CAN Protocol Theoretical

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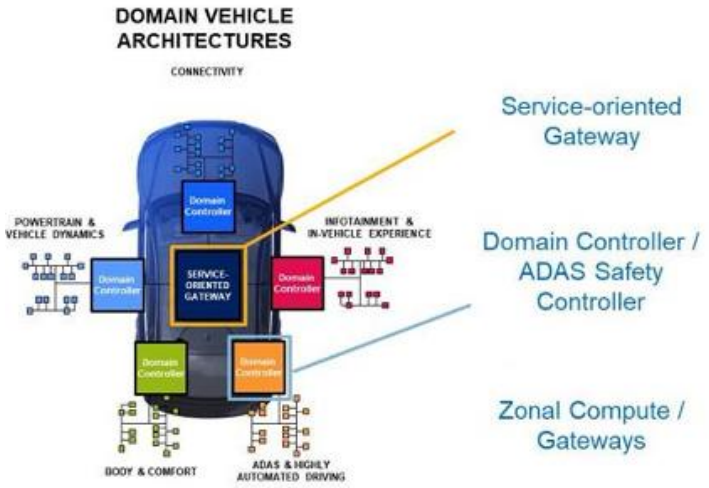
In Vehicle Network:

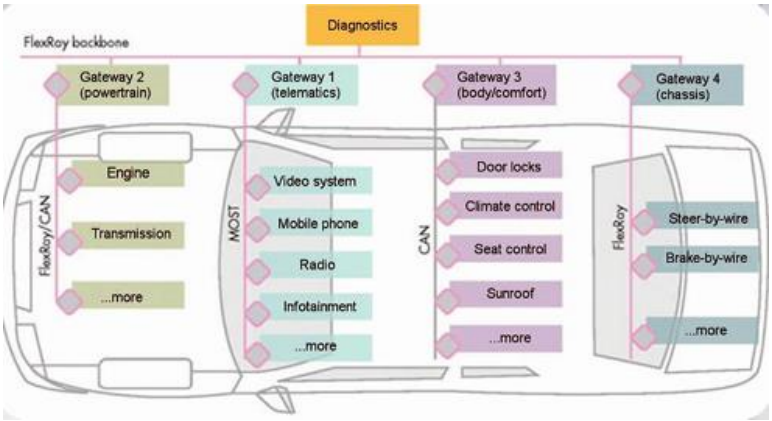
- ✓ **Definition**: How ECU'S Connected in Vehicle and connecting them according to what?

Evolution of in-vehicle networks:

1) Domain Vehicle Architecture:(Work in our days)

- This Classify ECUs in Vehicle Based on "Logical Domain".





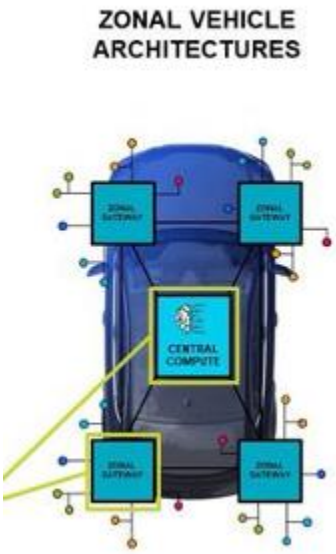
"**Gateway** is used to change from one protocol to another."

"**Diagnostics** Which connect It is used so that the technician recognizes the malfunction."

- Each Logical Domain Connected to gateway and gateway connected to service-oriented gateway.

2) Zonal Architecture:

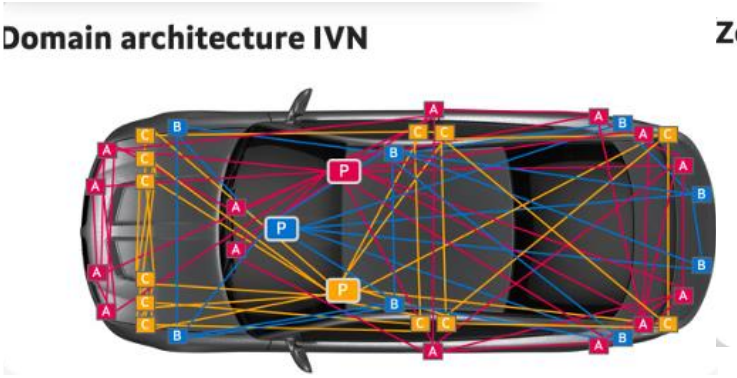
- In the future, the concept of specialized ECUs for domain-specific functions will continue, but the general trend is moving toward separation according to physical location (Zones) rather than by logical function.
- Zone ECUs connect via high-speed networks to a central ECU where much of the processing is done.

