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Inter-Networking Heterogeneous Embedded Networks through Universal Bus

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ABSTRACT

Distributed embedded systems can be developed either through wired or wireless based networking. Wired based networking is generally and frequently achieved through the use of protocols such as CAN, I2C, RS485, and USB. These protocols require uses different bus designs, protocols, terminations, arbitration, error control, device addressing, speed of communication, Formats of data packets etc. Interconnecting the Individual networks can be done using bridges, Single master interface, and Multi Master Interface. However the Number of buses running around will make the system complicated especially when interconnecting heterogeneous ES networks are implemented within automobiles like systems. The electrical characteristics of the signals flowing across these networks differ.

In this paper a method and a design is presented that show the way a single bus is used for releasing different ES networks, thus reducing the number of wires and signals flowing across the heterogeneous ES network implementation with the same application while supporting all the ES network specific issues that Include Protocol, Device addressing, Bus arbitration, Synchronisation, Data pocketing, error control, speed selection for data transmission, bus termination. Timing etc.

Key words: Embedded Networks, Universal Bus, ES networks**.**

1. INTRODUCTION

Many kinds of embedded networks are in existence and in use for implementing different types of Applications. The Most important Embedded System networking being in use include the networks that were built using the communication systems that Include I2C, CAN, RS485, USB. But as they technologies are emerging, a necessity arises that require bridging the ES networks that were built around ES networking standards.

All ES networking standards differ in many ways that include network termination, device identification, Type and format of data packets, type of signals used, speeds of communication.

Hybridisation of Embedded Networks can be achieved through interconnecting different types of wired networks that include I2C, CAN, USB, and RS48. Serial communication takes place among the hybridised networks. Hybridisation can also be achieved through establishing wireless networks or through a combination of wireless and wired networks. The major issue in such kind of networking is the management of communication speeds and data rates. May architectures can be used for achieving the Hybridisation of the networks which include single master integrations, multi master integrations, use of hardware based bridge, multimaster integration etc. The way a hybridised system works is dependent on the type of hybridisation method used. As on date Hybridisation through a Bridge device is proposed by [17]. Hybridisation can be achieved through other methods that include Single master catering for the communication, using Multi master interface and by developing Universal bus that caters for most of ES communication Standards.

2. PROBLEM DEFINITIONS

The main problem is interconnecting the heterogeneous embedded network while keeping the Bus width as small as possible.

3. RELATED WORKS

Lou Guohuan et al., [1] have analysed CAN bus and Modbus protocols and then proposed a protocol conversion interface and then shown the designing process that deals with various issues related to connecting devices that can get connected to one of the protocols

Xianjun Wang et al., [2] have analysed RS232C and CAN bus protocols that are supported on PIC Microcontroller. They have analysed both protocols and found the differences. They have designed and implemented the protocol conversion with an Idea of a device with CAN interface communicate with RS232C interface.

Lou Guohuan et al., [3], studied different fieldbus protocols and developed a gateway which is developed on ARM based Microcontroller system. The gateway is designed to support

many-to-many field bus conversion using a standard gateway packet.

Hao Zhang et al., [4] have studied both Profibus and Modbus protocols and since they cannot be interconnected have designed and developed a gateway that convert data packets moving across Profibus and Modbus busses. The have shown how the gateway can be used to facilitate communication between AT899C52 which supports profibus and the Siemen SPC3

Anupama K Benachinamardi et al., [5] have developed a CAN transmitter that has a I2C interface. It is easy to implemented I2C on any Microcontroller that has the CAN interface built inti it.

In a smart Grid system there is interconnect required between condition Monitoring system which is built on the basis of Modbus and a Monitoring system that is built on standardises system which is built using IEC61850 interface. When communication between standardise and a Non-standardised system is required, protocol conversion is needed. Fan Zhang et al., [6] have proposed a conversion method that converts the data packets moving either way between a Modbus and IEC61850 either way.

Most of the personnel computers are provided with SPI interfaces for communicating with the devices which have built in SPI interface. But the devices SPI interface cannot communicate with the devices that communicate using I2C interface. A protocol converter is required for making the devices with SPI and I2C interface to communicate with each other. Kiran et al., [7] have presented a protocol converter to effect communication through read and write in between the devices that are built with SPI and I2C Interface. The converter presented by them is an effective low power technique that includes clock gating insertion, dynamic power gating and use of Multi-threshold standard cells for reducing leakage power.

