

# A2-6 Digital Communications

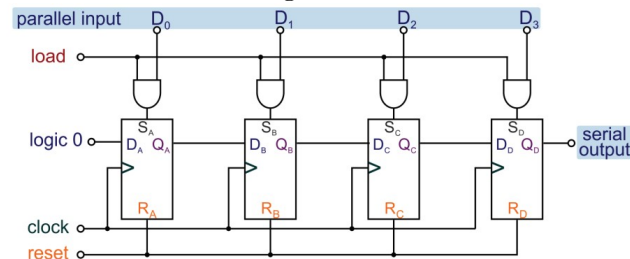
Revision sheet

## 1 Shift Registers

Data can be transmitted either in serial or parallel form. Serial is where you transmit one bit after the other, with the MSB first. Parallel is where all the bits are transmitted simultaneously. Generally, data signals are transmitted in serial.

### 1.1 PISO

The circuit diagram for a *Parallel In Serial Out* shift register is shown below.



A PISO works as follows

1. A logic high pulse is sent to the reset pin - resetting all flip-flops
2. The 4-bit word is setup on  $D_0$  to  $D_3$  inputs
3. The load line is taken high,  $D_0$  to  $D_3$  is transferred to the flip-flops
4. Clock is pulsed to shift data out, MSB first
5. After  $n-1$  pulses, whole word is transmitted
6. After  $n$  pulses the shift register is empty

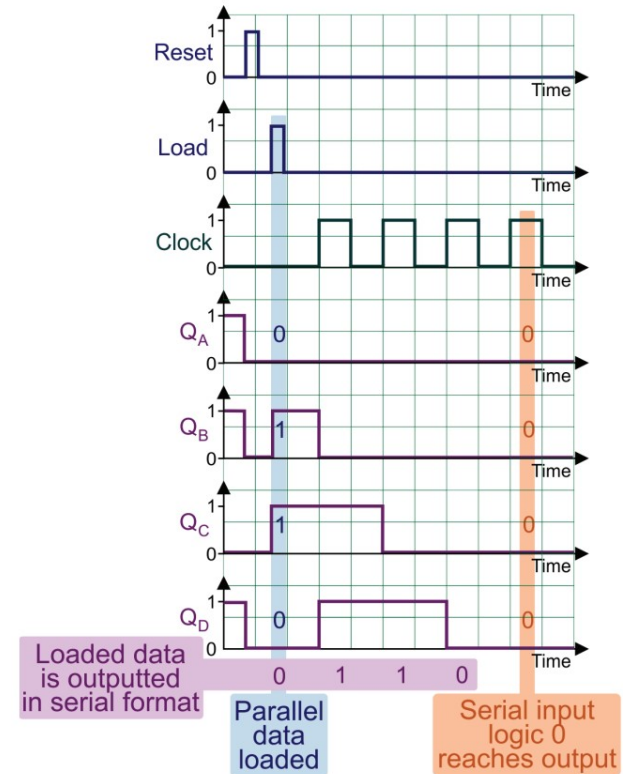
(where  $n$  = number of bits)

The progress of bits through the PISO can be displayed in a table.

Clock	D	$Q_A$	$Q_B$	$Q_C$	$Q_D$	
0	0	0	1	1	0	Data loaded
1	0	0	0	1	1	Data moving through output
2	0	0	0	0	1	
3	0	0	0	0	0	Data output complete
4	0	0	0	0	0	

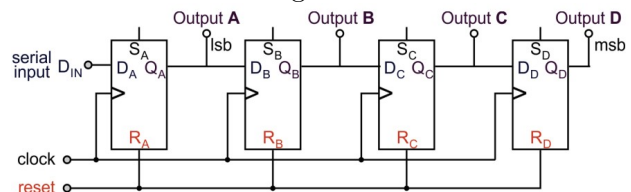
The outputs  $Q_A$  to  $Q_D$  can be

displayed on a timing diagram.



### 1.2 SIPO

The circuit diagram for a *Serial In Parallel Out* shift register is shown below.



