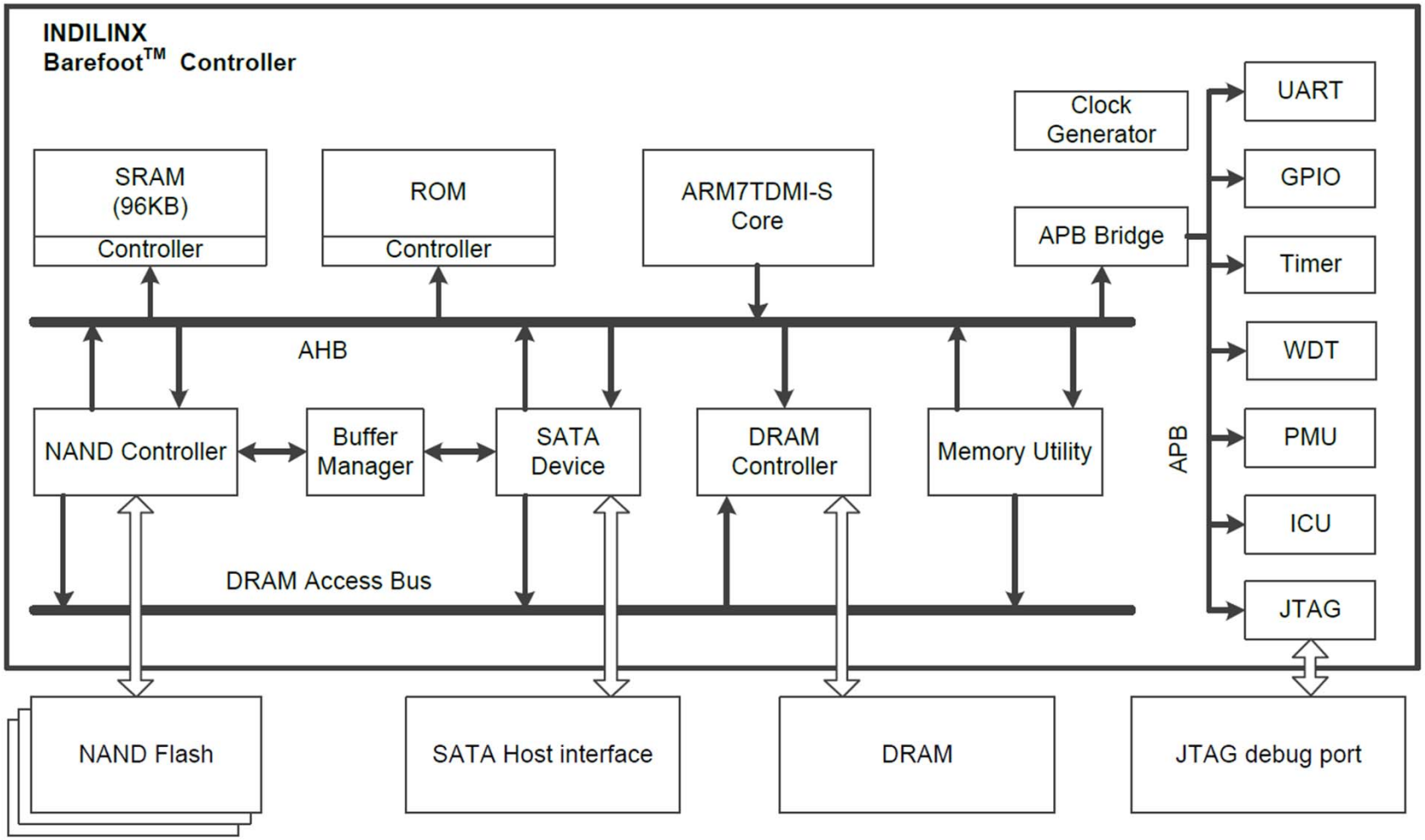
I/O Devices

Jasmine Block Diagram



Timers and Counters

- A timer is incremented by a periodic signal
- A counter is incremented by an asynchronous, occasional signal

- Rollover causes interrupt

Jasmine Timers (1)

- Timer base address at 0x82000000
- Four 32-bit countdown timers
- The clock speed of timer is CLOCK_SPEED/2 (87.5MHz by default)
- Timer 4 reserved for SATA retry timer
- In periodic mode, the timer generates an interrupt when the counter reaches zero, and then reloads the initial value.

