Digital Sensors:
Digitization &
Data Communication

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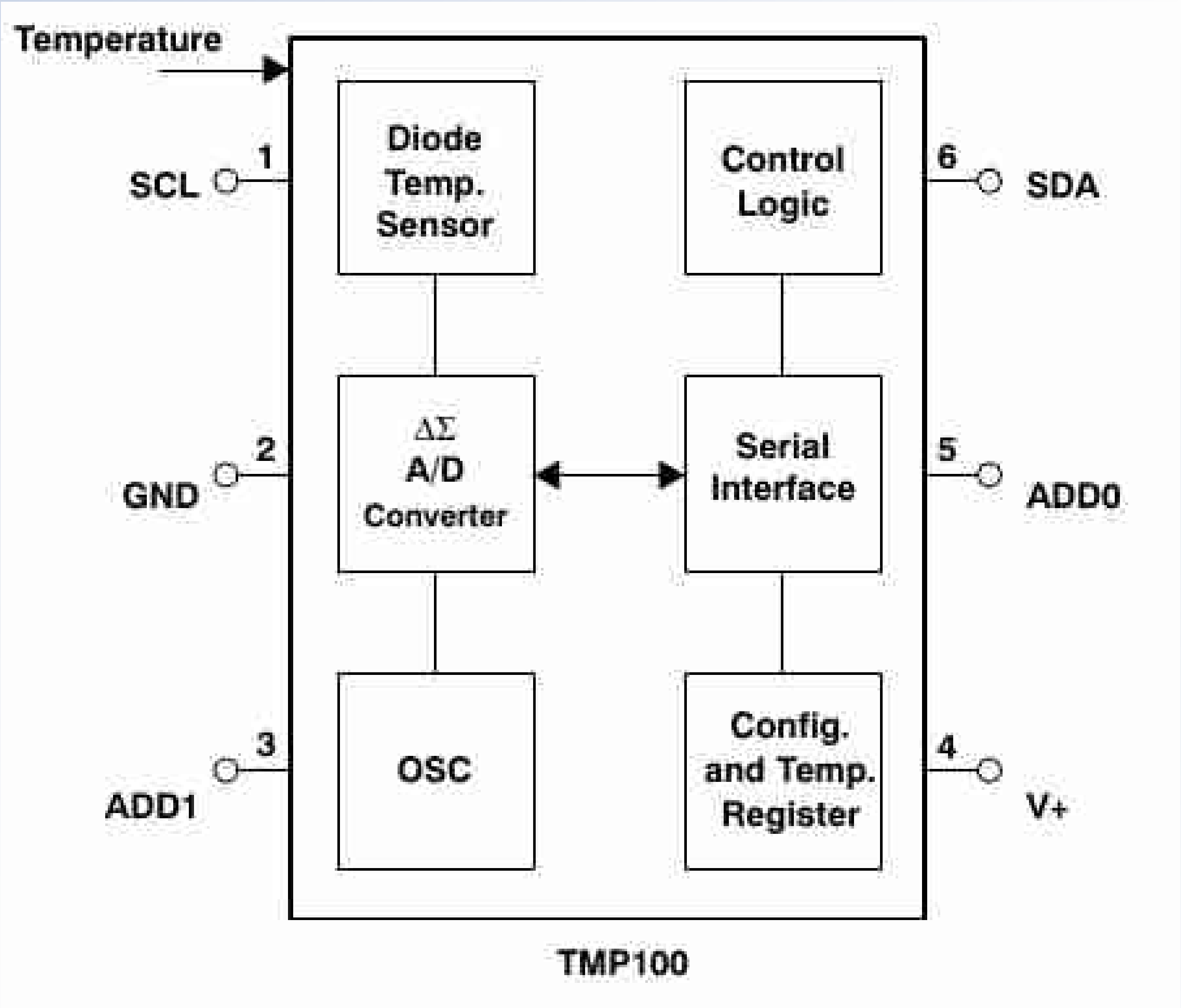
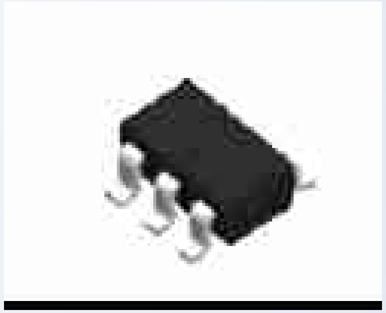
Lecture - Outline

