ECE 5725
Embedded Operating Systems
Lecture 10

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News

Lab 1 Report,

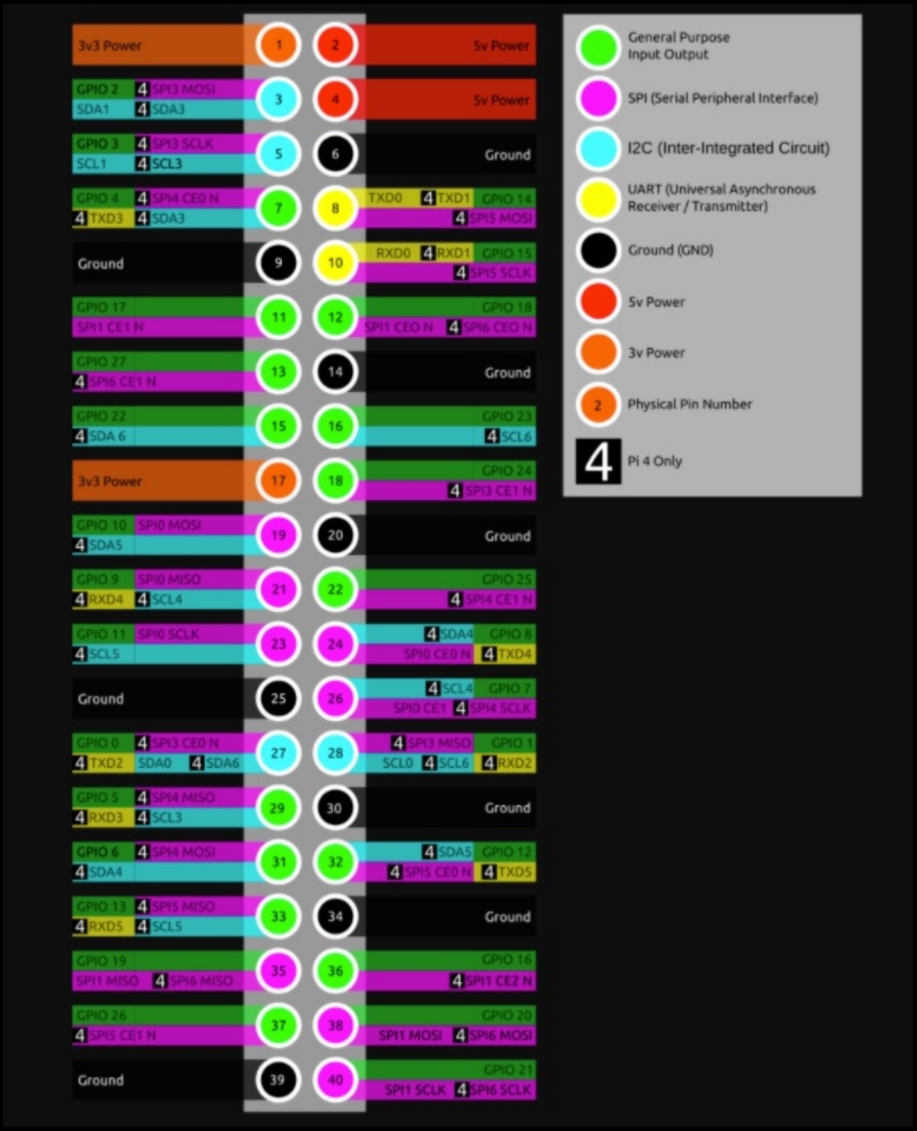
Homework 2

Lab2 Week1 :