Jasmine Timers (2)

- Timer registers

Name	Address	Usage
TM_1_LOAD	TIMER_BASE + 0x00	Initial value of the timer. Reloaded in periodic mode.
TM_1_VALUE	TIMER_BASE + 0x04	The current value of the timer
TM_1_CONTROL	TIMER_BASE + 0x08	Enable/disable the timer, Set clock prescaling and free-running mode vs. periodic mode
TM_1_INT_CLR	TIMER_BASE + 0x0c	Clear an interrupt generated by the timer

Jasmine Timers (3)

- Predefined resolution:

Name	Input clock divided by	Resolution	Ticks/sec	Time to rollover
TIMER_PRESCALE_0	1	11.43 ns	87,489,064	49 s
TIMER_PRESCALE_1	16	182 ns	5,494,506	781 s
TIMER_PRESCLAE_2	256	2.9 us	344,828	12,455 s

- Starting and reading a timer:

```
start_interval_measurement (TIMER_CH1, TIMER_PRESCALE_0);
…
UINT32 current = GET_TIMER_VALUE (TIMER_CH1);
```

Jasmine Timers (4)

- Programming a timer

```
start_interval_measurement (TIMER_CH1, TIMER_PRESCALE_0);
```

```
#define SETREG(ADDR, VAL)        \
                        *(volatile UINT32*)(ADDR) = (UINT32) (VAL)
#define GETREG(ADDR)             (*(volatile UINT32*)(ADDR))


...
SETREG (TM_1_CONTROL, 0);
SETREG (TM_1_INT_CLR, 0x01);
SETREG (TM_1_LOAD, 0xffffffff);
SETREG (TM_1_CONTROL, TM_ENABLE | TM_BIT_32
                        | TM_MODE_PRD | TIMER_PRESCALE_0);
```

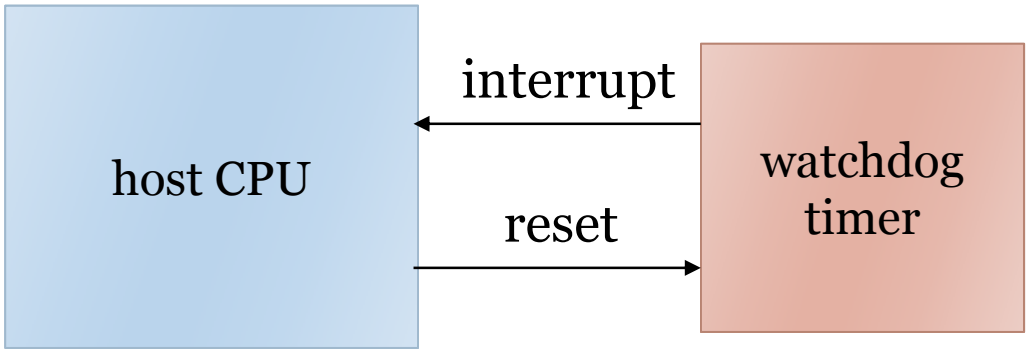
Jasmine Timers (5)

- Measuring the elapsed time

```
void ptimer_start (void) {
   start_interval_measurement (TIMER_CH1, TIMER_PRESCALE_0);
}

UINT32 ptimer_stop (void) {
    return (0xffffffff – GET_TIMER_VALUE (TIMER_CH1));
}

void f (void) {
   UINT32 ticks;
   …
   ptimer_start ();
   do_something ();
   ticks = ptimer_stop ();                  // OK if within 49 sec
}
```

Watchdog Timer

- Watchdog timer is periodically reset by system timer
- If watchdog is not reset, it generates an interrupt to reset the host