- Digital Sensors
- Digitization
- Numerical data representation
- Data transfer
- Packet data
- Wireless and network data transfer
- Digital to Analog - Pulse width modulation (PWM)

Digital Temperature sensor - TMP100





TMP100 – Data format

TEMPERATURE (°C)	DIGITAL OUTPUT (BINARY)	HEX
128	0111 1111 1111	7FF
127.9375	0111 1111 1111	7FF
100	0110 0100 0000	640
80	0101 0000 0000	500
75	0100 1011 0000	4B0
50	0011 0010 0000	320
25	0001 1001 0000	190
0.25	0000 0000 0100	004
0.0	0000 0000 0000	000
–0.25	1111 1111 1100	FFC
–25	1110 0111 0000	E70
–55	1100 1001 0000	C90
–128	1000 0000 0000	800

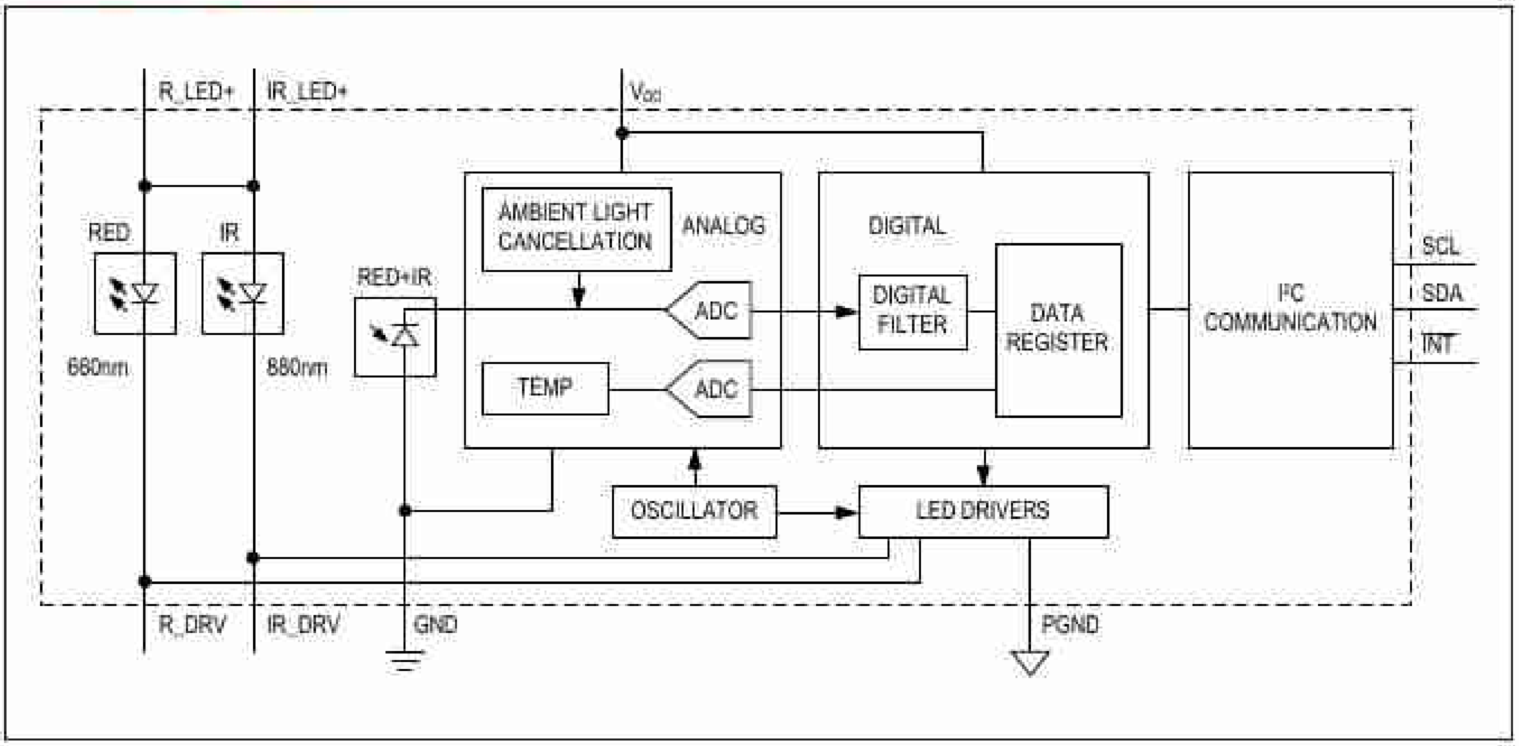
Table 5. Temperature Data Format