- External Inputs
- Interrupt Call-backs
- Perf ormance Monitoring
- PyGame

GPIO

GPIO#	2nd func	pin#		pin#	2nd func	GPIO#
N/A	+3V3	1		2	+5V	N/A
GPIO2	SDA1 (I2C)	3		4	+5V	N/A
GPIO3	SCL1 (I2C)	5		6	GND	N/A
GPIO4	GCLK	7		8	TXD0 (UART)	GPIO14
N/A	GND	9		10	RXD0 (UART)	GPIO15
GPIO17	GEN0	11		12	GEN1	GPIO18
GPIO27	GEN2	13		14	GND	N/A
GPIO22	GEN3	15		16	GEN4	GPIO23
N/A	+3V3	17		18	GEN5	GPIO24
GPIO10	MOSI (SPI)	19		20	GND	N/A
GPIO9	MISO (SPI)	21		22	GEN6	GPIO25
GPIO11	SCLK (SPI)	23		24	CE0_N (SPI)	GPIO8
N/A	GND	25		26	CE1_N (SPI)	GPIO7
(Models A and B stop here)						
EEPROM	ID_SD	27		28	ID_SC	EEPROM
GPIO5	N/A	29		30	GND	N/A
GPIO6	N/A	31		32	-	GPIO12
GPIO13	N/A	33		34	GND	N/A
GPIO19	N/A	35		36	N/A	GPIO16
GPIO26	N/A	37		38	Digital IN	GPIO20
N/A	GND	39		40	Digital OUT	GPIO21


3v3 Power | 1 | 2 | 5v Power
GPIO 2, 4 SPI3 MOSI, SDA1, 4 SDA3 | 3 | 4 | 5v Power
GPIO 3, 4 SPI3 SCLK, SCL1, 4 SCL3 | 5 | 6 | Ground
GPIO 4, 4 SPI4 CE0 N, 4 TXD3, 4 SDA3 | 7 | 8 | TXD0, 4 TXD1, GPIO 14, 4 SPI5 MOSI
Ground | 9 | 10 | RXD0, 4 RXD1, GPIO 15, 4 SPI5 SCLK
GPIO 17, SPI1 CE1 N | 11 | 12 | GPIO 18, SPI1 CE0 N, 4 SPI6 CE0 N
GPIO 27, 4 SPI6 CE1 N | 13 | 14 | Ground
GPIO 22, 4 SDA 6 | 15 | 16 | GPIO 23, 4 SCL6
3v3 Power | 17 | 18 | GPIO 24, 4 SPI3 CE1 N
GPIO 10, SPI0 MOSI, 4 SDA5 | 19 | 20 | Ground
GPIO 9, SPI0 MISO, 4 RXD4, 4 SCL4 | 21 | 22 | GPIO 25, 4 SPI4 CE1 N
GPIO 11, SPI0 SCLK, 4 SCL5 | 23 | 24 | 4 SDA4, GPIO 8, SPI0 CE0 N, 4 TXD4
Ground | 25 | 26 | 4 SCL4, GPIO 7, SPI0 CE1, 4 SPI4 SCLK
GPIO 0, 4 SPI3 CE0 N, 4 TXD2, SDA0, 4 SDA6 | 27 | 28 | 4 SPI3 MISO, GPIO 1, SCL0, 4 SCL6, 4 RXD2
GPIO 5, 4 SPI4 MISO, 4 RXD3, 4 SCL3 | 29 | 30 | Ground
GPIO 6, 4 SPI4 MOSI, 4 SDA4 | 31 | 32 | 4 SDA5, GPIO 12, 4 SPI5 CE0 N, 4 TXD5
GPIO 13, 4 SPI5 MISO, 4 RXD5, 4 SCL5 | 33 | 34 | Ground
GPIO 19, SPI1 MISO, 4 SPI6 MISO | 35 | 36 | GPIO 16, 4 SPI1 CE2 N
GPIO 26, 4 SPI5 CE1 N | 37 | 38 | GPIO 20, SPI1 MOSI, 4 SPI6 MOSI
Ground | 39 | 40 | GPIO 21, SPI1 SCLK, 4 SPI6 SCLK
General Purpose Input Output
SPI (Serial Peripheral Interface)
I2C (Inter-Integrated Circuit)
UART (Universal Asynchronous Receiver / Transmitter)
Ground (GND)
5v Power
3v Power
2 Physical Pin Number
4 Pi 4 Only