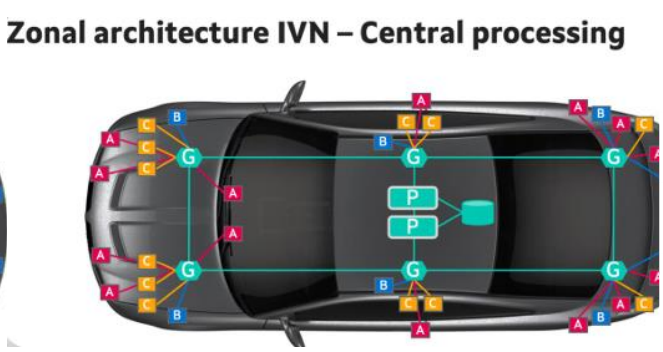


A typical wiring harness for a car:

- ✓ In many vehicles, the wiring that connects the electronic and electric components is so complex and extensive that, were it laid end to end, all those **cables would stretch over a mile.** This cable Obviously, complexity and weight both add significant costs, as well as energy consumption while driving
- ✓ Shedding the constraints of harnesses traditional wired, the most advanced vehicle designers are shifting toward **Zonal Architecture**, which leverages the backbone protocol Ethernet as between the car's different zones.

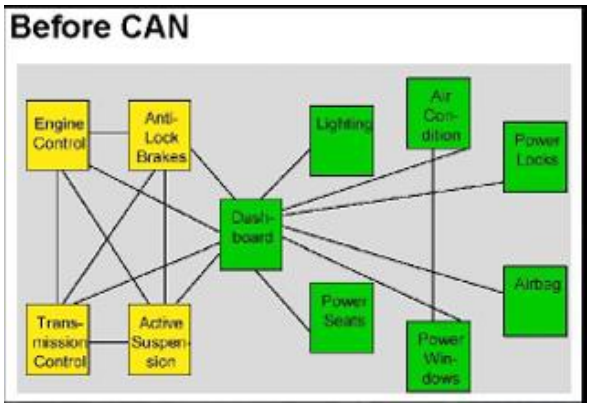
✓ Zonal Architecture dramatically streamlines automotive wiring requirements, reducing cable, labor and energy costs.

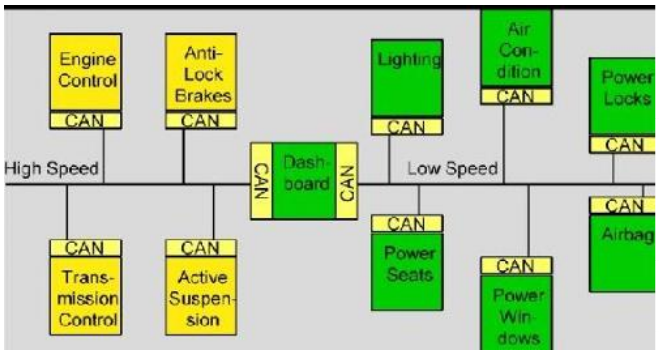




CAN bus– Controller Area Network bus:

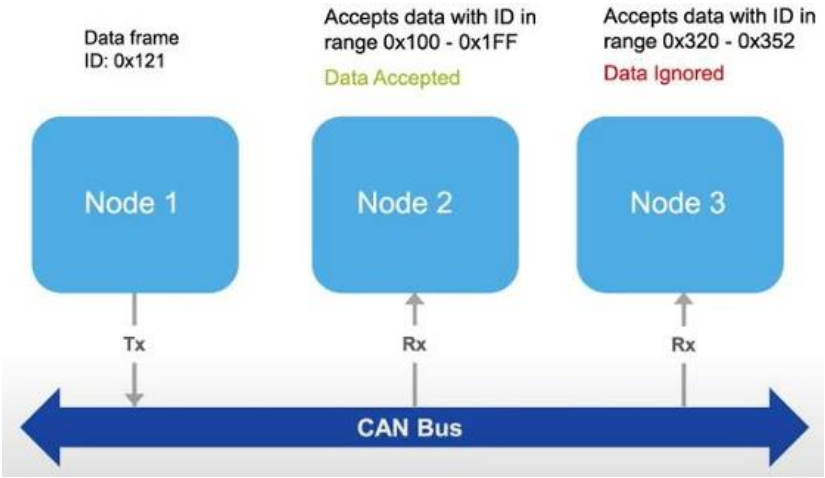
- ✓ Network multiple microcontrollers with 1 pair of wires.
- ✓ Allow microcontrollers to communicate with each other.
- ✓ High speed, real-time communication.
  - (Baud Rate up to 1 MbPS).
- ✓ Provide noise immunity in an electrically noisy environment.
- ✓ prioritization of messages.
- ✓ Low cost.





"Just only having CAN high, CAN low"

- ✓ **Efficient:** as there are priority and ID filtration as each node having range of IDs if msg send with ID in this range it accepts the msg and send ACK, if not having this ID not answer.



- ✓ **Reliable:** (There are five mechanisms for detecting errors in the CAN protocol)
  1. Bit monitoring
  2. Bit stuffing
  3. Frame check
  4. Acknowledgment checks
  5. Cyclic redundancy check

- ✓ **ROBUST**: High speed data lines are resistant to electrical disturbances.
- ✓ **Flexible**: Message-based protocol, this allows nodes to be added or removed from the system without hardware or software modifications to be done

CAN Bus History:

- ✓ 1983: First CANBUS project at Bosch.
- ✓ 1986: CAN protocol introduced.
- ✓ 1987: First CAN controller chips sold.
- ✓ 1991: CAN 2.0A specification published.

- ✓ 1992: Mercedes-Benz used CAN network.
- ✓ 1993: ISO 11898 standard.
- ✓ 1995: ISO 11898 amendment.

NOMENCLATURE	STANDARD	MAX. SIGNALING RATE	IDENTIFIER
Low–Speed CAN	ISO 11519	125 kbps	11-bit
CAN 2.0A	ISO 11898:1993	1 Mbps	11-bit
CAN 2.0B	ISO 11898:1995	1 Mbps	29-bit

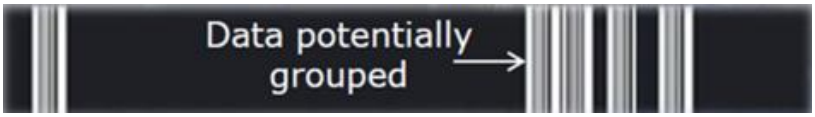
"Today semiconductor companies making bit in register to determine ID bits to be 11 or 29"

CAN Overview:

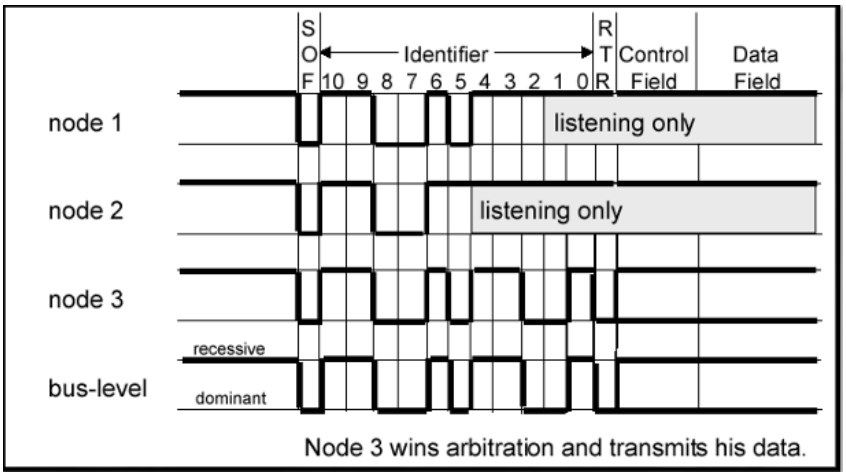
- ✓ **Multi-master protocol**
  - Any ECU can take a bus and send data on it.
- ✓ **Broadcasting**
  - Msg sent by ECUx reach to all nodes, each node can accept or discard according to its ID range.
- ✓ **Event-Driven**
  - Any ECU can send at any time.
- ✓ **Asynchronous communication (Event Triggered)**
  - There is no CLK between nodes, **but all nodes should have the same sample rate**.
- ✓ **Serial communication technology**
- ✓ **Priority-based bit-wise arbitration**
  - According to ID, CAN bus makes filtration, each Node make arbitration which mean that I send and also listen to check if my data is on bus or any node win.
- ✓ **Variable message priority based on 11-bit (or extended 29 bit) packet identifier**
- ✓ **Originally developed by Robert Bosch for automobile in-vehicle network in the 1980s**

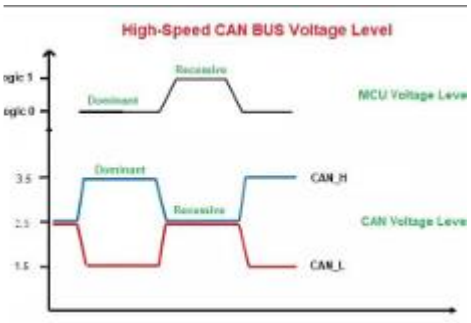
- ✓ **Differential, two wires with speed 1 Mbps**
  - Which immune to noise.
- ✓ **CSMA-CA= CSMA with Collision Avoidance**

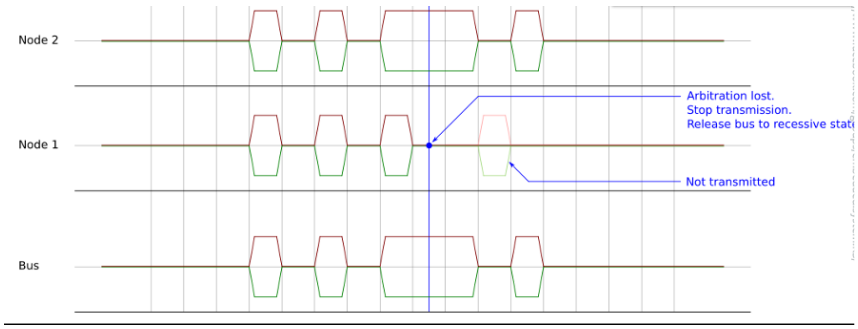
CAN General Characteristics:

- ✓ **Event Driven:**
  - Medium used only when necessary.
  - Time of message arrival is unknown.
  - 

- ✓ **Time Driven:**
  - Bandwidth utilization is known (duration of how long the medium is used).
  - Time of arrival is defined.
  - 

- ✓ **Bus Arbitration: "logical AND"**
  - Lower ID value = More important.
  - A "0" on the bus wins over a "1" on the bus.
  - Losing node stops transmitting, winner continues.
  - 

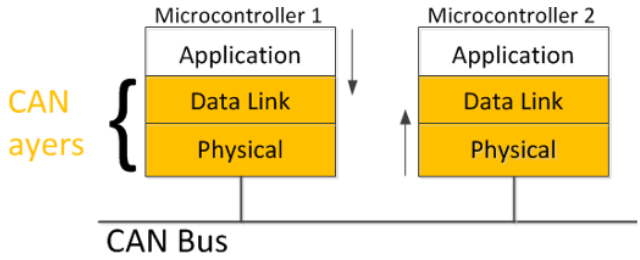




"Logic '0' called Dominant, while logic '1' called Recessive"

CAN stack and the OSI Model:

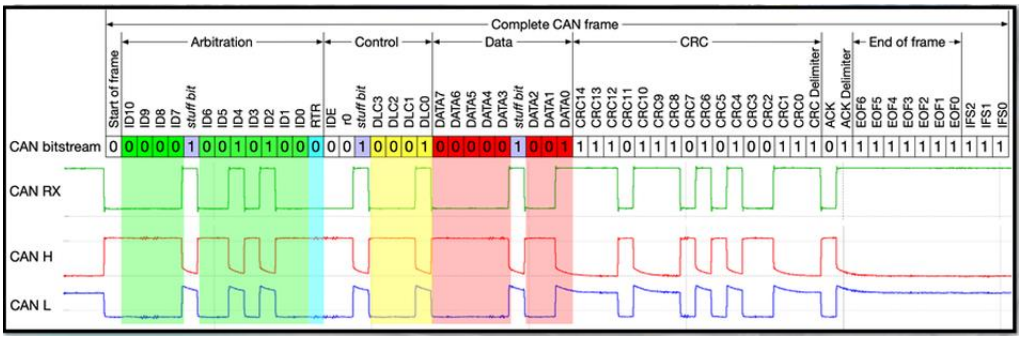
- ✓ CAN is a closed network
  - no need for security, sessions or logins.
  - no user interface requirements.

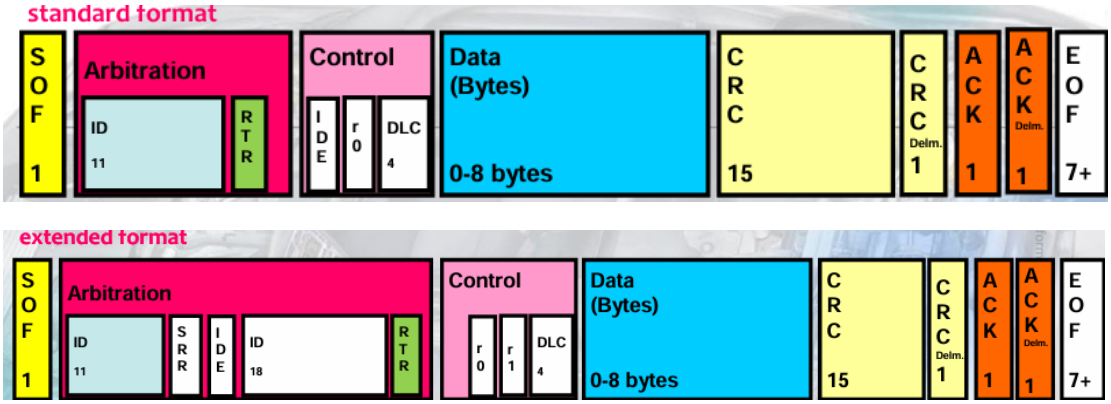


Types of CAN Messages:

1) Data frame
2) Remote frame
3) Error frame
4) Overload frame

1) Data frame:

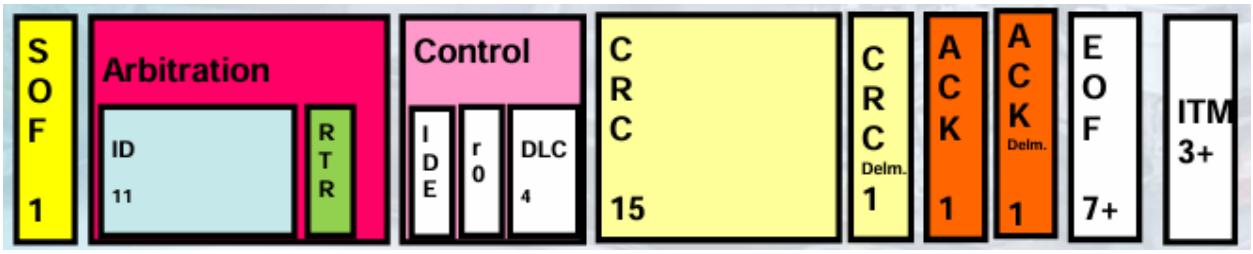




❖ Some Notes:

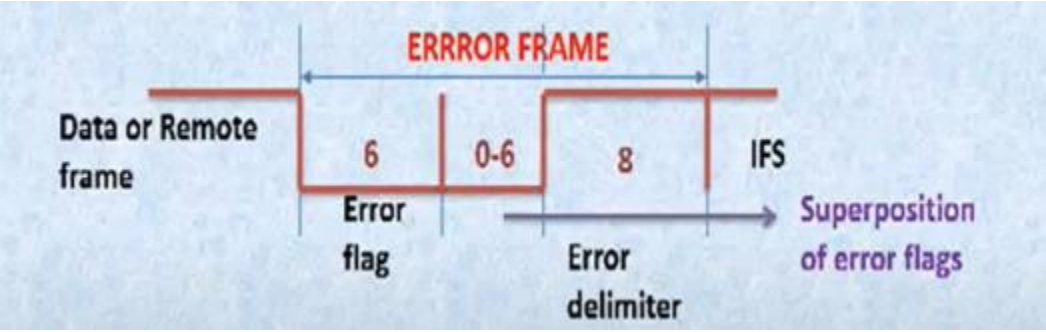
- RTR -> Remote Transmission Request.
  - If RTR = 1 Sending Remote Frame, RTR = 0 Sending Data Frame.
- To differentiate between Extended Format and Standard format Concentrate on SRR (substitute Remote Request) and IDE
  - if after ID (11) work Extended Format, if (0) work standard.
  - If IDE = 0 work standard, if (1) work extended.
- r -> Received bit.
- DLC -> Data length Counter to determine from it bytes size (0 ~ 8).
- After frame there is IFS Inter frame Space is at least 3 recessive bits called (ITM frame).

2) Remote Frame:



- Used by a node to request other nodes to send certain type of messages.
- Data Block removed from the frame.

3) Error frame:



- This frame consists of two fields.
  - The first field is given by the superposition of error flags contributed from different nodes.
  - The second field is the error delimiter. (Recessive)
- Error flag can be either an active-error flag or passive-error flag.
  - Active error flag consists of six consecutive dominant bits (0s).
  - Passive error flag consists of six consecutive recessive bits (1s).
- The error delimiter consists of eight recessive bits.

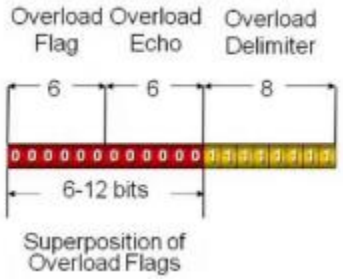
- In every CAN node, there are 2 error counters
  - Transmit Error Counter (TEC), When the transmitter detects an error in the transmitted frame, it increases the TEC by 8.
  - Receive Error Counter (REC), When the receiver detecting an error will increase its REC by 1.
  - On successful transmission/reception the error counters are reduced by 1.

- Based on the error counts, the node behavior varies.
  - By default, the Active Error frame will be transmitted on the bus, when TEC and REC < 96.
  - But when 127 < TEC \ REC > 255, the passive Error frame will be transmitted on the bus.
  - Finally, the node enters the Bus off state, when TEC > 255.

"If node enters into the bus off state, then no frames will be transmitted."

4) Overload Frame:

- Consists of two-bit fields: overload flag and overload delimiter
- The overload frame will be generated, when the receiving node is overloaded – i.e. it is not able to detect and receive the incoming messages
- The format is very similar to Error Frame (Active Error), but without the error counters incrementing.



✓ How does a CAN controller differentiate the overload frame and error frame?

- CAN node can distinguish them by **the time** when the frame was received:
  - An overload frame will only occur during the interframe space (IFS).
  - An error frame only during an actual CAN frame.

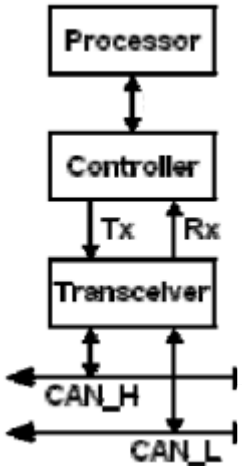
CAN Node:

✓ CAN Controller:

- deals with the communication functions described by the CAN protocol.
- It also triggers the transmission of CAN messages.