MAX30100 – Photoplethysmograph Sensor

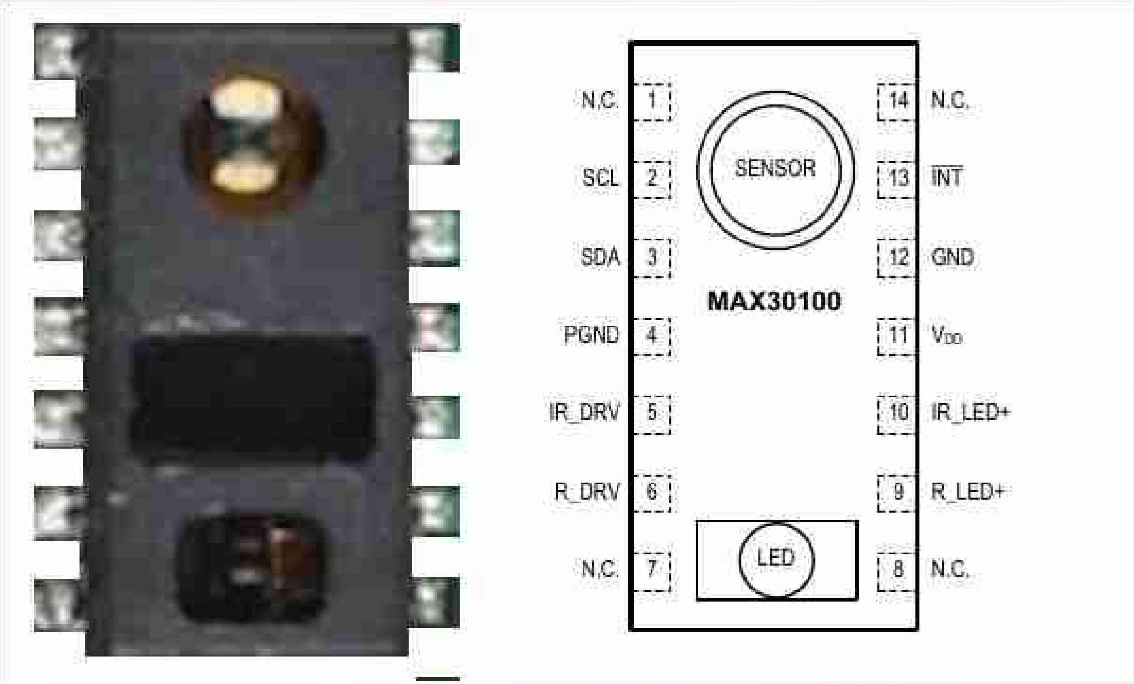
MAX30100

Pulse Oximeter and Heart-Rate Sensor IC
for Wearable Health

Functional Diagram

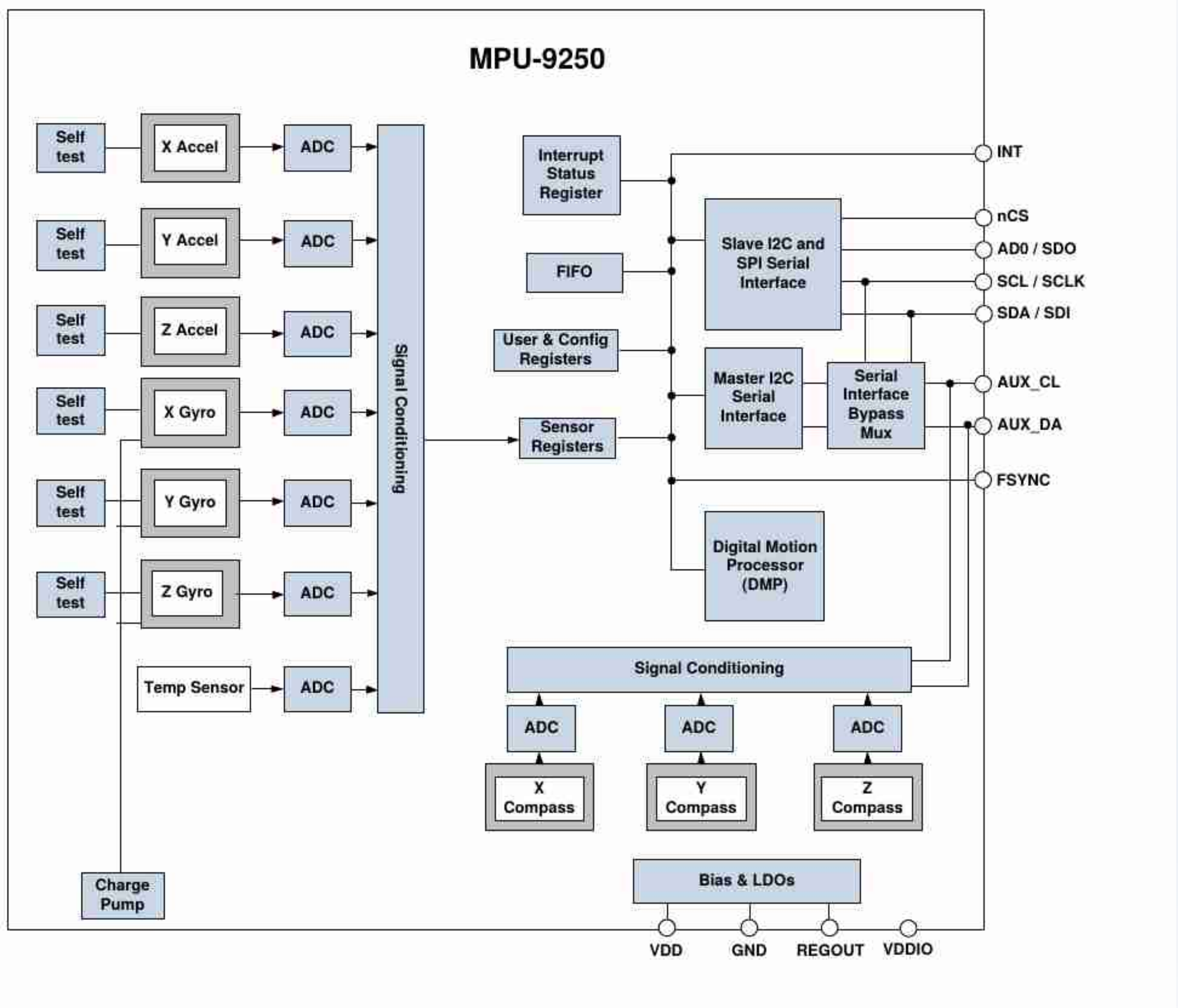


MAX30100 - IC

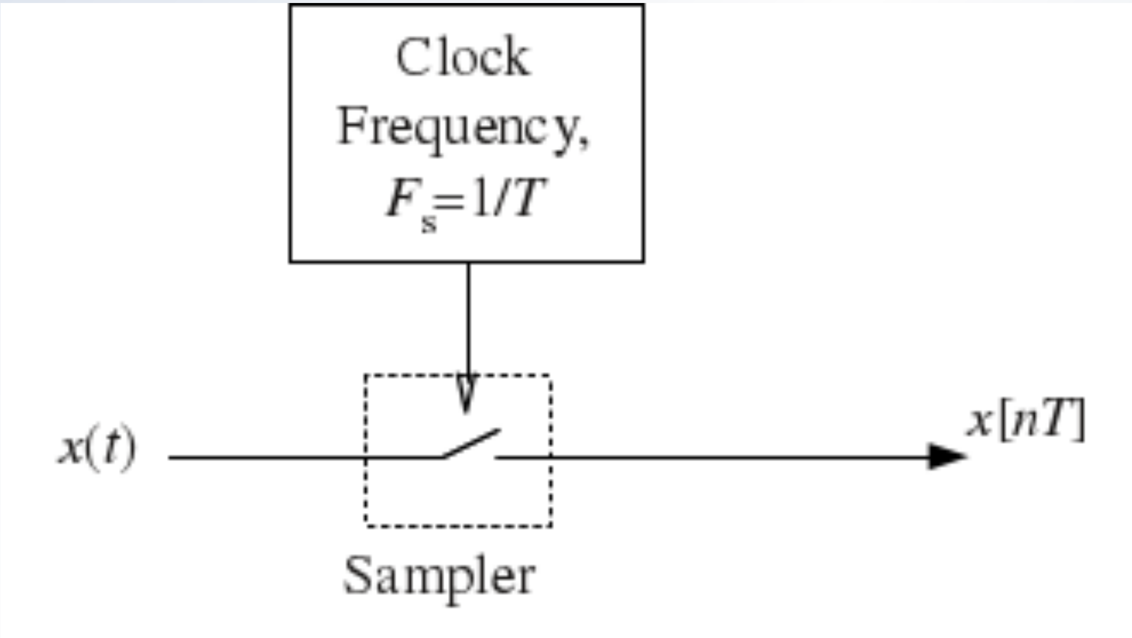


N.C.
SCL
SDA
PGND
IR_DRV
R_DRV
N.C.
1
2
3
4
5
6
7
SENSOR
MAX30100
LED