GPIO pin

Input or Output

Internal Pull-up or Pull-down

Alternate functions

3.3 Volts

GPIO pin Limits

3.3 Volts max on any pin

16 milliamp max from any output

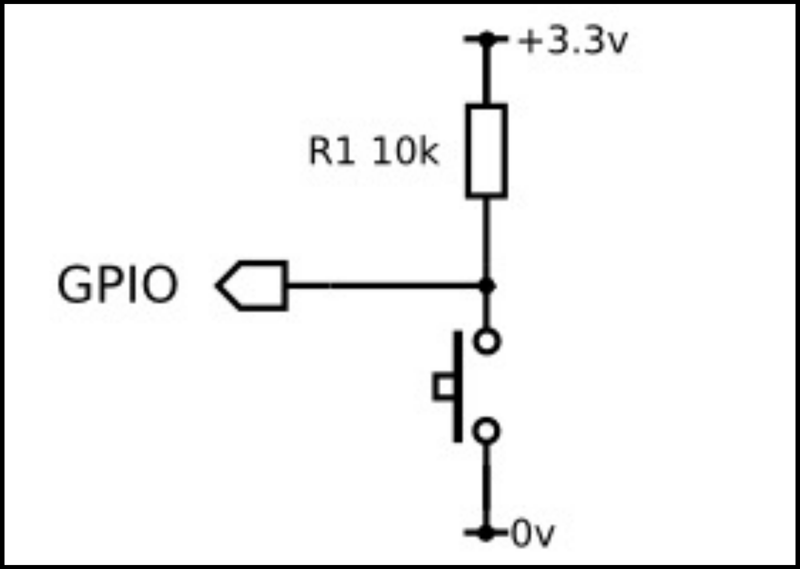
50 milliamp max from ALL GPIO pins

250 milliamp max from 5V supply pins

Using Rpi.GPIO

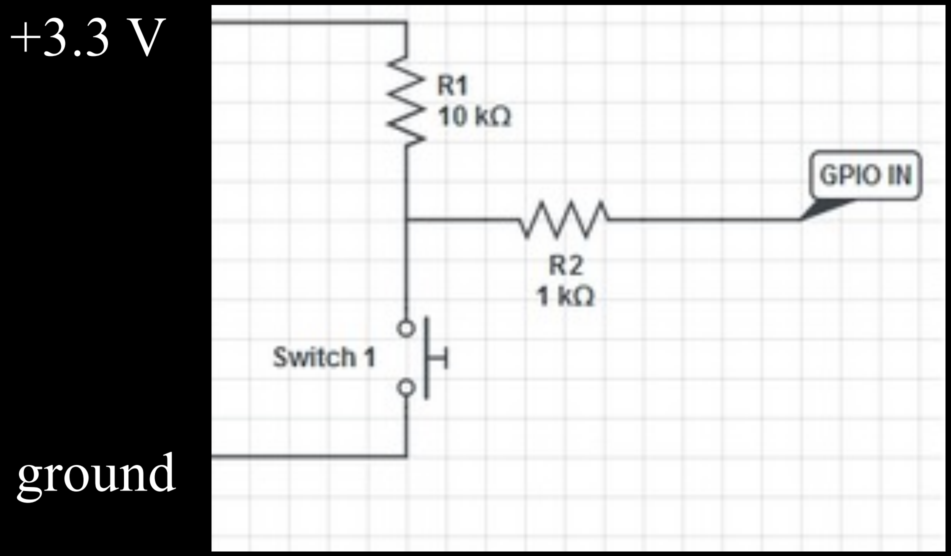
```
import Rpi.GPIO as GPIO

GPIO.setmode(GPIO.BCM)  # Set for broadcom numbering not board numbering
#   setup a GPIO for an input button…
#
GPIO.setup(26, GPIO.IN, pull_up_down=GPIO.PUD_UP)

while True:
   time.sleep(0.2)  # short sleep for screen output
   if ( not GPIO.input(26)) ):
      # Button is pressed
      print (“Button 26 has been pressed!”)
```