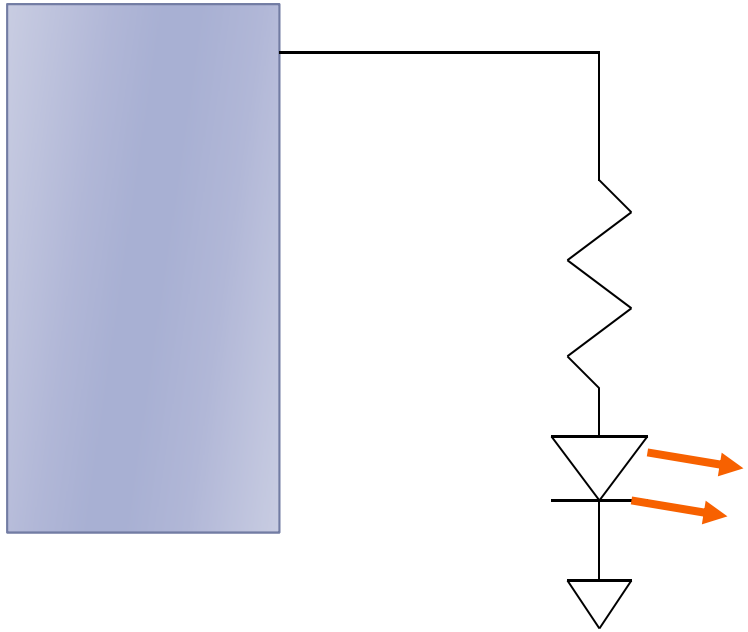


Jasmine Watchdog Timer

- Watchdog timer at 0x84000000
- 32-bit down counter with a programmable timeout interval
- Interrupt output generation on timeout
- Reset signal generation on timeout if the interrupt from the previous timeout remains unserviced by software
- Currently not used by Jasmine firmware

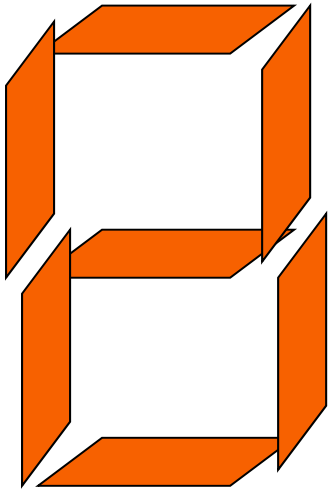
LED

- Must use resistor to limit current



7-Segment LCD Display

- May use parallel or multiplexed input



GPIO

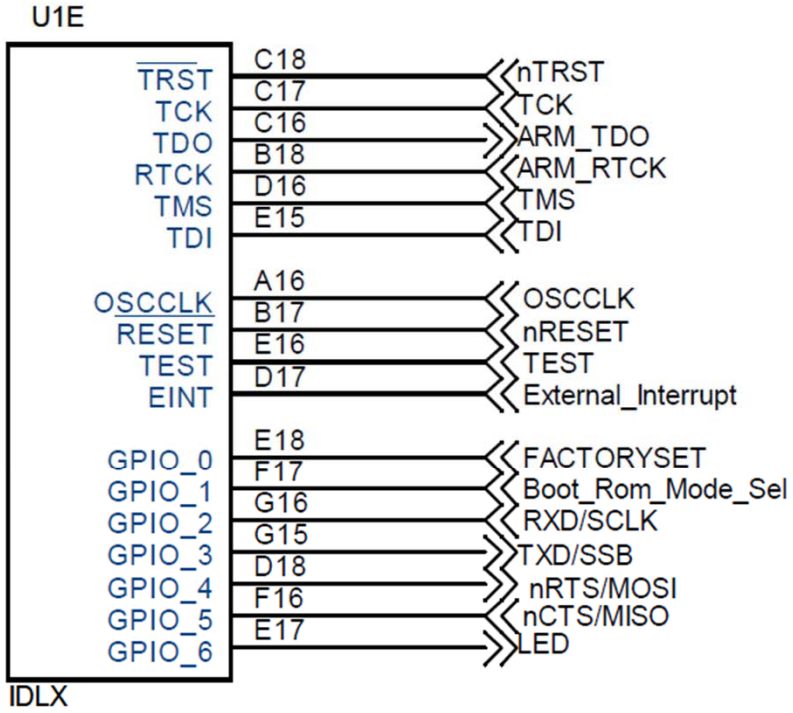
- General Purpose Input/Output (GPIO)
- A generic pin on a chip whose behavior can be controlled through software
- Each pin can be configured to be input or putout
- Save the hassle of having to arrange additional circuitry to provide additional control lines

