GPS

- Bc637PCIe (GPS)

One of the most used GPS functionality is the possibility of synchronization.

- ✓ Synchronization of the system clock with UTC (it is possible and quite easy to create NTP or PTP server)
- ✓ Use interrupts to execute a code periodically (see next slides)

Synchronization in MicroBoone

In MicroBoone experiment the data are acquired in frames. Frames are 1.6 msec long with data sampled at 2MHz. But the DAQ clock runs at a frequency of 16 MHz.

We need to know the GPS time corresponding to the frame number NOW.

The effect is that we have in memory a 3-column table of GPS time, DAQ Clock Time, Frame Number, as many rows as seconds that we want to keep in a circular buffer.

What is an interrupt?

Interrupt is "the forced suspension of a program in execution, in order to run a routine associated to the event that have generated the interrupt"

let's try to express it more clearly

Type of interrupt

There are three types of interrupts:

- ·External
- ·Hardware
- ·Software (Supervisor Call)

Only External interrupts are interesting for our purpose, then I will talk only about this type of interrupts.

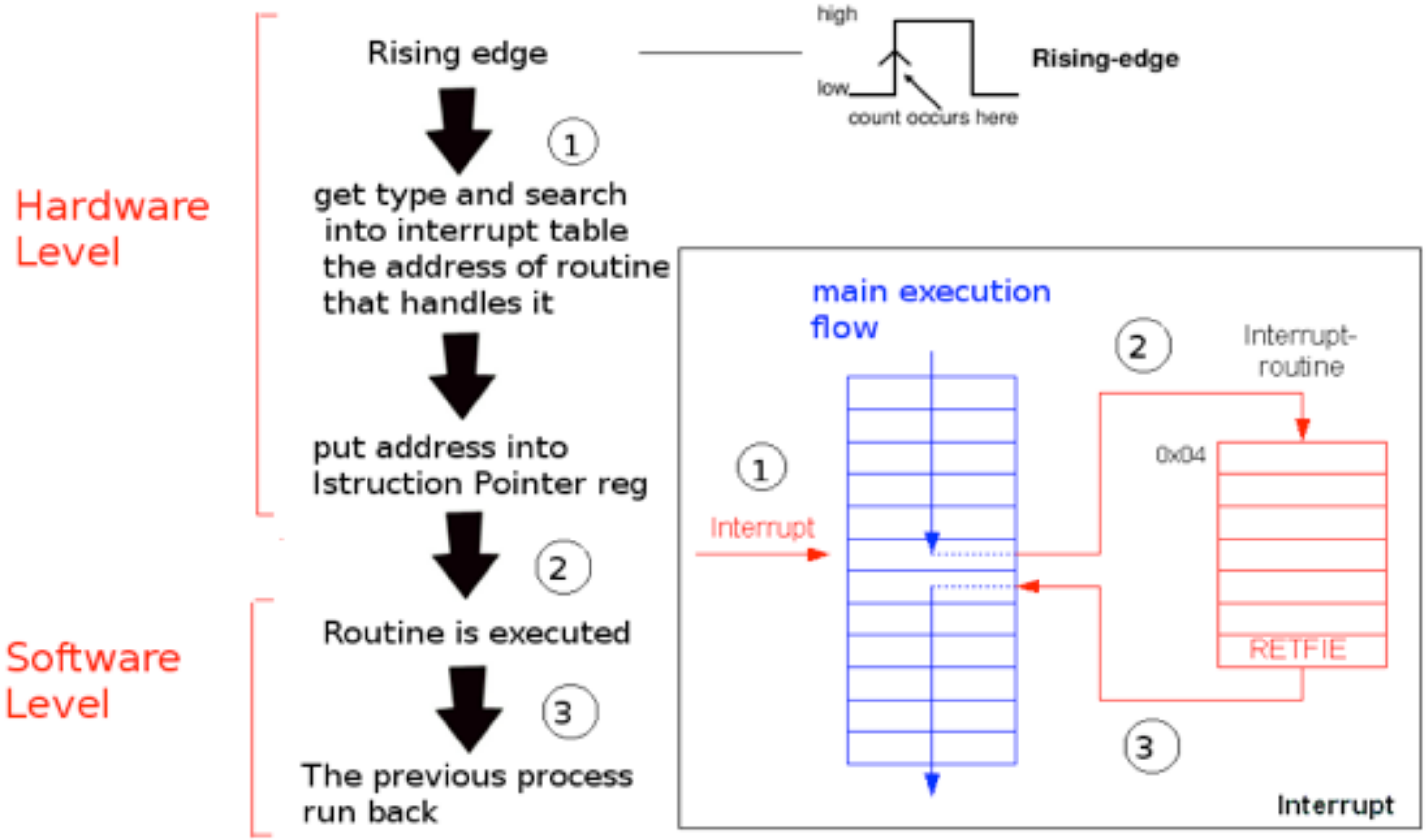
External Interruputs

This interrupts are associated with event that occurs outside CPUs.