A SIPO works as follows

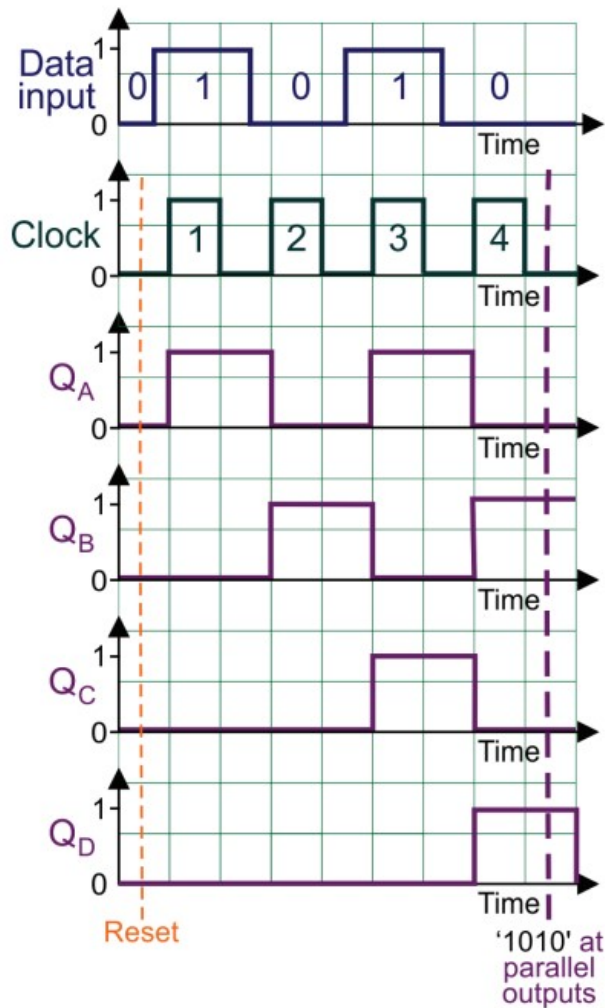
1. A logic high pulse is sent to the reset pin which resets all the flip-flops
2. On each clock pulse, the data on input  $D_A$  is loaded onto  $Q_A$ . Each bit is shifted along one
3. After  $n$  pulses, the whole word is received

(where  $n$  = number of bits)

The progress of bits through the SIPO can be displayed in a table.

Clock	D <sub>IN</sub>	Q <sub>A</sub>	Q <sub>B</sub>	Q <sub>C</sub>	Q <sub>D</sub>
0	1				
1	0	1			
2	1	0	1		
3	0	1	0	1	
4	0	0	1	0	1

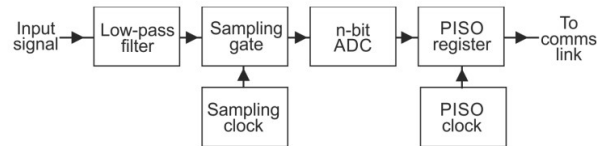
The outputs on  $Q_A$  to  $D$  can be displayed on a timing diagram.



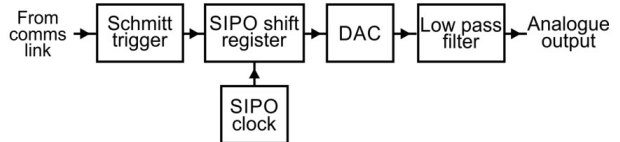
## 2 Pulse Code Modulation

The process of sampling analogue signals and converting them into binary codes is known as pulse code modulation (PCM). Many of the blocks in the block diagrams shown below are the same as in the Digital Audio Systems within Signal Conversion.

### 2.1 Transmitter



### 2.2 Receiver



The Schmitt trigger is used to regenerate the signal.

## 3 Time Division Multiplexing

Time Division Multiplexing is used to increase the capacity of a Pulse Code Modulation communications link. To illustrate how TDM works, a PCM telephone system will be used as an example.

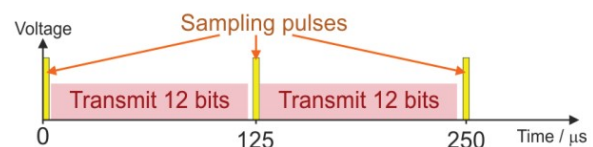
In the UK, telephone bandwidth is limited to  $3.4\text{kHz}$ , therefore  $f_s = 6.8\text{kHz}$ . However, in reality we use  $8\text{kHz}$  and a 12-bit ADC.

This means that

$$f_s = 8\text{kHz}$$

$$\therefore T_s = \frac{1}{8 \times 10^3} = 125\mu\text{s}$$

Where  $T_s$  is the sampling period, which can be seen in the graph below.



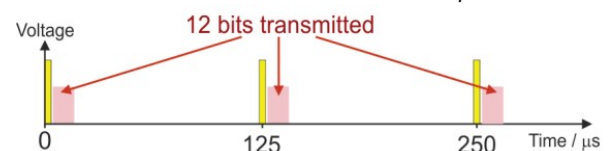
The frequency of the PISO shift register ( $f_{PISO}$ ) can be calculated as follows:

$$f_{PISO} = 12 \times 8 = 96\text{kHz}$$

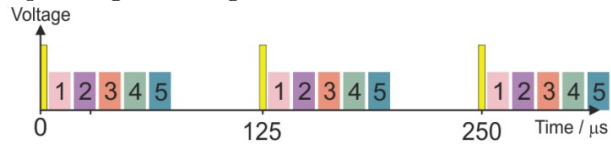
$$\therefore T_{PISO} = \frac{1}{96 \times 10^3} = 10.4\mu\text{s}$$

Where  $T_{PISO}$  is the time period of the PISO (time taken to set one bit).