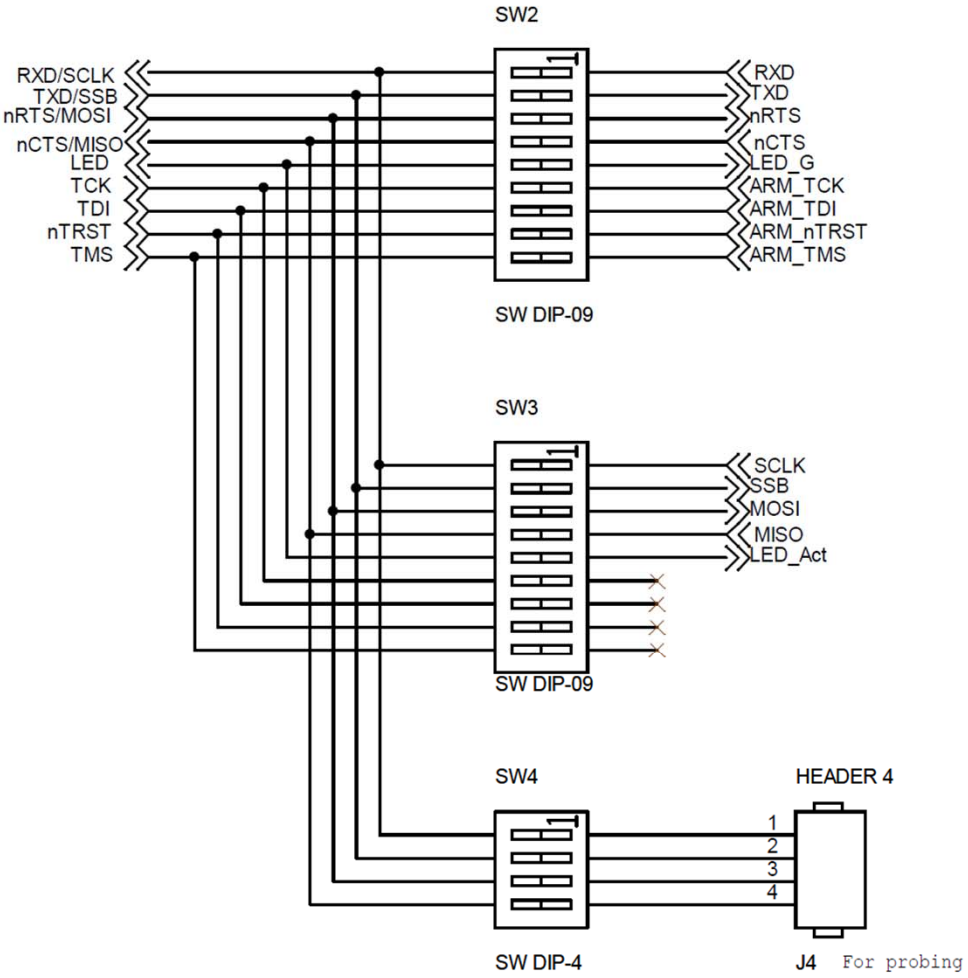
Jasmine GPIOs (1)

- GPIO base address at 0x83000000
- 7 GPIO pins (GPIO_0 ~ GPIO_6)
- 4 GPIO pins (GPIO_2 ~ GPIO_5) can be used to probe signals by a logic analyzer for debugging purpose
- GPIO_2 ~ GPIO_5 are also used for UART
- GPIO_0 used for factory mode jumper (J2)
- GPIO_6 is connected to LED (D4)

Jasmine GPIOs (2)

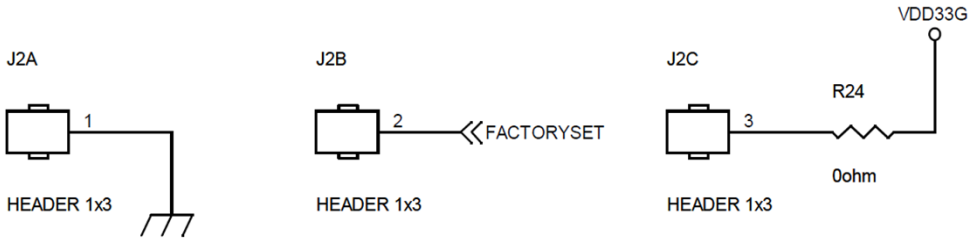
Controller GPIO Section





Jasmine GPIOs (3)

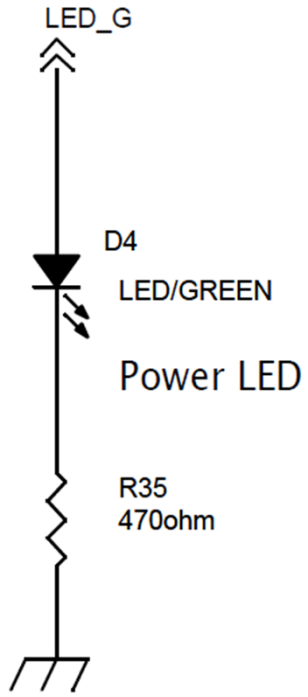
Factory Mode Jumper (J2)