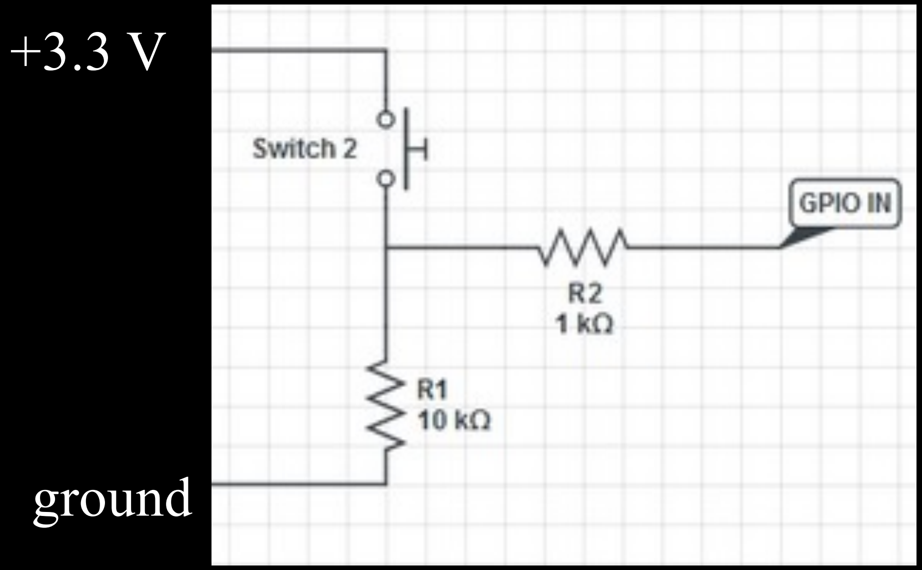
Connect external button



BAD Button!
Do NOT use!!

Connect external button





GOOD: Correct for RPi

Py Game Python Library

Python

Simple Directmedia Layer (SDL)

PyGame Python Library

Define a surface

Rect = drawing rectangle

Initialize PyGame
Display loop
   compose ‘new’ image
   blank the screen
   display new image

PyGame Display Example

```
import pygame     # Import pygame graphics library
import os    # for OS calls

#   os.putenv('SDL_VIDEODRIVER', 'fbcon')   # Display on piTFT
#   os.putenv('SDL_FBDEV', '/dev/fb1')

pygame.init()

size = width, height = 320, 240
speed = [2,2]
black = 0, 0, 0

screen = pygame.display.set_mode(size)
ball = pygame.image.load("magic_ball.png")
ballrect = ball.get_rect()

while 1:
      ballrect = ballrect.move(speed)
      if ballrect.left < 0 or ballrect.right > width:
         speed[0] = -speed[0]
      if ballrect.top < 0 or ballrect.bottom > height:
         speed[1] = -speed[1]

      screen.fill(black)              # Erase the Work space
      screen.blit(ball, ballrect)   # Combine Ball surface with workspace surface
      pygame.display.flip()        # display workspace on screen
```