Jaskirat Kaur et al., [8] have addressed the issue of communicating between any of the wireless technologies RF, Bluetooth, and ZigBee and the GSM the cellular Mobile Communication, Any signal that may be RF or Bluetooth and ZigBee shall be converter to GSM. They presented a Multiprotocol gateway based on principle of WPAN (wireless personnel area network)

Many devices exists which communicate with different protocols. Converters are required for establishing communications among the devices that have different communication interfaces. The combinations of such conversions required are too many that lead to a requirement of general purpose converter. Jing Cao et al., [9] have proposed a general design over the concepts of buffers that can be used for implementing any type of protocol conversion. They have defined correctness conditions and have proved that their general purpose converters meet the correctness conditions. The model proposed by them also supports that the user defines the correctness conditions and the general purpose converters gets adjusted to the requirements. They hhave verified the correctness of their model using model checker.

Shwetha et al., [10] have proposed a Multi-protocol Interface that allows devices with multiple protocols that Include USB, SPI, Ethernet with the devices that are built with either SPI or RS232C interface. They have implemented the Multi-protocol conversion using DSP processor.

Multiple devices are used in IIoT (Industrial Internet of things) requiring frequent protocol conversion adding to too much of overhead to be processed. The performance of an IoT network as such depends on the time required for protocol conversion. The overhead becomes significant when communication has to be carried using multi-hop transmission over multiple gateways that convert one protocol to the other. Revathy Narayanan et al.,[11] have proposed a probabilistic framework that qualifies amount of time spent in conversion when a packet move over several hydrogenous gateways that implements different protocol conversions.

The speed of correspondence through I2C and RS232C get influenced because of the presence of complex electromagnetic condition as presence of such a domain will result into inappropriate disposal of the signals to the interfaces. Inappropriate transfer of electromagnetic will result into low speed and dependability. A few strategies are to be invented that help handling the issue of speed through legitimate cushion the executives [12].

Utilizing remote advances for the improvement of conveyed implanted frameworks is testing contrasted with wired systems because of presence of vulnerability and less unwavering quality that is caused because of attractive obstruction, blurring, reflection and so on. Consistency of remote correspondence is an issue. It turns out to be very unsafe for a framework when it needs to meet some security basic prerequisite by getting information through a remote system. The vulnerabilities existing with the remote correspondence can be settled through utilization of half breed models or undertaking hybridization of structural models. The idea of hybridization is increasingly common in the automotive area where everything must work consummately disregarding unsureness. Hybridization helps when the correspondence needs to occur in questionable circumstances. An engineering has been displayed that can be utilized to actualize applications requiring the idea of Hybridization. There are numerous interface gives that must be considered and took care of through a programming model which makes the framework hybridization-mindful [13].

Two gauges are as often as possible utilized which incorporate field bus and CAN bus for executing industry based applications, field bus benchmarks are not uniform and incredibly varies from industry to industry. Correspondence between the gadgets utilizing field bus in that capacity is entangled. In industry, both the transport based systems administration frameworks are often utilized. This has prompted a prerequisite of converting one kind of

correspondence to the next which can be accomplished through convention transformation. Convention transformation can be planned and actualized at equipment level [14].

CAN transport based correspondence can be utilized for systems administration with frameworks. The engineers needs to comprehend the CAN convention, Interface, controller and Physical associations before the applications can be created utilizing CAN based correspondence. Actualizing CAN based correspondence at net root level is entangled and furthermore needs thorough testing. The advancement of utilizations utilizing CAN is made to be straightforward through CAN module. The CAN being a convention suite can be coordinated with any inserted framework Software. Sending and getting the information can be accomplished through CAN module [15]. When CAN is to be utilized alongside other correspondence conventions, for example, I^2C, protocol transformations can be actualized at work level rather than net root level. In the event that another module that modified works I^2C communication is grown, at that point convention transformation can be accomplished at work level.