Setting for UART

SW2 pin 1, 2, 3, 4	ON
SW3 pin 1, 2, 3, 4	OFF
SW4 pin 1, 2, 3, 4	OFF

LED Indicator (D4)



Jasmine GPIOs (4)

- Initializing GPIOs

```
// <init_jasmine() @ target_spw/initialize.c>
#if OPTION_UART_DEBUG
SETREG (GPIO_DIR, BIT3 | BIT4 | BIT 6);
#else
SETREG (GPIO_DIR, BIT6);
#endif
```

- Reading and writing GPIOs

```
UINT32   temp = GETREG (GPIO_REG);
SETREG (GPIO_REG, 0x3);       // Set Pins 0 and 1 to HIGH
```

Jasmine GPIOs (5)

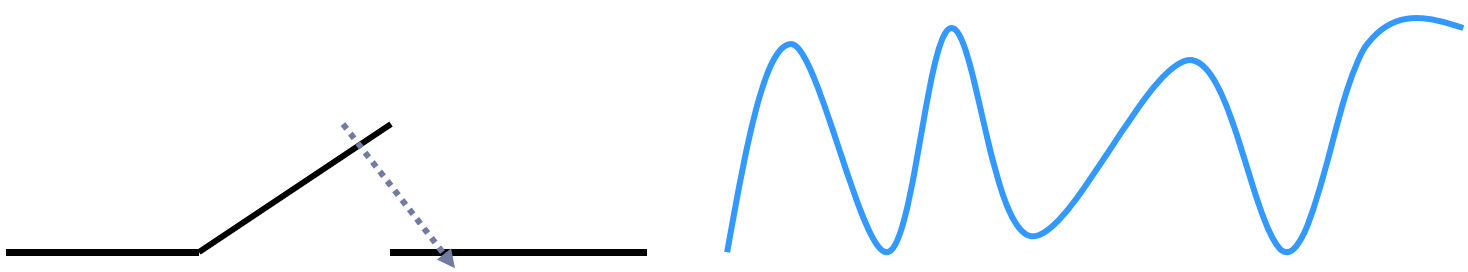
- Controlling LED (D4) < target_spw/misc.c>

```
void led (BOOL32 on)
{
    UINT32 temp;

    temp = GETREG (GPIO_REG);

    if (on)
        temp |= (1 << 6);
    else
        temp &= ~(1 << 6);

    SETREG (GPIO_REG, temp);
}
```

```
// NOTE: Infinite loop!!!

void led_blink (void)
{
    while (1)
    {
        led (1);
        delay (700000);
        led (0);
        delay (700000);
    }
}
```

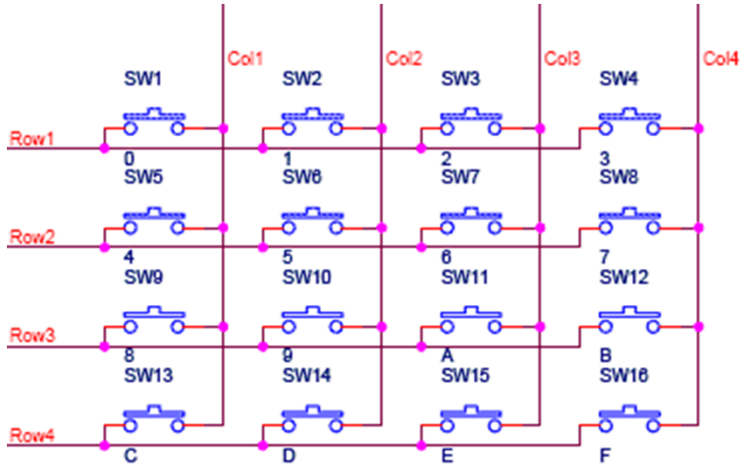
Keyboard

- A switch must be debounced to eliminate multiple contacts caused by mechanical bouncing:



Encoded Keyboard

- An array of switches is read by an encoder
- Contain a microprocessor to preprocess button inputs
- Reads only one row of switches at a time
- N-key rollover remembers multiple key depressions