14
13
12
11
10
9
8
N.C.
INT
GND
V_{DD}
IR_LED+
R_LED+
N.C.

Inertial Motion Sensor - MPU9250



Digitization



Sampling Theorem

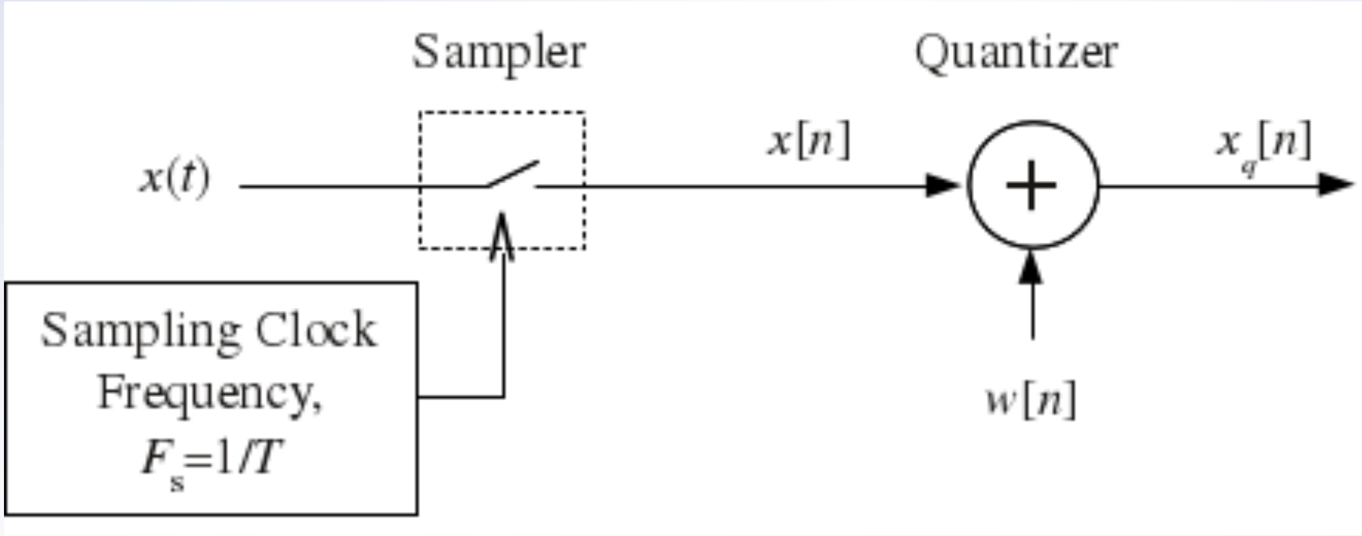
- If a signal is sampled at a rate of at least twice the highest frequency contained in the signal, then the original signal can be reconstructed from the samples.

