CS/ECE 6780/5780

Al Davis

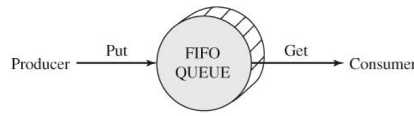
Today's topics:

•FIFO's 6812 style

•hopefully a review?

FIFO's

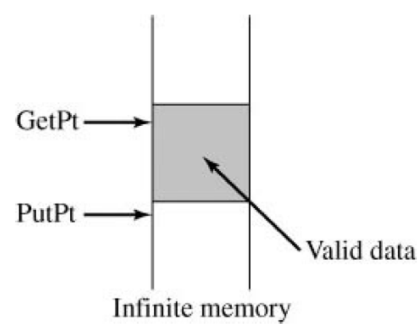
- **Useful interface**
  - **provide slack to decouple producer and consumer rates**
  - **provides order preserving buffering**
    - » **for the case where all produced values are important**
      - **alternative – single memory location**
        - **for the case when only the most recent value is needed**
  - **circular queue is a useful buffered I/O interface**
    - » **statically allocated global memory**
      - **aids in controlling memory footprint when resources are limited**
        - **e.g. as in your lab kits**
      - **can be shared by main and ISR's**
        - **access must be carefully controlled to get it right however**



Producer Consumer Examples

Source/producer	Sink/consumer
Keyboard input	Program that interprets
Program with data	Printer output
Program sends message	Program receives message
Microphone and ADC	Program that saves sound data
Program that has sound data	DAC and speaker

FIFO w/ Infinite Memory



Basic Code Model

- **Not robust however**

```
char static volatile *PutPt;  // put next
char static volatile *GetPt;  // get next
// call by value
int Fifo_Put(char data){
  *PutPt = data;     // Put
  PutPt++;           // next
  return(1);         // true if success
}
// call by reference
int Fifo_Get(char *datapt){
  *datapt = *GetPt; // return by reference
  GetPt++;          // next
  return(1);        // true if success
}
```

What's missing?

2-pointer Finite FIFO Initialization

```
#define FIFOSIZE 10 /* can hold 9 */
char static volatile *PutPt;  /* Pointer to put next */
char static volatile *GetPt;  /* Pointer to get next */
        /* FIFO is empty if PutPt == GetPt */
        /* FIFO is full  if PutPt+1 == GetPt (with wrap) */

char static Fifo[FIFOSIZE];

void Fifo_Init (void)
{
  unsigned char SaveSP = begin_critical();
  PutPt=GetPt=&Fifo[0]; /* Empty when PutPt=GetPt */
  end_critical (SaveSP);
}
```


Atomicity Functions

```
unsigned char begin_critical (void)
{
  unsigned char SaveSP;
  asm tpa
  asm staa SaveSP
  asm sei
  return SaveSP;
}

void end_critical (unsigned char SaveSP)
{
  asm ldaa SaveSP
  asm tap
}
```

What is another way to do this?

Put for a 2-pointer Circular FIFO

```
int Fifo_Put(char data)
{
  char *Ppt; /* Temp put pointer */
  unsigned char SaveSP = begin_critical();
  Ppt=PutPt;     /* Copy of put pointer */
  *(Ppt++)=data; /* Try to put data into fifo */
  if (Ppt == &Fifo[FIFOSIZE]) Ppt = &Fifo[0];  /* Wrap */
  if (Ppt == GetPt ) {
    end_critical (SaveSP);
    return(0);    /* Failed: fifo was full */
  } else {
    PutPt=Ppt;
    end_critical (SaveSP);
    return(1);    /* Successful */
  }
}
```

Is this correct?

Put Example

Initially

data = 0x04

	0xXX
GetPt →	0x01
	0x02
	0x03
PutPt →	0xXX
	0xXX

```
int Fifo_Put(char data) {
   char *Ppt;
   unsigned char SaveSP = begin_critical();
   Ppt=PutPt;
   *(Ppt++)=data;
   if (Ppt == &Fifo[FIFOSIZE])
      Ppt = &Fifo[0];
   if (Ppt == GetPt ) {
      end_critical (SaveSP);
      return(0);
   } else {
      PutPt=Ppt;
      end_critical (SaveSP);
      return(1);
   }
}
```


Put Example

data = 0x04

	0xXX
GetPt →	0x01
	0x02
	0x03
PutPt/Ppt →	0xXX
	0xXX

```
int Fifo_Put(char data) {
   char *Ppt;
   unsigned char SaveSP = begin_critical();
   Ppt=PutPt;
   *(Ppt++)=data;
   if (Ppt == &Fifo[FIFOSIZE])
      Ppt = &Fifo[0];
   if (Ppt == GetPt ) {
      end_critical (SaveSP);
      return(0);
   } else {
      PutPt=Ppt;
      end_critical (SaveSP);
      return(1);
   }
}
```


Put Example

data = 0x04

	0xXX
GetPt →	0x01
	0x02
	0x03
PutPt →	0x04
Ppt →	0xXX

```
int Fifo_Put(char data) {
   char *Ppt;
   unsigned char SaveSP = begin_critical();
   Ppt=PutPt;
   *(Ppt++)=data;
   if (Ppt == &Fifo[FIFOSIZE])
      Ppt = &Fifo[0];
   if (Ppt == GetPt ) {
      end_critical (SaveSP);
      return(0);
   } else {
      PutPt=Ppt;
      end_critical (SaveSP);
      return(1);
   }
}
```