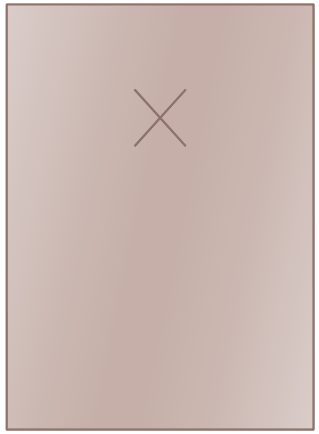


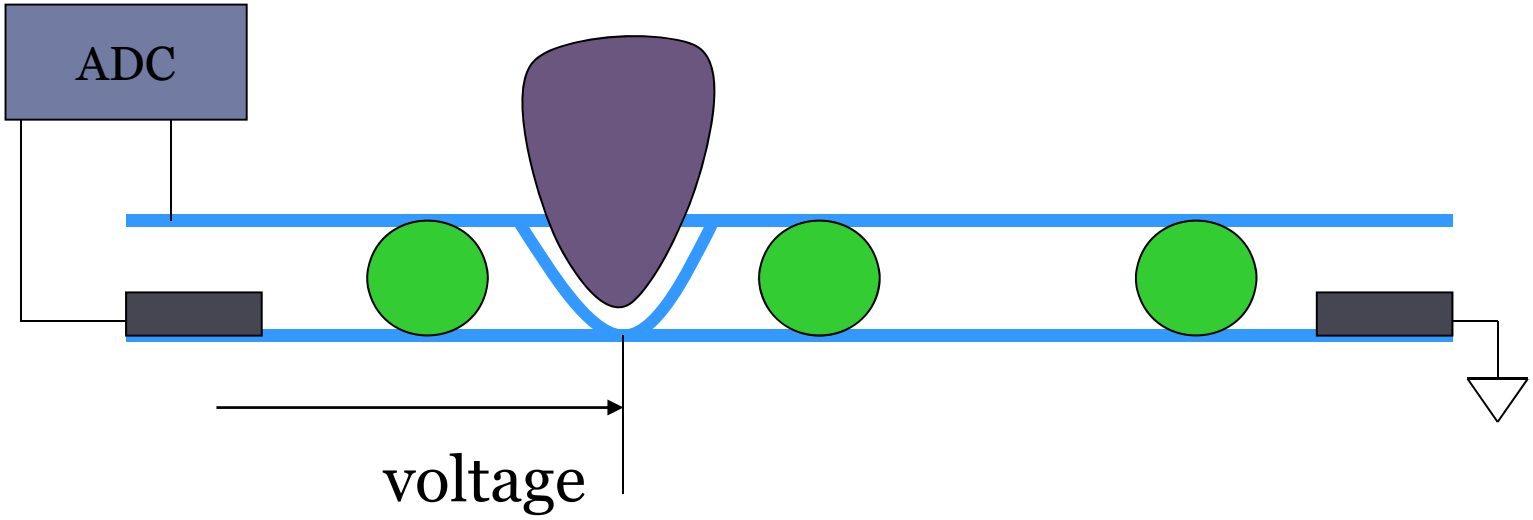
High-Resolution Display

- Liquid crystal display (LCD) is dominant form
- Plasma, OLED, etc.
- Frame buffer holds current display contents
  - Written by processor
  - Read by video

Touchscreen

- Includes input and output device
- Input device is a two-dimensional voltmeter (resistive touchscreen)