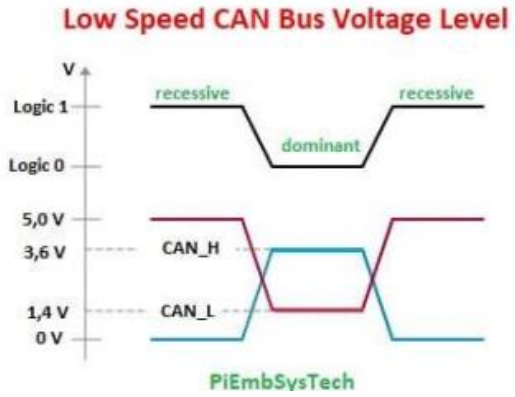
✓ CAN Transceiver:

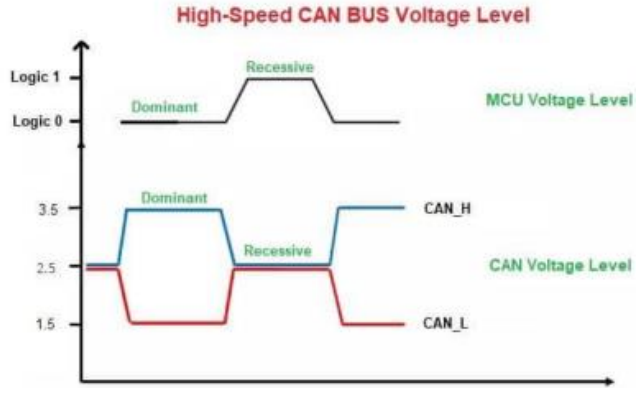
- is responsible for the transmission of data on the CAN bus.
- It converts the data signal into the stream of data collected from the CAN bus.



✓ **CAN BUS use two signal levels:**

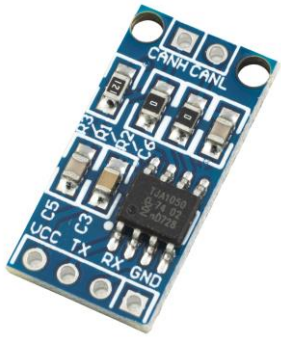
- Logic 1 is known as a Recessive bit.
- Logic 0 is known as a Dominant bit.





"All Transceivers use High Speed CAN Bus Voltage level"

✓ **TJA1050 CAN Bus Transceiver Module:**

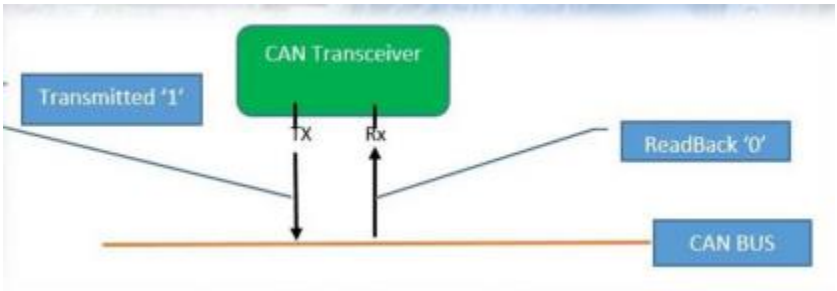


- Up to 1Mb/s bus speed.
- Up to 1000-meter bus length.
- 5V Operation.

CAN Bus Errors:

1. Bit error.
2. Stuff error.
3. CRC error.
4. Acknowledgment error.
5. Form Error.

1) Bit Error:



- If a bit mismatch detected during Arbitration field or ACK then transmitter neither looks it as bit error nor introduce any error frame because as per the CAN standard these fields has defined functionality.
- CRC Delimiter, ACK and EOF are also fixed length fields in CAN frame so it will also not be the part of bit error frame execution if more than five consecutive bits are found.

2) Stuff Error:

- More than 5 consecutive bits of the same polarity in CAN frame between the start of Frame (SOF) to CRC field is considered as a faulty frame on CAN Bus and it signaled as stuff error on CAN line.

