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SECOND COLLEGE ON MICROPROCESSORS: TECHNOLOGY AND APPLICATIONS IN PHYSICS

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CONTROL OF EXPERIMENTS

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These are preliminary lecture notes, intended only for distribution to participants.
Missing or extra copies are available from Room 230.

DATA ACQUISITION AND CONTROL IN LABORATORY

- Essentially involves acquiring, processing, and transmitting a variety of data
- Complexity depends upon experiment
- Many experiments that use complex electronic control can be more efficiently implemented by a microprocessor
- The microprocessor operates in 'on-line' mode

  Receives data from sources that are part of the experiment and the output (after processing) is used for some control operation

- Microprocessor provides several additional facilities like fault monitoring, report generation, etc. which conventional hardware does not provide

on-line and off-line processing

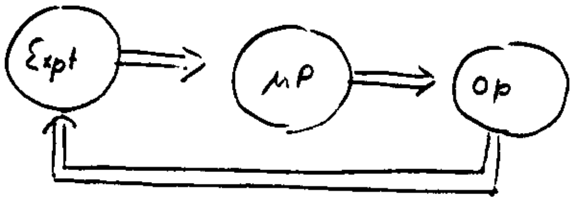
off line processing: no critical time relationship

Inputs and outputs connected via peripherals such as card / tape readers, printers and similar devices

- On-line processing: The microprocessor is a slave to the external events
  - It is always expected to be ready to receive them and process data, and deliver an output

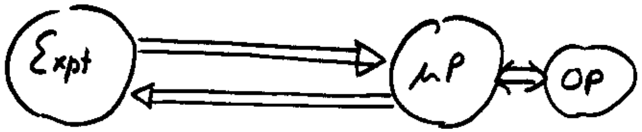
    (also called real time control)
  - The time relationship between input and output is very important and could be critical

The control situation:



Off line control

(open loop, semi automatic mode)



Closed loop control

Feed back loop is complete.
Design is important. Loop parameters are to be properly matched
(otherwise instability and other undesirable behaviour may result)

Components / subsystems

Principal operations:

Data acquisition; Processing; Outputting

Data:
very wide variety

- On/off signals (switches, relays)
- Direct digital input (//, serial, binary BCD, etc)
- Angular position (shaft encoder)
- Number of pulses (eg. from counter)
- Zero crossings
- Timing signals
- Real time clock

Analog types:

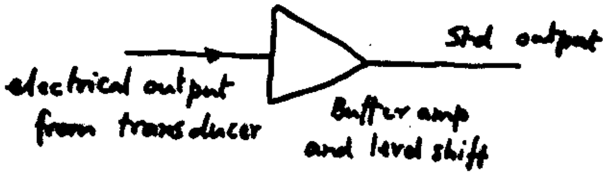
. Temperature	. conductivity	
. Pressure	. resistance	
. Tension	. voltage	
. Viscosity	. current	etc. etc.
. Strain guage	. optical intensity	
.	. energy level	

No of signals 100's to 1000's

Signal conditioning

(Amplification and/or level conversion)

- Electrical output is suitably amplified and/or translated to match the system requirement.
  Bring it to a standardized range
  Buffering



low impedance

0 – 10 v
± 5 v (typ)

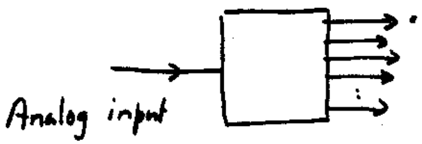
(higher voltage level easy to process, multiplex, etc.)

- High gain, high input impedance, low output imp.
  instrumentation amplifiers

For "digital" signals

These are buffered and brought to a std level e.g. TTL.

ANALOG / DIGITAL CONVERSION



broad characteristics :

- Accuracy : number of bits
  .1% → 10 bits binary
- Speed of conversion : μs ? ms ?
- Linearity
- Stability

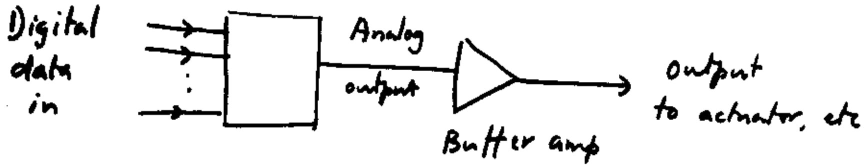
Many types

- Flash or parallel ADC : Very fast, very expensive, few bits
- Successive approx. type : Fast, good accuracy
- Integrating types : rel. slow, higher accuracy, noise tolerance, lower cost
  - Monolithic or Hybrid ICs

(requires std. voltage and a comparator, can be implemented by a μP, but not efficiently)

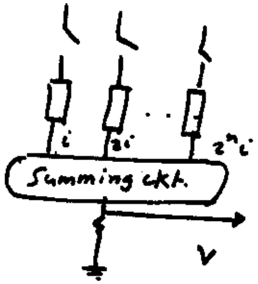
Digital to Analog Converter (DA..