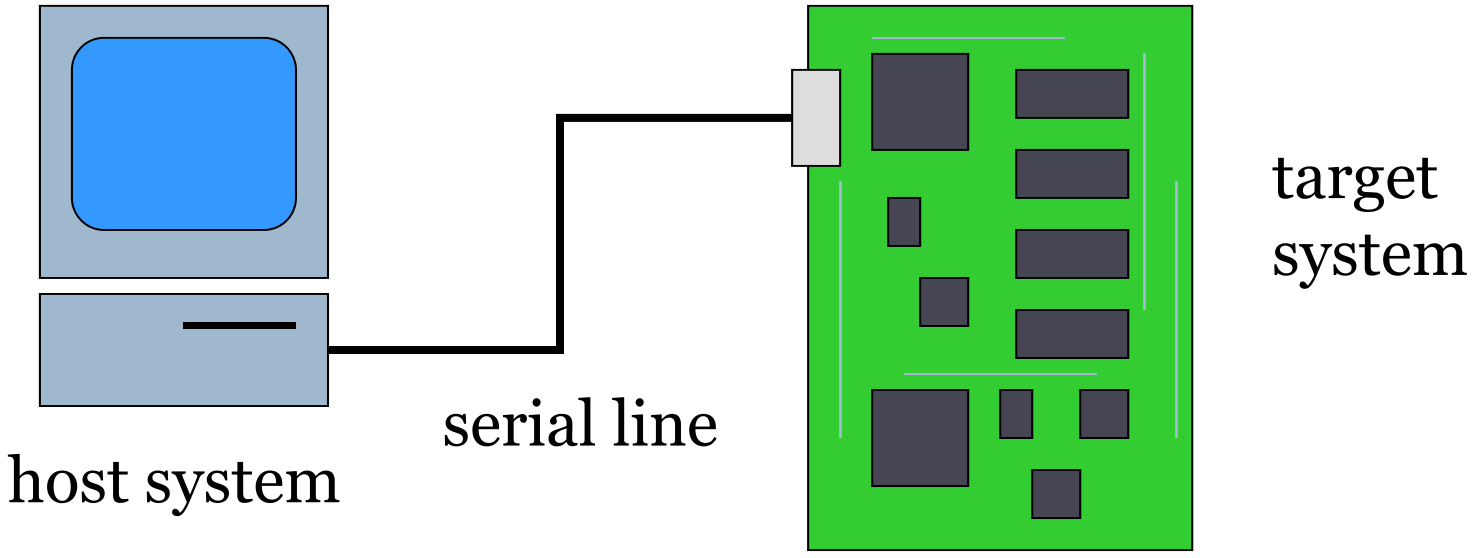
Development & Debugging

Debugging Challenges

- Target system may be hard to observe
- Target may be hard to control
- May be hard to generate realistic inputs
- Setup sequence may be complex

Host/Target Design

- Use a host system to prepare software for target system:



Host-based Tools

- Cross compiler
  - Compiles code on host for target system
- Cross debugger (or remote debugger)
  - Displays target state, allows target system to be controlled

Software Debuggers

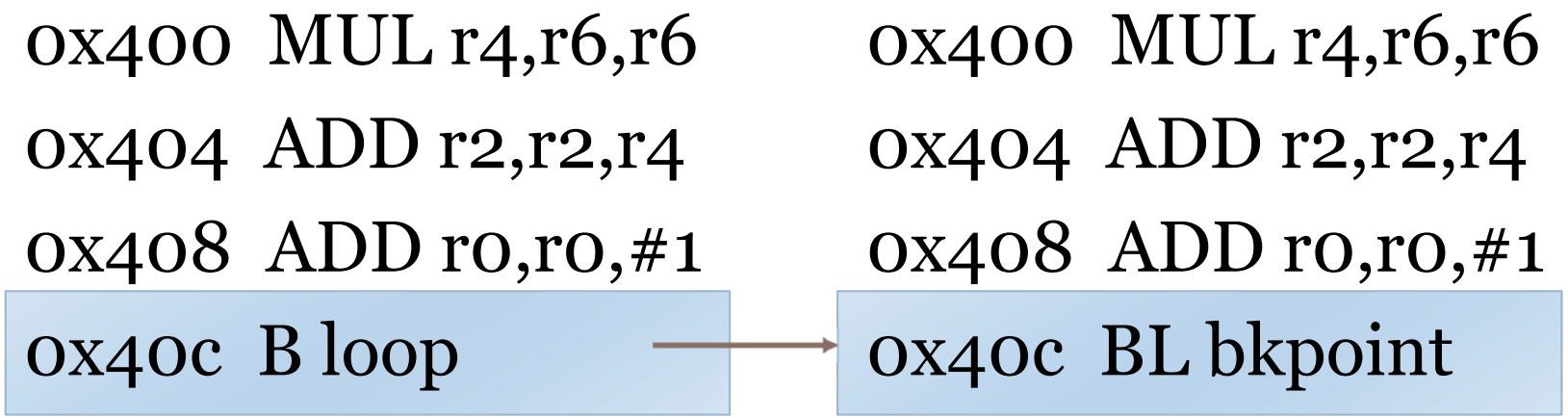
- A monitor program residing on the target provides basic debugger functions
- Debugger should have a minimal footprint in memory
- User program must be careful not to destroy debugger program
- The debugger should be able to recover from some damage caused by user code

Breakpoints

- A breakpoint allows the user to stop execution, examine system state, and change state.