A different gadget can be structured and built up that has the capacity of doing convention change utilizing numerous Microcontroller based frameworks, fast double port RAM information sharing innovation, and continuous multi-entrusting framework μC/OS-II. A convention converter that helps correspondence somewhere in the range of RS232C and RS485 has been built up that can be actualized inside savvy instruments, information securing frameworks, etc. [16]. The gadget can be interfaced with a remote checking framework through Ethernet based correspondence. Along these lines, sequential gadgets can be connected to the system control layer. This gadget built up along these lines has high unwavering quality and continuous execution and acknowledge information trade, information sharing and data handling among various Micro controller based frameworks

Field bus convention is nonstandard and has been actualized in various forms. There is additionally an issue of interconnecting distinctive field buses. At the point when two systems are manufactured utilizing distinctive field bus correspondence convention transformation is required. ARM controller can be used for accomplishing the change. The convention transformation is accomplished through advancement of a protocol utilizing a standard information parcel. The strategy isn't constrained to coordinated transformation and is free of the area of the transport and the sort of convention utilized by the field buses [17].

A USB and I^2C convention varies in numerous angles considering the manner in which the correspondence is attempted. The information bundle groups, length of the system, number of gadgets that can be associated, number of ace, transport discretion, synchronization strategy, and stream control and so on varies a great deal. A mapping between I^2C and USB has been done both at the equipment and product level. The product structure that can be utilized for accomplishing the change has been displayed [18].

Modbus and Profibus are two correspondence frameworks utilized for accomplishing the modern mechanization. Both the specialized strategies are generally utilized in modern control field. Anyway, these two transports can't be associated straightforwardly because of presence of extraordinary fluctuation between them. An entryway is required for interfacing two unique transports through which convention transformation can be conveyed. A passage is created utilizing AT89C52 Microcontroller. Profibus and Modbus are two progressively basic mechanical field transport, they were generally utilized in modern control field. Since the two transports can't interconnect with one another, a Profibus and Modbus convention conversion js required. SPC3 is incorporated with the Micro Controller to achieve Profibus and Modbus conversions [19].

Numerous kinds of sub-frameworks are to be created and actualized, utilizing distinctive correspondence frameworks. For example, s Flight control, banking, therapeutic, and other high affirmation frameworks which should be executed most unequivocally. Since correspondence framework utilizes distinctive signalling, sheathing, commotion separating, signal disconnection and so forth., one should structure and build up the framework to such an extent that one sub-framework doesn't meddle with the other.

Following a data stream at equipment level is one strategy that can be utilized to distinguish and channel the differences. Door level in-arrangement stream following (GLIFT) framework is built up that provides a technique for testing data streams that happens inside I^2C and USB. Time division various access (TDMA) has been utilized that can confine a gadget on the BUS from the streams [20].

Mechanical Ethernet innovation (EPA) and Modbus correspondence innovation (MODBUS) are every now and again utilized correspondence frameworks to actualize modern procedures. No immediate communication in that capacity can be conveyed in the middle of these two frameworks as there is no immediate similarity between them. A correspondence passage is created for accomplishing the necessary interface between these two innovations. A passage has been created utilizing ARM based smaller scale controller and μCOS continuous working system. Bidirectional correspondence can be accomplished through utilization of the entryway. The correspondence entryway can give a steady, secure, constant and adaptable answer for process control of the power plants [21].

Two kinds of industry explicit correspondence frameworks are utilized in the power segments which are intended for National power dispatching and for controlling the breeze factories. For giving the coordinated vitality the board framework theories correspondence frameworks must be interfaced with one another. A door has been produced for to accomplish convention transformation that executes capacities like interconnectivity, convention information type, and configuration change and scaling, information approval, the board of neighbourhood/remote directions, recreation of information parcels transmission and

solicitations, communication bundles investigation and repetitive correspondence joins [22].

Field buses are utilized in industry for trade of information between several microcontrollers and field gadgets through affecting communication among them. Numerous adaptations of the field bus communication frameworks exist. Structuring a correspondence framework for impacting correspondence among the gadgets that keep diverse fieldbus correspondence benchmarks is mind boggling and by and large, prompts convoluted usage of equipment and programming. An effective correspondence interface is the requirement for executing a solid framework utilizing restrained field bus correspondence norms. CAN transport is additionally being utilized nowadays for actualizing a significant number of the mechanical procedure. There is a need to interconnect among CANBUS and MODBUS. The correspondence conventions are to be mapped considering various parts of correspondence and afterward an interface is required to be created. An interface that between associates both the transport based correspondence frameworks has been introduced. [23][24].