(required at the output side for control)

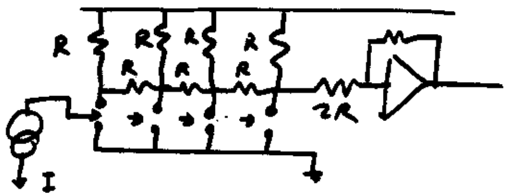


Mainly two types

- Current summing type



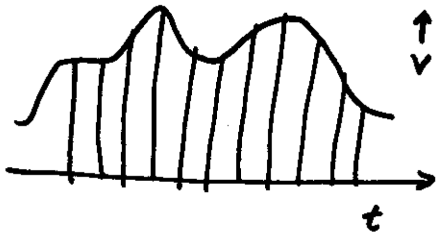
- R-2R ladder network

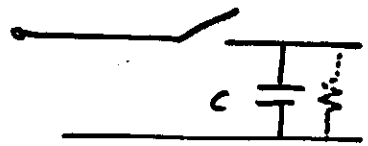


There are other types also.

Sample and Hold Circuits

- Processing AC signals is done by sampling the waveform
  - Sampled output goes to an ADC. Input to the ADC <u>should not</u> change significantly during conversion period (<< l.s.b.)
  - Sampled voltage is required to be held constant done by S/H circuit





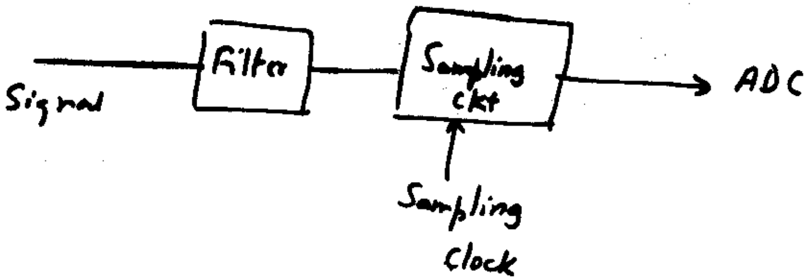
FET based circuit, the capacitor is charged to the sampled voltage. Low leakage permits holding the voltage constant for required time

SAMPLING RATE

- Sampling should be done at high rate

  at atleast two times the highest significant frequency component in the signal

- Otherwise "aliasing" will occur

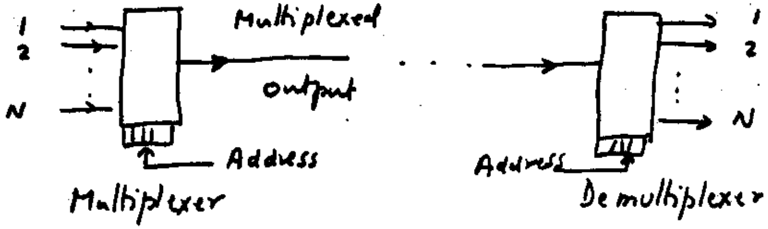


e.g. telephone speech 300 - 3400 Hz

Sampling is done at 8KHz rate

8 bits per sample, hence 64 kbps rate per channel

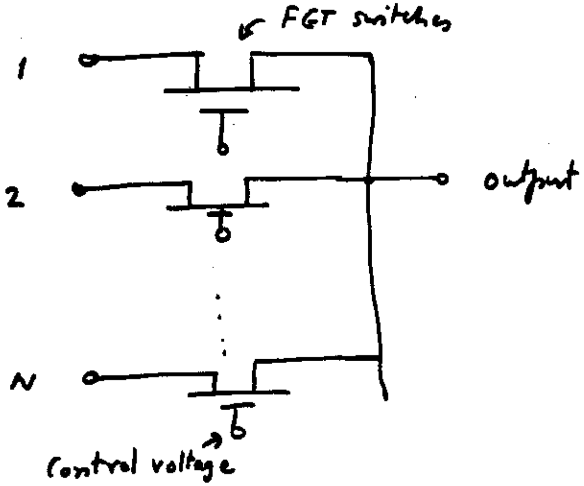
MULTIPLEXING



Digital multiplexing : Gating , trivial operation

Analog multiplexing

problems of leakage, offset voltage, etc.