Performance Monitoring with Linux Perf

Two Subsystems

- SYSCALL
- User space tools

Perf installed in kernel

Only need to install perf executable

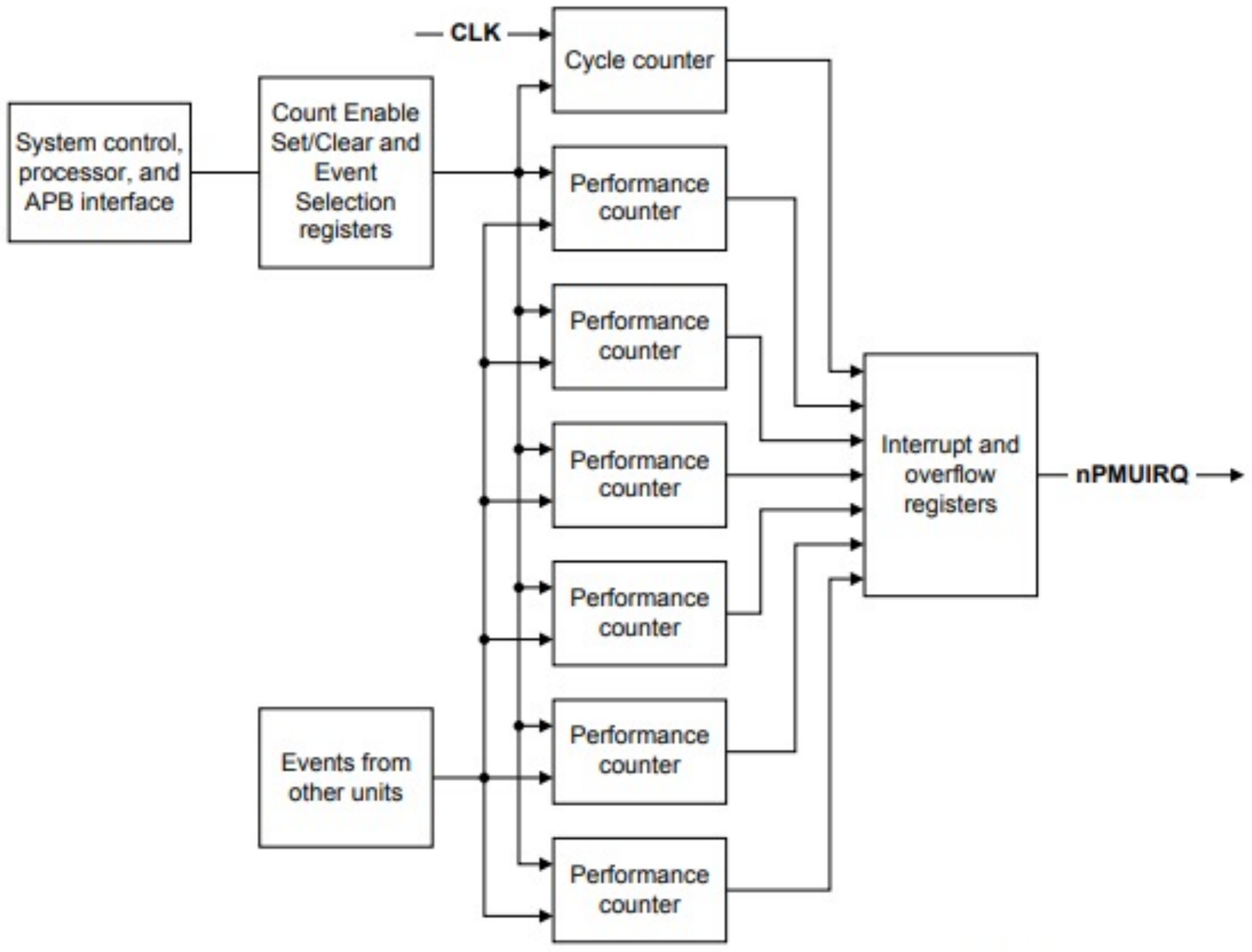


Figure 11-1 PMU block diagram

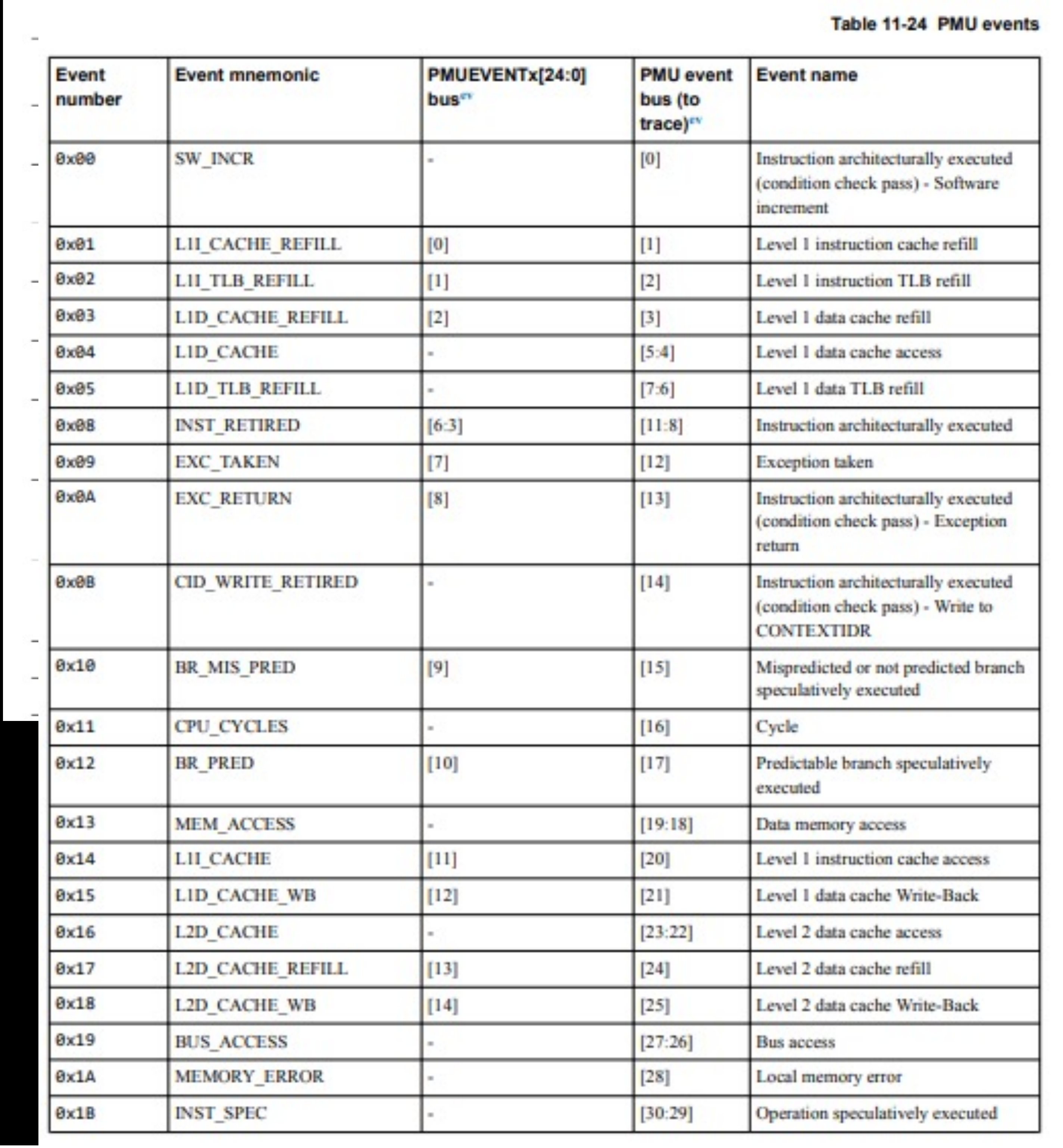


Table 11-24 PMU events

Event number	Event mnemonic	PMUEVENTx[24:0] bus	PMU event bus (to trace)	Event name
0x00	SW_INCR	-	[0]	Instruction architecturally executed (condition check pass) - Software increment
0x01	L1I_CACHE_REFILL	[0]	[1]	Level 1 instruction cache refill
0x02	L1I_TLB_REFILL	[1]	[2]	Level 1 instruction TLB refill
0x03	L1D_CACHE_REFILL	[2]	[3]	Level 1 data cache refill
0x04	L1D_CACHE	-	[5:4]	Level 1 data cache access
0x05	L1D_TLB_REFILL	-	[7:6]	Level 1 data TLB refill
0x08	INST_RETIRED	[6:3]	[11:8]	Instruction architecturally executed
0x09	EXC_TAKEN	[7]	[12]	Exception taken
0x0A	EXC_RETURN	[8]	[13]	Instruction architecturally executed (condition check pass) - Exception return
0x0B	CID_WRITE_RETIRED	-	[14]	Instruction architecturally executed (condition check pass) - Write to CONTEXTIDR
0x10	BR_MIS_PRED	[9]	[15]	Mispredicted or not predicted branch speculatively executed
0x11	CPU_CYCLES	-	[16]	Cycle
0x12	BR_PRED	[10]	[17]	Predictable branch speculatively executed
0x13	MEM_ACCESS	-	[19:18]	Data memory access
0x14	L1I_CACHE	[11]	[20]	Level 1 instruction cache access
0x15	L1D_CACHE_WB	[12]	[21]	Level 1 data cache Write-Back
0x16	L2D_CACHE	-	[23:22]	Level 2 data cache access
0x17	L2D_CACHE_REFILL	[13]	[24]	Level 2 data cache refill
0x18	L2D_CACHE_WB	[14]	[25]	Level 2 data cache Write-Back
0x19	BUS_ACCESS	-	[27:26]	Bus access
0x1A	MEMORY_ERROR	-	[28]	Local memory error
0x1B	INST_SPEC	-	[30:29]	Operation speculatively executed