Many issues related to networking have been discussed [25][26][27][28][29][30][31] with reference to testing Distributed Embedded Systems

Various Methods and strategies have proposed by Rajasekhar et al., [32] for hybridising the networking of heterogeneous embedded networks. The interconnection between a I2C network and a CAN network can be achieved by developing a device that bridges both the networks. Speed Matching is one of the most important consideration that must be handled **[33][34]**.

The way networking of the embedded systems is carried depends on the kind of communication standard used USB[35], RS485 [36], CAN[37] and I2C[38] and also the kind of Microcontroller based systems used for networking.

Sastry et al., [39] have presented a method that helps in scheduling the messages that must be communicated over a RS485 network considering a specific application

4. GAP

Most of the Literature is on protocol conversion either one to one or through use of gateways. The issue of networking using heterogeneous embedded networks is discussed in terms of bridges or multi-master interfaces. But the number of such implementations required will be huge and also the networking becomes complicated. The complexity can only be reduced drastically if a Universal Bus can be implemented.

5. INVESTIGATIONS AND FINDINGS

5.1 Prototype Application for finding the complexity of using heterogeneous systems

An automobile System is developed using 4 Different ES networks each is built to meet a specific function. Table-1 shows the details of the functions implemented within each of the sub-net.

The networking diagrams of the individual sub-nets are shown in Figure-1, Figure-2, Figure-3 and Figure-4. Apart from other complexities, the main issue is dealing with signals and signal carrying wires within the automobile system. As many as 12 Signals and a Bunch of 12 wires have to be moved around in realising all the subnets which is the most complicated issue. One more complicated issue is dealing with signals with similar signal Range. The Device that get connected to different networks gets confused due to similar signal strength moving across the Bus

Table 1: Sub-nets and the Functions

Serial Number	Name of the Network	Function of the Network
1.	I2C Network	To measure the distance of the Object from the Car while reversing
2.	CAN Network	To control the Functioning of FAN located in engine
3.	USB Network	To control the Lighting System within the Automobile System
4.	RS485 network	To sense Temperature existing in the Engine

All the four networks require signals of similar strength. However this will not be an issue when a separate bus is used for each type of the network. The signal management will be Complicated when a Universal bus is used for driving the signals required for communicating with devices that follow different protocols. The devices as such gets confused. Unwanted devices may receive the signal starts interpretation and using the signals as most of the signals in different ranges are same making it difficult to differentiate.

In the case that one master is driving all the sub-nets, the master must be capable of handling four different protocols which differs greatly in many ways which include device identification, Bus Length, Synchronous/Asynchronous communication, Half Duplex/Full Duplex communication, .Error Detection and Broad casting, Arbitration, Communication Speeds, Bit rates, Number of devices, number and type of data packets and the size of the Data packets that can be transmitted, Bus termination etc. **Table 2** shows the comparison of the Characteristics of the protocols that Include I2C, CAN, USB, RS485 and Ethernet