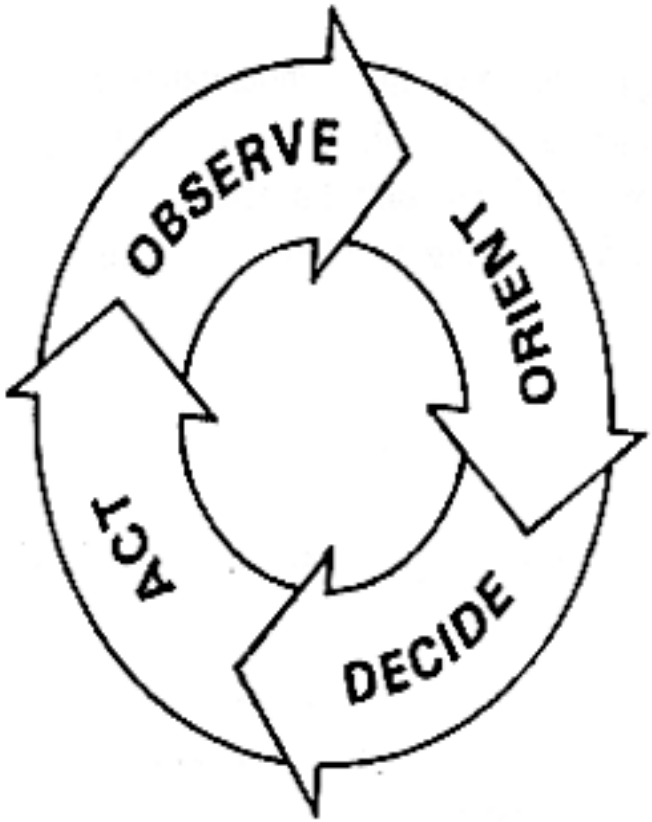
More concretely an events it is represented by a rising edge of an input signal.

In our application it corresponds with the pps signal that GPS card generates on PCI bus (it is a little bit more complex in reality)

Interruption management flow



Why interrupts?



Interrupts are very useful for device management and this mechanism is the most used by modern operating systems(e.g. keyboard, mouse, screen are managed in this way).
For example they allow to avoid busy waiting.

Interrupt + GPS

- As we have already said GPS generate a periodic signal that is called Pulse Per Second
- It is possible to see this signal as an event, and to associate to it an appropriate routine.

Interrupt + GPS 2

- In this way we can obtain a periodic routine, with a period accurate at nanoseconds
- It is possible to implements periodic routine also using timer (I've done it in the consumer, see later)

Difference PPS/Timer

- There are two important advantages in use PPS+interrupts implementation
  - PPS is strongly more accurate than Timer
  - PPS is Synchronized with Coordinated Universal Time. Therefore, for example, two different hosts, using PPS, execute their routine at the same time.

My codes

I've wrote some sample codes that implement this mechanism, called fancifully:

- GPS_1
- GPS_1_5
- GPS_2
- connection_control

GPS_1

- This code include a main that sets up the card and the OS Interrupt table, and an interrupt routine, associated with PPS event, that reads directly time and print it.
- The role of this is just demonstrate how to write and set a periodic PPS code.

GPS_1 code: main

Main calls initialization functions and wait:

- bcStartPci(); sets and starts the device
- pci_set_ints(hBC_PCI); sets Interrupt Descriptor Table placing handler routine in it (bcStartIntEx(hBC_PCI, bcIntHandlerRoutine, INTERRUPT_1PPS & 0x7F))

GPS_1 code: interrupt

Interrupt code:

```
//Get current time
// bcReadDecTimeEx is a library function that reads current time
bcReadDecTimeEx (hBC_PCI, &dectime, &min, &nano, &stat);

//Print time read
printf("pps_routine: %02d:%02d:%02d.%06lu%d \n",
     dectime.tm_hour, dectime.tm_min, dectime.tm_sec, min,
  nano);
```

GPS_1 output

OUTPUT:
...
bcIntHandlerRoutine
pps_routine: 80:156:66.0040402
bcIntHandlerRoutine
pps_routine: 80:156:67.0140657
bcIntHandlerRoutine
pps_routine: 80:156:68.0030917
bcIntHandlerRoutine
pps_routine: 80:156:69.0041193
bcIntHandlerRoutine
pps_routine: 80:156:70.0041424
bcIntHandlerRoutine
pps_routine: 80:156:71.0041674
bcIntHandlerRoutine
pps_routine: 80:156:72.0141917
bcIntHandlerRoutine
pps_routine: 80:156:73.0052188
bcIntHandlerRoutine
pps_routine: 80:156:74.0032431
bcIntHandlerRoutine
pps_routine: 80:156:75.0032680
bcIntHandlerRoutine
pps_routine: 80:156:76.0022934
...