3) CRC Error:

- The transmitter transmits CRC of transmitted data at CRC field of CAN frame
- The receivers also calculate CRC on received data.
- If the receiver found Calculated CRC is different from received CRC at CRC field, then receiver signaled it as CRC error and introduce an error frame on CAN line.

4) Acknowledgment error:

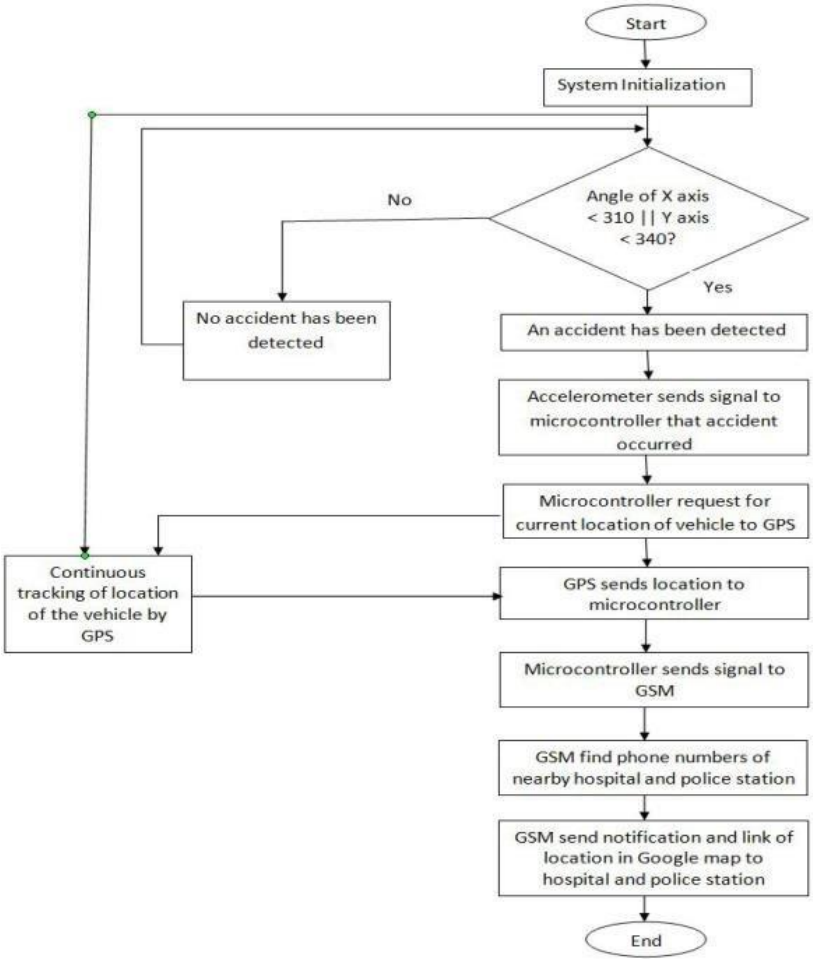
- After Transmission of CRC field of CAN frame.
- Transmitter send ACK (a recessive bit) and receiver makes it dominant as a part of acknowledgment to the transmitter.

- During the readback, transmitter found the dominant bit and considered it as receiver acknowledgment and if it reads a recessive bit then transmitter signaled it as ACK error and introduce an error frame.

5) Form Error:

- As per CAN Frame Format, there are some fields of fixed length and format like CRC Delimiter, ACK Delimiter, EOF, Interframe Space and if it is detected corrupted at receiver side then it signaled as Form Error and Node will introduce an error frame on CAN line.

Flow diagram of Project:



References:

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- CAN Bus Protocol:
  - A SEMINAR REPORT ON CAN BUS PROTOCOL | PDF (slideshare.net)
  - Control Area Network | PPT (slideshare.net)
  - Role of CAN BUS in automotives | PPT (slideshare.net)
  - Controller Area Network (Basic Level Presentation) | PPT (slideshare.net)
- TJA1050 Transceiver:
  - MCP2515 CAN Bus Module – Free Electronics (free-electronic.com)