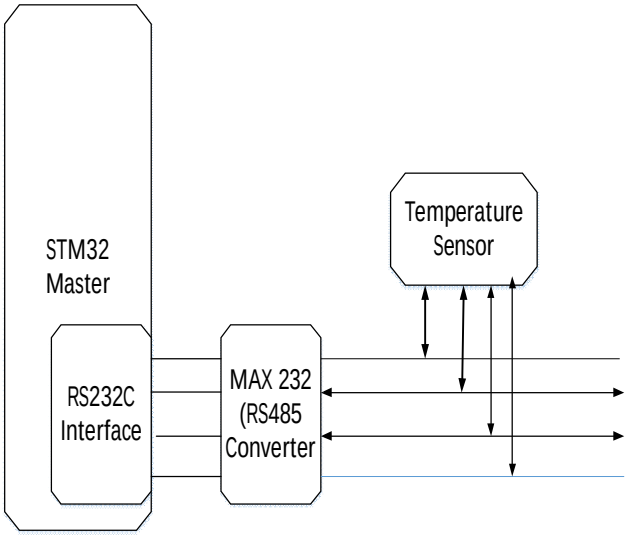

Figure 1: Reading Engine Temperature through RS485 Network

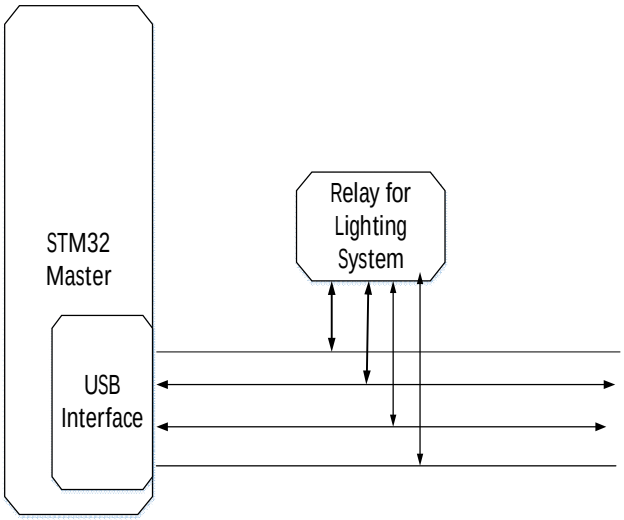

Figure 2: Controlling the Lighting System within an Automobile system using USB network

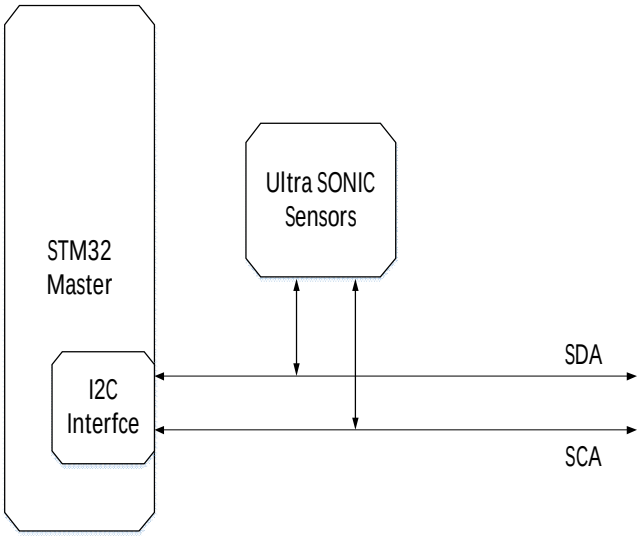

Figure 3: Reading the Distance of the Object while reversing the CAR using I2C network

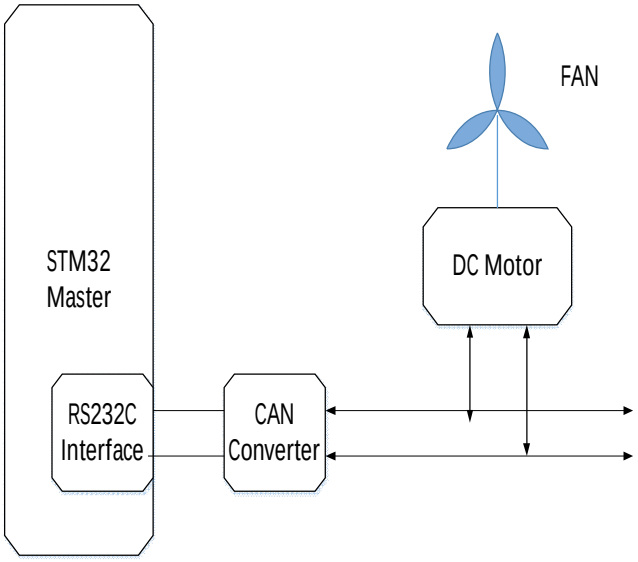

Figure 4: Controlling the FAN System within an automobile system using CAN Network

5.2 Design of Universal Bus

While all the characteristics of a protocol can be controlled by the respective protocols, it is the question of maintaining the proper electrical signals such that the devices connected to uniform bus will be able to recognise the signals and the signals emanated through execution of a protocol do not conflict with other signals asserted due to simultaneous execution of other protocols

The electrical signals of I2C and CAN do not get conflicted as separate signal lines are used within the Universal Bus. The I2C and CAN signal lines are used for transmission of RS485 and USB signals which also carry signals in the range of the signals used by I2C and CAN. When these signals are asserted, on the I2C and CAN lines, the actual devices connected to I2C and CAN will be activated generating spurious inputs or outputs. There is a need to normalise and de-normalised the signals, so that signals are differentiated and used appropriately as required. **Table 3** Shows the normalisation and de-normalisation of the signals

Table 3: Signal Normalisation

Type of Network	Voltage Range	Normalised voltage Signals	De-Normalised voltage Signals
I2C network	+5V or +3.3V	+5V or +3.3V	+5V or +3.3V
CAN	+5V or +3.3V	+10V or +6.6V	+5V or +3.3V
USB	3.3V	9.9	3.3V
RS485	5V	15V	5V

Figure 5 shows the design of Universals bus that uses 4 signal lines when compared to 12 signal lines used for implementing the proto type application.