Performance Monitoring with Linux Perf

stat

record

report

top

GPIO Events

Polling on GPIO events

Interrupt on GPIO event

- GPIO Edge Detection
- Trigger python on an event

Python GPIO interrupts

```
import RPi.GPIO as GPIO
GPIO.setmode(GPIO.BCM)

GPIO.setup(26, GPIO.IN, pull_up_down=GPIO.PUD_UP)

Try:
   print "Waiting for falling edge on port 26"
   GPIO.wait_for_edge(26, GPIO.FALLING)
   print ”Falling edge detected on port 26”
except KeyboardInterrupt:
   GPIO.cleanup()       # clean up GPIO on CTRL+C exit


GPIO.cleanup()          # clean up GPIO on normal exit
```

GPIO threaded callback interrupt

Initialize GPIO

Setup a callback routine

Connect callback to GPIO

Python GPIO interrupts

```
import RPi.GPIO as GPIO
GPIO.setmode(GPIO.BCM)

GPIO.setup(19, GPIO.IN, pull_up_down=GPIO.PUD_UP)

def GPIO19_callback(channel):
    print "falling edge detected on 19”

# “ main” part of the program
GPIO.add_event_detect(19, GPIO.FALLING, callback=GPIO19_callback)

# Continue on with main processing
#     Background code goes here…

GPIO.cleanup()          # clean up GPIO on normal exit
```

GPIO threaded callback interrupt

More than one interrupt?

Multiple threaded callbacks

Python GPIO interrupts

```
import RPi.GPIO as GPIO
Import subprocess
GPIO.setmode(GPIO.BCM)

GPIO.setup(19, GPIO.IN, pull_up_down=GPIO.PUD_UP)
GPIO.setup(13, GPIO.IN, pull_up_down=GPIO.PUD_UP)

def GPIO19_callback(channel):
    print "falling edge detected on 19”

def GPIO13_callback(channel):
   cmd = 'echo “pause” '
   subprocess.check_output(cmd, shell=True)

# “ main” part of the program
GPIO.add_event_detect(19, GPIO.FALLING, callback=GPIO19_callback)
GPIO.add_event_detect(13, GPIO.FALLING, callback=GPIO13_callback)
# Continue on with main processing – Background code….

GPIO.cleanup()          # clean up GPIO on normal exit
```

Python GPIO interrupts

```
import RPi.GPIO as GPIO
Import subprocess
GPIO.setmode(GPIO.BCM)
GPIO.setup(19, GPIO.IN, pull_up_down=GPIO.PUD_UP)
GPIO.setup(13, GPIO.IN, pull_up_down=GPIO.PUD_UP)
GPIO.setup(26, GPIO.IN, pull_up_down=GPIO.PUD_UP)
def GPIO19_callback(channel):
    print "falling edge detected on 19”
def GPIO13_callback(channel):
   cmd = 'echo “pause”’ ‘
   subprocess.check_output(cmd, shell=True)
# “ main” part of the program
GPIO.add_event_detect(19, GPIO.FALLING, callback=GPIO19_callback, bouncetime=300)
GPIO.add_event_detect(13, GPIO.FALLING, callback=GPIO13_callback, bouncetime=300)
 Try:
     print "Waiting for falling edge on port 26"
     GPIO.wait_for_edge(26, GPIO.FALLING)
     print ”Falling edge detected on port 26”
 except KeyboardInterrupt:
     GPIO.cleanup()       # clean up GPIO on CTRL+C exit
GPIO.cleanup()         # clean up GPIO on normal exit
```