PROCESSING

e.g.
- Signal processing
- data processing

Signal Processing

Extracting significant frequency and phase and amplitude data

- Passive filters
- Active filters
- Switched capacitor filters
- Digital filter
- FFT processor

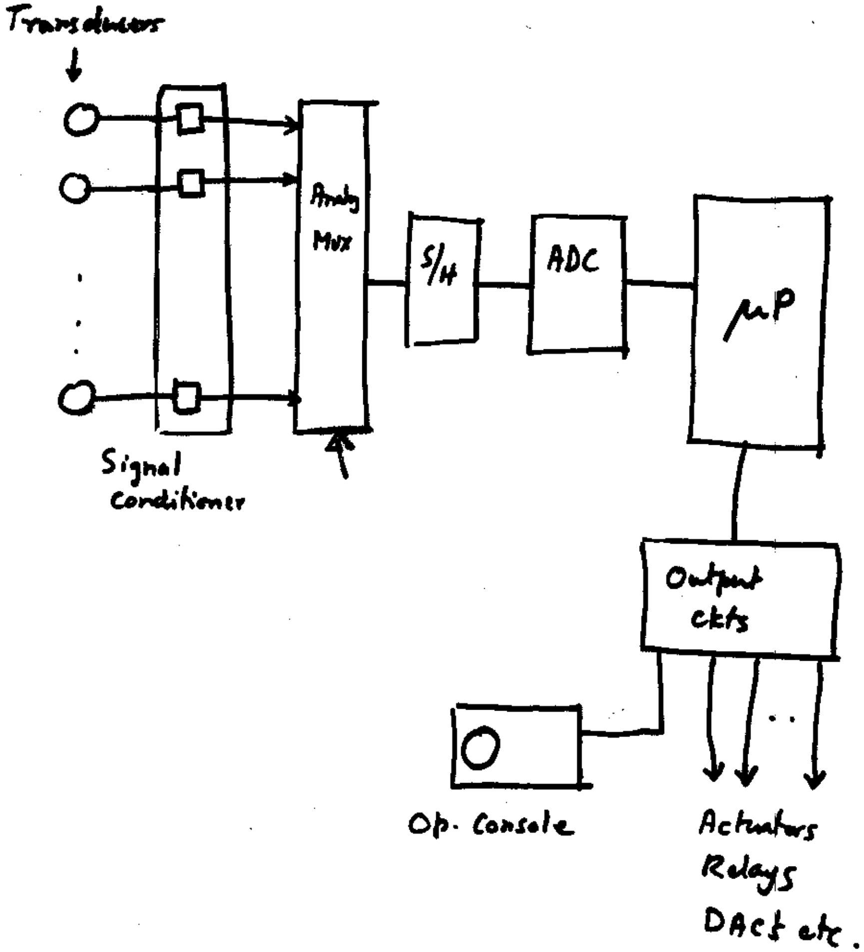
(for the last item an additional FFT array processor may generally be necessary)

Examples :
- Optical data processing (feature extraction, etc.)
- Image processing
- Acoustic / sonar signal processing

OTHER PROCESSING

- Arithmetic Computation
- Find best (optimum) value
- Table look up
- Tabulation of data
- Sorting
- Correlations
- Compensating for limitations of transducers (e.g. linearization of resistance thermometer)
- generation of random values