The bus got reduces by 3 Times making it essay to run through the automobile system. Signals of different strengths moves over the Bus. While some signals are valid for a specific protocol, rest of the signals shall be floating. Signals other than I^2C are converted to different strength of the signals as defined in **Table 3**. The signals are converted to the device specific signals using the signal converter.

5.3 Algorithm to drive the Data across the Universal Bus from Master Side

Step -1

Maintain a table that describe the parameter and the Network to be used for Inputting and Outputting using the specific network. **Table 4** shows the details

Table 4: Parameters operated through Respective ES networks

Serial Number	Type of Parameter	Type of network	Input/output
1	Engine Temperature	RS485	Input
2	Distance of the Object behind the Car while Reversing	CAN	Input
3	Relay control for operating the Lighting System within the Automobile System	USB	Output
4	Control the Speed of engine FAN	I2C	Output

Step-2

Set Thresholds
Initiate 4 Tasks for Dealing with each parameter

Step-3

Initiative RS485 Task
Start RS485 Task
While (True)
{
Delay 10 Mille Secs
De-Assert Signals
Develop a Request Packet
Transmit the Packet
Wait for synchronisation time
Read Temperature Data

}

Step-3

Initiative CAN Task
Start CAN Task
While (True)
{
Delay 20 Mille Secs
De-Assert Signals
If the Temperature> 2 * threshold Set FullSpeed
If the Temperature>threshold Set Half full speed or else set normal speed
Transmit Speed data

}

Step-4

Initiative USB Task
Start USB Task
While (True)

{
Delay 12 Mille Secs
De-Assert Signals
If the Distance read is < threshold value Transmit data to set the RELAYON else set the RELAYOFF
Transmit the Relay status data

}

Step-5

Initiative I2C Task
Start I2C Task
While (True)

{
Delay 15 Mille Secs
De-Assert Signals
Transmit request for reading Distance Data
Wait for Synchronisation time
Read Distance Data

}

6. CONCLUSIONS

Gateways are helpful for transmission of data from network layer to layer especially on peer to peer basis

Communication between heterogeneous devices can be undertaken using protocol conversion, but the issue is limited to peer to peer communication

Embedded networks can be achieves through use of BUS based protocols such as USB, I2C, CAN and RS485. Each BUS based networking using a specific protocol is different as the protocol differs.

Internetworking between heterogeneous embedded networks can be achieved through use of networking bridge, Multi-master Interface, using single master Interface etc. However such kind of implementation makes the bus width so high and complicated

Developing a Universal Bus that integrates the different buses and achieving the interconnecting between heterogeneous embedded networks is most efficient and implementable.

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Table 2: Comparison of Embedded Networking protocols

Parameters	**I2C**	**CAN**	**Ethernet**	**USB**	**RS485**
Speed of transmission	100 kbps, 400kbps, 3.4mbps, 5kbps	500kbps, 250kbps, 125kbps, 10kbps	10mbps, 100mbps, 1gbps	12Mbit/s,480 Mbit/s	10Mbits/50 feet
Maximum Bus Length	100 Meters	1KM	4KM	3 meters for low speed 5 meters high speed	4000feet
Data length	8 bits	0-64 bits	368 to 12000bits	data field is not a fixed length range of 0 - 8192 bits long	8 bits
Max bits per sec	1 bit	1 bit	1 bit	480 megabits per second (mbps), or 60 megabytes per second (mbps)	1bit
Type of communication	serial	serial	serial	serial	serial
No of devices	Address	112	16	127	32
Bus termination	Both SDA &SCL are 5V	No reflection at end of cable nodes	Ethernet coaxial 50 ohm 10BASE2 networks absolutely must have proper termination with a 50 ohm BNC terminator	The USB Line termination is reached through the series resistors placed in the D+ and D− lines	Using termination resisters
Input Voltage Range	+5 V or +3.3 V	+5 V or +3.3 V	3.3 V to 5V	3.3V	5V
Synchronous and Asynchronous Communication	Synchronous	Asynchronous serial	Asynchronous serial	Asynchronous serial	Asynchronous serial
Device Identification Method	Address	Identification field	IP address	Address	Slave ID
Duplex/Half Duplex Communication	Half Duplex	Half Duplex	Full Duplex	Full Duplex	Half Duplex