If we now set  $f_{PISO}$  to  $1\text{MHz}$ ,  $T_{PISO} = 1\mu\text{s}$  therefore the whole 12 bits take  $12\mu\text{s}$  to send.



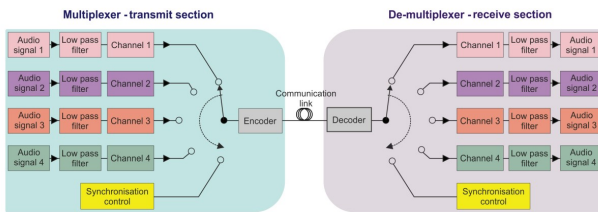
This means that we can now multiplex multiple signals together in the time domain.



The maximum number of signals (channels) which can be multiplexed together can be calculated using the following formula.

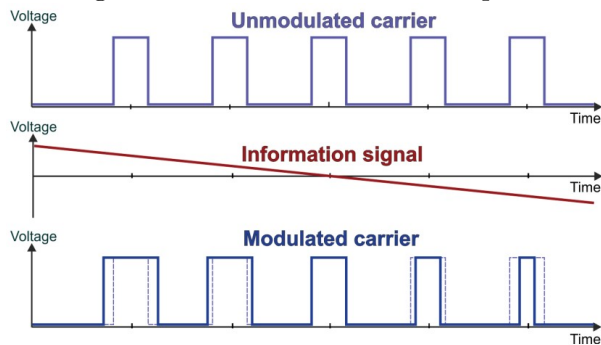
$$\text{Max channels} = \frac{\text{sampling period}}{\text{num of bits} \times \text{PISO period}}$$

Shown below is a block diagram of the entire TDM system.



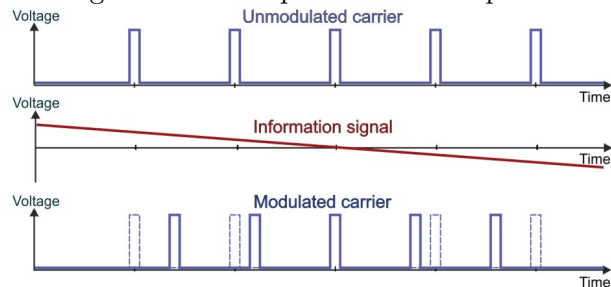
## 4 Pulse Width Modulation

PWM represents the amplitude of the information signal with the width of the pulse train.



## 5 Pulse Position Modulation

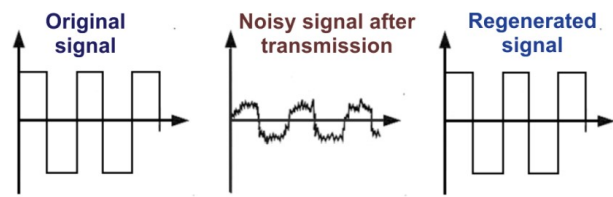
PPM represents the amplitude of the information signal with the position of the pulse train.



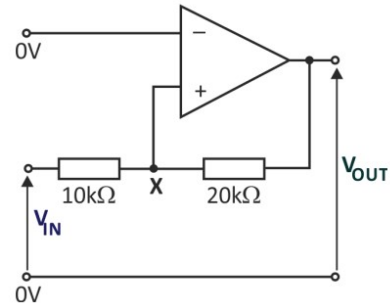
## 6 Schmitt Triggers

When signals are transmitted, the signal quality can degrade. A schmitt trigger can be used to

regenerate the signal and provide a clean wave.



### 6.1 Non-Inverting Schmitt Trigger



If  $V_{OUT} = +V_{SAT}$ , it stays in saturation as  $V_X$  is positive.  $V_{OUT}$  will flip when  $V_{IN}$  goes negative, causing  $V_X$  to be pulled negative.

If  $V_{OUT} = -V_{SAT}$ , stays in saturation as  $V_X$  is negative.  $V_{OUT}$  will flip when  $V_{IN}$  becomes positive enough to pull  $V_X$  positive.

The inverting input is  $V_{REF}$ .

#### 6.1.1 Calculating Thresholds

In the exam, it is quite common to be asked to calculate a threshold for a schmitt trigger. First, assume that the comparator is initially in positive saturation and it will switch to negative saturation when  $V_X < 0$ ; from this, calculate the lower threshold. Then assume the comparator is in negative saturation and calculate the upper threshold. If  $V_{REF} = 0V$ , the thresholds are symmetrical (eg, 6V & -6V).