Reconstruction of original signal from the samples

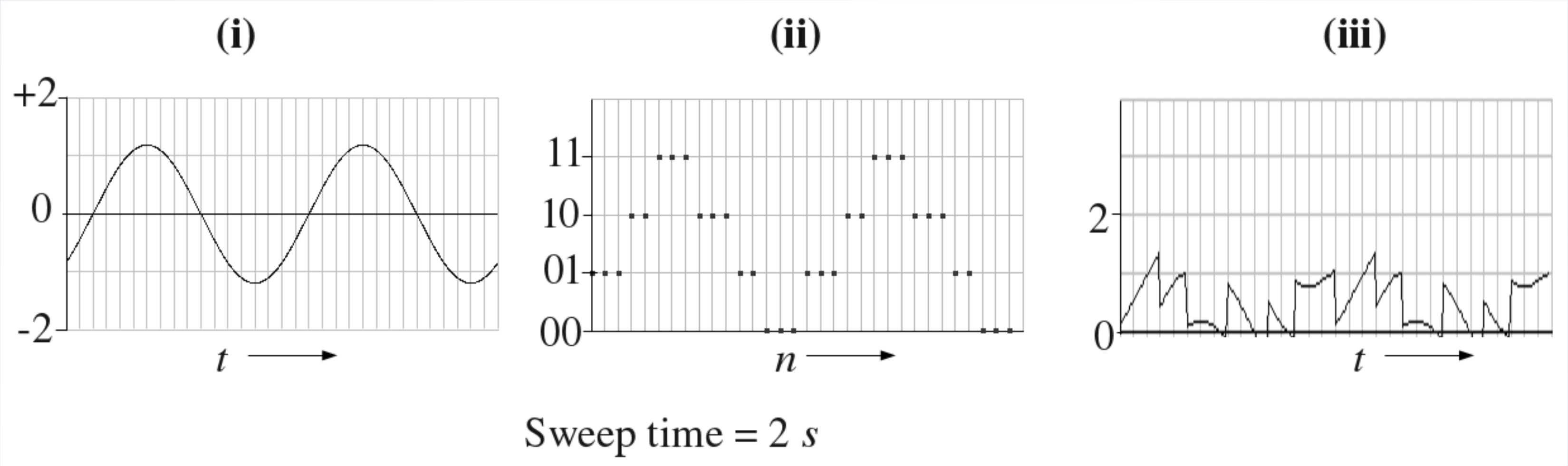
- The original signal contains frequencies less than half the sampling rate.
- If the sampled signal is low-pass filtered with a cutoff of exactly half of the sampling rate, then the original signal will be recovered.

- Practically, this method is difficult and expensive
- Approximate methods:
  - Zero-order hold
  - First order interpolation
  - Analog low-pass filter

Digitization and Quantization



Quantization “Noise”



Number representation

- Straight binary – only positive numbers
- For both positive and negative numbers
  - First half of numbers → same as straight binary
  - Second half → negative numbers
- Floating point numbers
  - Significand (fraction) and exponent

Parallel Data Transfer

- One wire per bit
- Plus ground wire
- Data updated when available
- Data read when desired

Serial Data Transfer

- Sequential transfer of bits
  - Big endian, little endian
- Synchronous
  - Requires a separate clock line
  - Clock rate determined by one Master clock
- Asynchronous
  - Each devices has Independent clocks
  - Clock rate needs to be same on all devices

Data lines – electrical connection

- Low voltage and high voltage data lines
- Ground referenced data line
- Differential data lines
  - USB, CAN
  - Immunity to electrical noise

Individual Bytes versus Packet data transfer

- Individual bytes
  - Simple universal protocol
  - Well established standard
- Packet data
  - Packet contains header and data
  - Header can contain source and destination information, other information
- Packet identifier and delimiters
  - Start of packet
  - Packet length