Outline of a Typical System



Out ice

Switches

Relays

Motors

Heaters

Light Sources

Valves

X Y Tables

CRTs

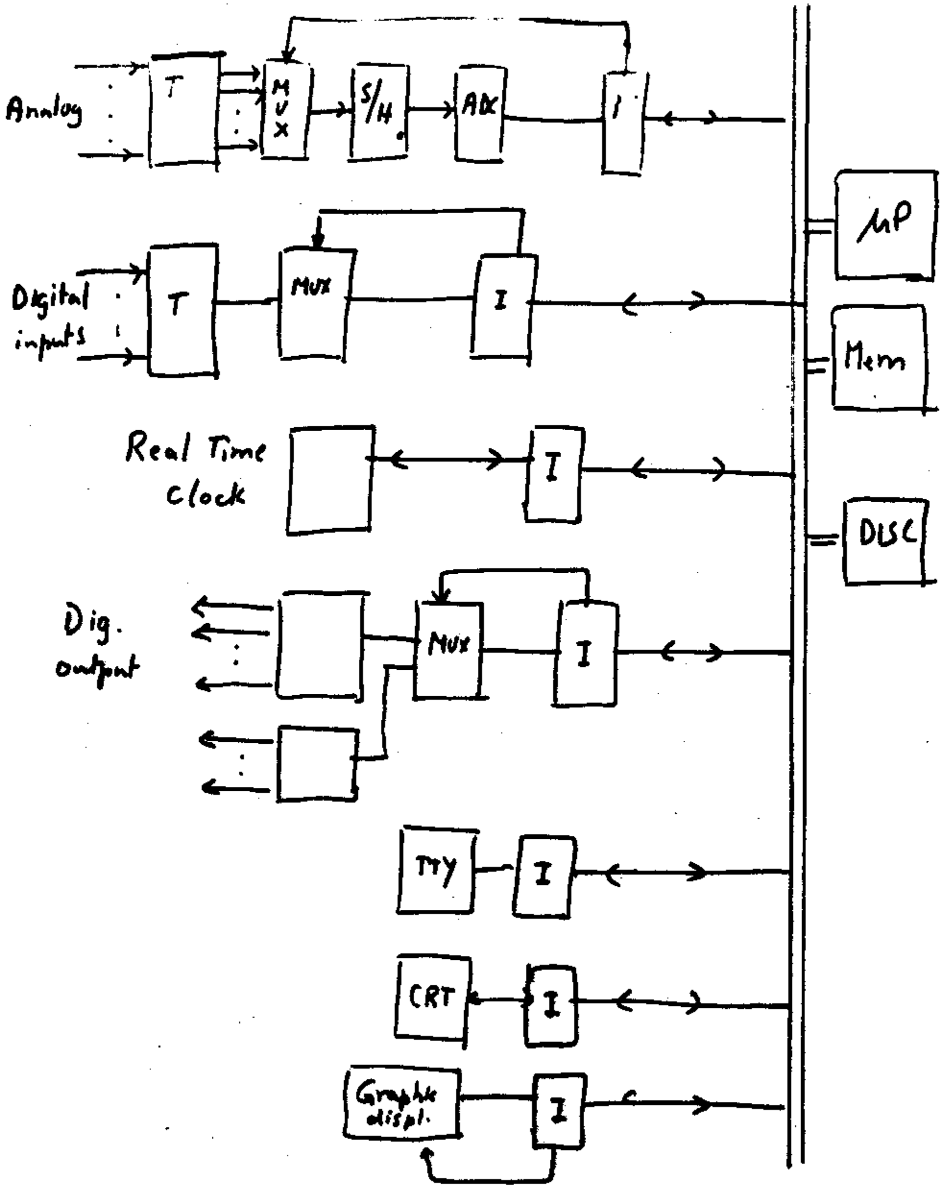
Coordinatograph

Special Display Devices

Graphic Displays 256 x 256 or better

with light pen / interactive facility

or joystick



DATA LOGGING AND CONTROL SYSTEM

SOFTWARE

- Matched for R.T. application. good O.S., etc
- Interrupt processing
- Multilevel priority (hw or sw)
- For speed, coding efficiency is imp
- μP must address directly large memory space
- DMA capability for transfer of large blocks of data
- Fast recovery from failures
- Undesirable effects due to a fault should restrict to a small area
- Manual changeover
- Modularity and flexibility, same basic system should be adaptable for a wide range of applications
- Duplicated control for higher reliability.

HARDWARE / SOFTWARE TRADE OFFS

- Optimized design in view of limited processing power
- Many trivial hardware operations if done by software require significant work load
- Simple repetitive functions that take up lot of real time processing should be delegated to hardware
- Functions with speed criticality are best best handled by separate hardware
- Some computation may be transferred to
  - a table lookup operation (ROM)
- A separate microprocessor may be employed to perform well defined fn that requires separate hardware

MONITORING FUNCTIONS

- Checking serious deviations from expected values
- Invite operator attention
- Test components / subsystems
- Assign low and high values to each variable
- Check result of computation