Get for a 2-pointer Circular FIFO

```
int Fifo_Get(char *datapt) {
  if (PutPt == GetPt ) {
    return(0);   /* Empty if PutPt=GetPt */
  } else {
    unsigned char SaveSP = begin_critical();
    *datapt=*(GetPt++);
    if (GetPt == &Fifo[FIFOSIZE])
      GetPt = &Fifo[0]; /* Wrap */
    end_critical (SaveSP);
    return(1);
  }
}
```

2-pointer vs. Counter FIFO's

- **2 pointer version**
  - **implicit number of elements**
    - » **how do you calculate how many values are in the queue?**
- **Alternative is explicit store of current size**
  - **2-pointer counter FIFO**
    - » **requires an extra variable – e.g.** `Size`
    - » **but has compensating advantages**

Initialization of a 2-pointer Counter FIFO

```
#define FIFOSIZE 10  /* can hold 10 */
char static volatile *PutPt; /* Pointer to put next */
char static volatile *GetPt; /* Pointer to get next */
char Fifo[FIFOSIZE];
unsigned char Size;     /* Number of elements */
void Fifo_Init(void) {
  unsigned char SaveSP = begin_critical();
  PutPt=GetPt=&Fifo[0]; /* Empty when Size==0 */
  Size=0;
  end_critical (SaveSP);
}
```


Put Function

```
int Fifo_Put(char data) {
  if (Size == FIFOSIZE ) {
    return(0);       /* Failed, fifo was full */
  } else {
    unsigned char SaveSP = begin_critical();
    Size++;
    *(PutPt++)=data; /* put data into fifo */
    if (PutPt == &Fifo[FIFOSIZE]) {
      PutPt = &Fifo[0]; /* Wrap */
    }
    end_critical (SaveSP);
    return(1);        /* Successful */
  }
}
```


Get Function

```
int Fifo_Get (char *datapt) {
  if (Size == 0 ) {
    return(0);   /* Empty if Size=0 */
  } else {
    unsigned char SaveSP = begin_critical();
    *datapt=*(GetPt++);
    Size--;
    if (GetPt == &Fifo[FIFOSIZE]) {
      GetPt = &Fifo[0];     /* Wrap */
    }
    end_critical (SaveSP);
    return(1);
  }
}
```

What advantages come from the `Size` variable?

Yet Another FIFO Option

- First two options
  - used pointers
- Index FIFO
  - accesses elements via array indices

Index FIFO Initialization

Same basic idea but w/o pointer weirdness

```
#define FIFOSIZE 10  /* Number of 8 bit data in the Fifo */
unsigned char PutI;  /* Index of where to put next */
unsigned char GetI;  /* Index of where to get next */
unsigned char Size;  /* Number of elements in the FIFO */
                     /* FIFO is empty if Size=0 */
                     /* FIFO is full  if Size=FIFOSIZE */
char Fifo[FIFOSIZE]; /* The statically allocated fifo data
void Fifo_Init(void)
{
  unsigned char SaveSP = begin_critical();
  PutI=GetI=Size=0;  /* Empty when Size==0 */
  end_critical (SaveSP);
}
```


Index FIFO Put

```
int Fifo_Put (char data)
{
  if (Size == FIFOSIZE ) {
    return(0);         /* Failed, fifo was full */
  } else {
    unsigned char SaveSP = begin_critical();
    Size++;
    Fifo[PutI++]=data; /*  put data into fifo */
    if (PutI == FIFOSIZE)
      PutI = 0;  /* Wrap */
    end_critical (SaveSP);
    return(1);        /* Successful */
  }
}
```


Index FIFO Get

```
int Fifo_Get (char *datapt)
{
  if (Size == 0 ) {
    return(0);   /* Empty if Size=0 */
  } else {
    unsigned char SaveSP = begin_critical();
    *datapt=Fifo[GetI++];
    Size--;
    if (GetI == FIFOSIZE)
      GetI = 0;
    end_critical (SaveSP);
    return(1);
  }
}
```

FIFO Dynamics

Rates of production/consumption vary dynamically.

t_p is time between `Put` calls, r_p is arrival rate ($r_p = \frac{1}{t_p}$).

t_g is time between `Get` calls, r_g is service rate ($r_g = \frac{1}{t_g}$).

If min $t_p \geq$ max t_g, FIFO is not necessary.

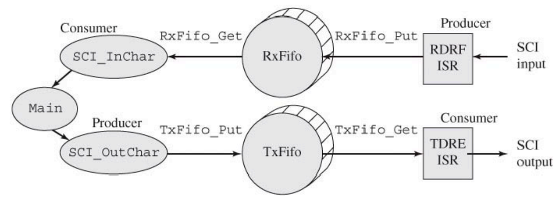
If arrival rate can temporarily increase or service rate temporarily decrease, then a FIFO is necessary.

If average production rate exceeds average consumption rate (i.e., $\overline{r}_p > \overline{r}_g$), then FIFO will overflow.

A full error is serious because ignored data is lost.

An empty error may or may not be serious.

SCI Data Flow Graph w/ Two FIFOs



Concluding Remarks

- **Basic FIFO service**
  - decouple rate of production from rate of consumption
  - ideal size depends on maximum slack between the rates
- **Cost**
  - some RAM utilization and a few CPU cycles
  - note crtical section occupancy
    - » if it's longer the t_p or t_c then there is a problem
      - solution?
- **Real systems have FIFO's everywhere**
  - main reason why this lecture had such a narrow focus
  - what's the fundamental reason for this?
- **FIFO's are concurrent data structures**
  - touched by main + ISRs or threads
- **Writing correct concurrent data structures can be hard**
  - if done right then using them is easy