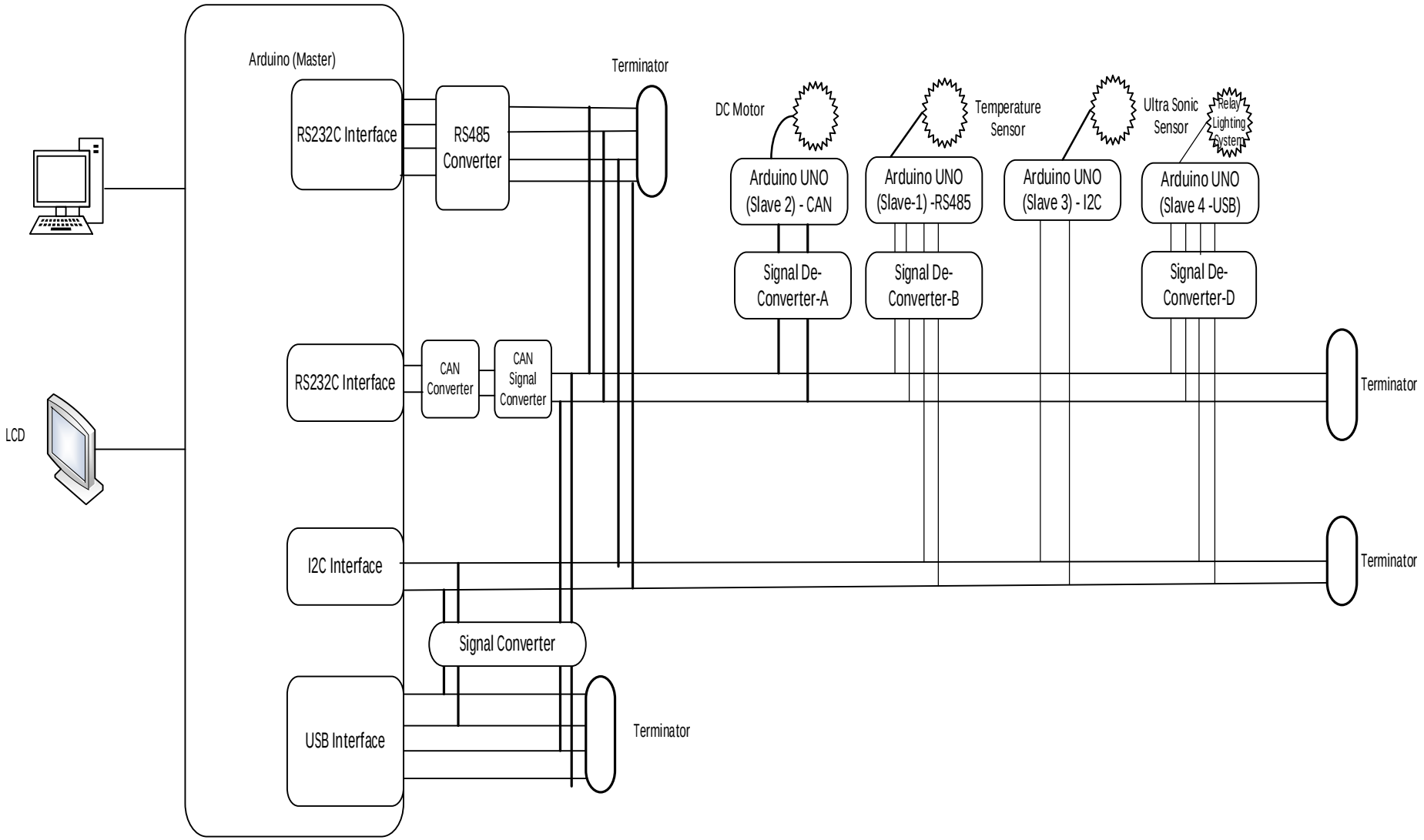

Figure 5: Universal Bus Design