This output demostrate that:

- Routine occours each second
- Time is captured with a random delay, due by the execution of software between interrupt signal and data acquisition.

GPS_1_5

- This code is similar to the previous (GPS_1). The difference lies in how the current time is obtained: in this new implementation we use event register, latching (on hardware level) the time in which PPS arrives in it.
- This code demostrate how to latch an event (that could be different from PPS) time

Code differences between 1 and 1_5

Into main I need to setup event register:

```
iVal=1;
EvDat.evtsrc = (BYTE)iVal;
EvDat.evtctl = (BYTE)iVal;
iVal=0;
EvDat.evtlock = (BYTE)iVal;
EvDat.evtsense = (BYTE)iVal;
bcSetEventsData (hBC_PCI, &EvDat);
```

Into interrupt routine I only need to take time with another function:

```
bcReadEventTimeEx (hBC_PCI, &evtmaj, &evtmin, &evtnano, &stat);
```

GPS_1_5 output

OUTPUT:
...
Time: 09/13/2012 17:01:07.0000000   Status: 7
Time: 09/13/2012 17:01:08.0000000   Status: 7
Time: 09/13/2012 17:01:09.0000000   Status: 7
Time: 09/13/2012 17:01:10.0000000   Status: 7
Time: 09/13/2012 17:01:11.0000000   Status: 7
Time: 09/13/2012 17:01:12.0000000   Status: 7
Time: 09/13/2012 17:01:13.0000000   Status: 7
Time: 09/13/2012 17:01:14.0000000   Status: 7
Time: 09/13/2012 17:01:15.0000000   Status: 7
Time: 09/13/2012 17:01:16.0000000   Status: 7
Time: 09/13/2012 17:01:17.0000000   Status: 7
...

N.B.:This output does not demonstrate anything about precision of GPS: This is GPS time, and not UTC time. Then is obvious that GPS says that signal, that it thinks to generate each second, has a infinite precision.

GPS_2

This code evolves GPS_1 (it doesn't use event register), implementing the classic paradigm of communication Producer-Consumer, where producer is the interrupt and consumer is a stand-alone thread. The shared information is the number of PPS that are arrived.

Shared memory

- In computing, shared memory is memory that may be simultaneously accessed by multiple programs with an intent to provide communication among them.
- Linux permits a controlled use of shared memory, showing it like a device called shm.

GPS_2 code

Producer(interrupt):

```
//each time I need  to get shared
//address
memory_loc_key = ftok(".",'M');
if((id = shmget( memory_loc_key,
 sizeof(long int), 0666 ))<0){/*...*/ }
shm_ptr = shmat (id,NULL,0);
if((int)shm_ptr == -1){...}


//increment pps_counter
(*((long int*)shm_ptr))++;
```

Consumer(thread):

```
//get shared address (one time)
memory_loc_key = ftok(".",'M');
  if((id = shmget( memory_loc_key, sizeof
   (long int), 0666 ))<0){/*...*/ }
  shm_ptr = shmat (id,NULL,0);
  if((int)shm_ptr == -1){...}
                  [...]
  While(1){
      //use data
   printf("I'm the consumer!: %ld \n", *((long
   int*)shm_ptr));
                  /*wait 0.5 sec*/
 }
```

GPS_2 output

```
...
bcIntHandlerRoutine
I'm the consumer!: 2926
I'm the consumer!: 2926
pps_routine: 87:144:244.0059356
bcIntHandlerRoutine
I'm the consumer!: 2927
I'm the consumer!: 2927
pps_routine: 87:144:245.0039618
bcIntHandlerRoutine
I'm the consumer!: 2928
I'm the consumer!: 2928
pps_routine: 87:144:246.0059860
bcIntHandlerRoutine
I'm the consumer!: 2929
I'm the consumer!: 2929
pps_routine: 87:144:247.0030130
...
```

connection_control

This simple code periodically (about 4 sec) requires packet46 to GPS card, and reads in it information about status of connection. Then it prints a message describing this status.

connection_control output

...
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
Status: No usable satellites
...

This output was taken when the antenna was disconnected.

Conclusions

The codes that I've briefly explained are simply sample codes, and they try to show functionalities. It would be simple to modify them, in order to satisfy the various needs.