- Replace the breakpointed instruction with a subroutine call to the monitor program

ARM Breakpoints



uninstrumented code

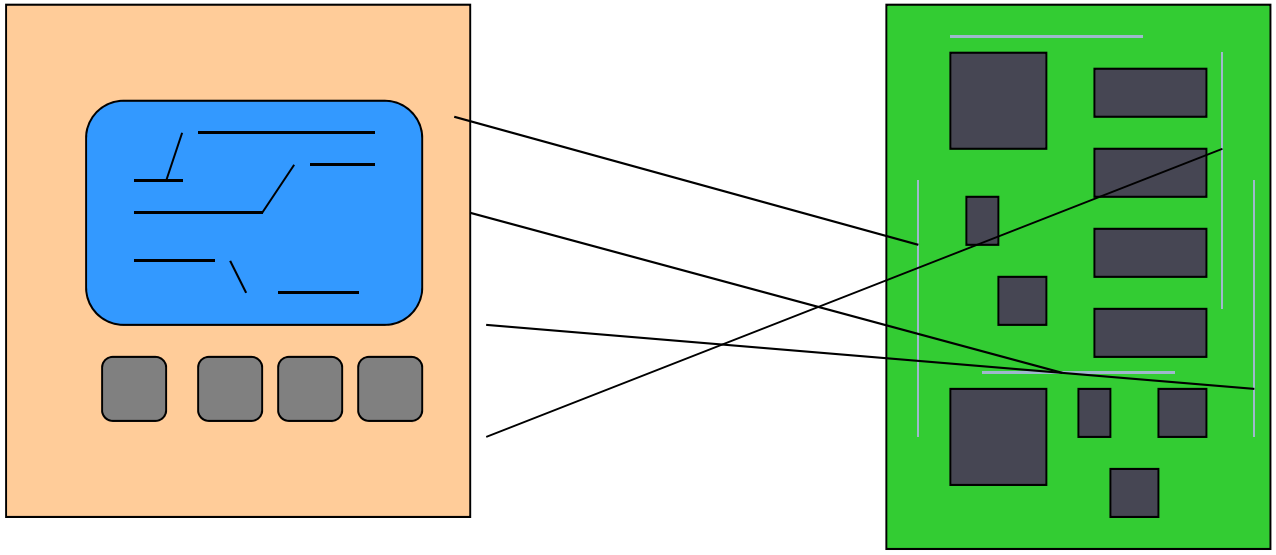
code with breakpoint

Breakpoint Handler

- Save registers
- Allow user to examine machine
- Before returning, restore system state
  - Safest way to execute the instruction is to replace it and execute in place
  - Put another breakpoint after the replaced breakpoint to allow restoring the original breakpoint

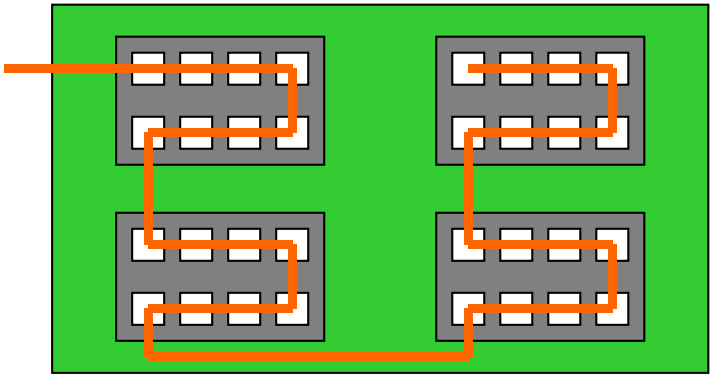
Logic Analyzers

- A logic analyzer is an array of low-grade oscilloscopes



Boundary Scan

- Simplifies testing of multiple chips on a board
  - Registers on pins can be configured as a scan chain
  - Used for debuggers, in-circuit emulators



In-Circuit Emulators

- A microprocessor in-circuit emulator is a specially-instrumented microprocessor
- JTAG-based hardware debuggers use on-chip debugging hardware with standard production chips
- Allows you to stop execution, examine CPU state, modify registers

How to Exercise Code

- Run on host system
- Run on target system
- Run in instruction-level simulator
- Run on cycle-accurate simulator
- Run in hardware/software co-simulation environment

Debugging Real-Time Code

- Bugs in drivers can cause non-deterministic behavior in the foreground problem
- Bugs may be timing-dependent