Network and wireless data transfer

- Network topologies
- Formation of networks
- Packet data transfer

Network Topology

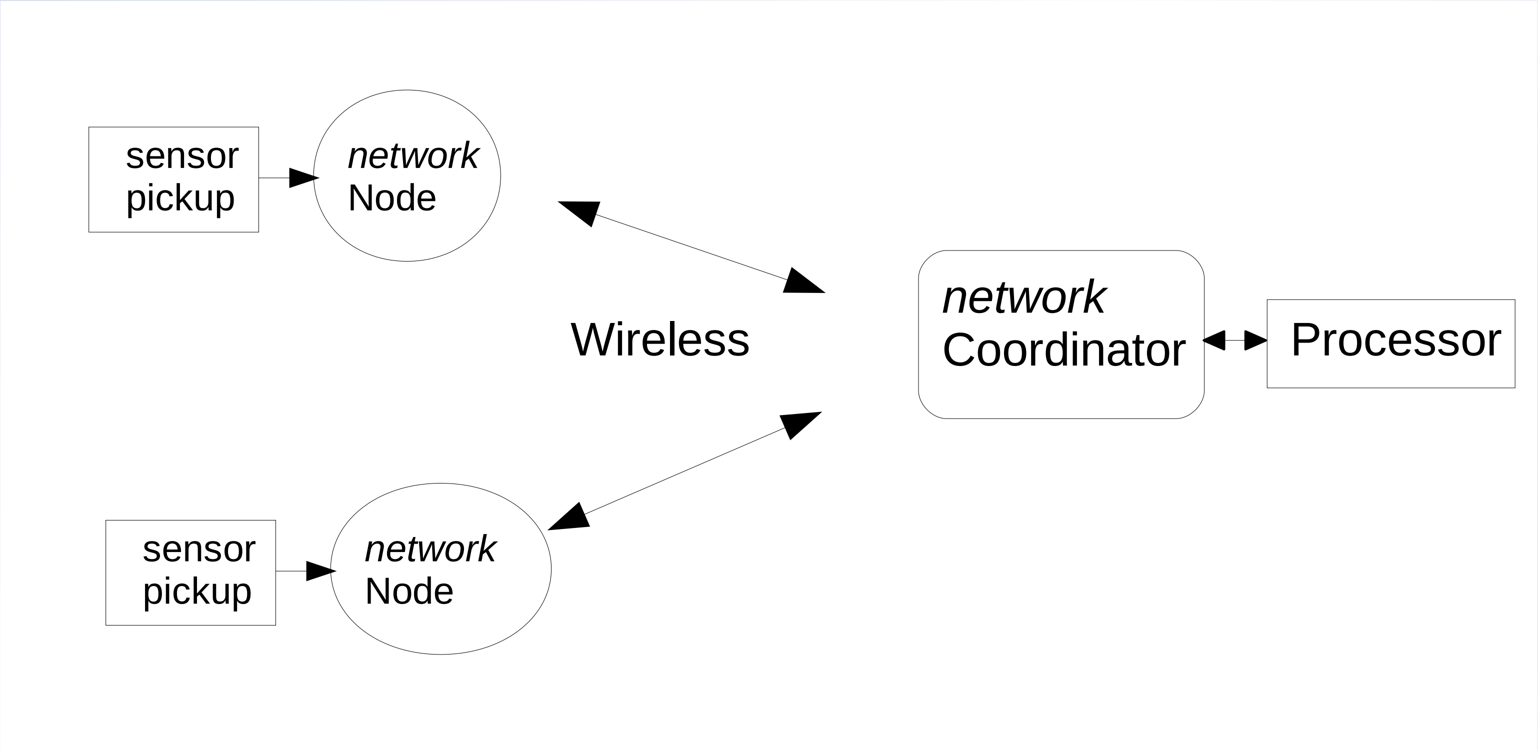
- Network topologies
  - Star
  - Peer-to-peer
  - Mesh

- Co-ordinator devices
  - Terminal node Input/Output devices

Example wireless network

- IEEE 802.15 for Wireless Personal Area Networks - ad hoc networks
- Frequency band is 2.4GHz, 16 channels (channels 11-26), license free.
- Uses carrier sense multiple access (CSMA) with collision avoidance (CA)
- Zigbee protocol is one realization of the IEEE 802.15.4 specification
- Physical layer (PHY), & part of MAC (media access control) with AES (advanced encryption standard) are incorporated in hardware.
- Globally unique address
  - 64 bit MAC address
  - 24 bit OUI, and 40 bit manufacturer assigned
  - additional 16 bit network address designating the current network

Wireless network - star



Node software

- At node power up
  - searches the medium for the presence of a network
  - if a network is found, the node checks the network identity
  - if it is a recognizable network, makes a request to join
- Micrcontrollers of the netowkr nodes have digitized sensor data
  - e.g., data is sampled at 1000 samples/second
  - Node uses a timer interrupt for ADC
  - Data packets size 80 bytes
  - 16 bytes are for a header specifying the type of data
  - 64 bytes of data

Co-ordinator software

- coordinator power up
  - checks the medium for networks
  - if its own network identity does not already exist, starts own network
  - after network has been started any recognizable node is allowed to join
- Coordinator is a state machine
  - States set by Software (Bluetooth/Zigbee) stack (interrupt driven)
  - States are polled for priority of action
  - Coordinator can also send data packets to the nodes

Pulse width modulation (PWM)

- Fixed clock rate, variable pulse width
  - Information encoded as pulse width
- Easy to decode
  - Estimate pulse width
  - Lowpass filter
- Poor error correction capability

End of Lecture