Infrared CAN Interface – Principles of CAN Data Transmission using infrared light

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Motivated by the necessity of connecting CAN nodes without high installation expenses, the principles for infrared light based data transmission were developed applying the inherent CAN protocol. Unlike in concepts using radio transmission bitwise arbitration and acknowledge remained available. A first functional example for an infrared CAN Bus, coupled to standard CAN-controllers, has been implemented. Different configurations have been tested. The presented system opens the way for new applications of CAN as for data acquisition in explosive, liquid or any transparent substances, for short term experimental installations and in automation systems where wired networks are not applicable as in rotating systems.

1. Motivation

Planning experimental measurements on the boogie of trains a lot of sensors have to be installed for only some hours. For safety reasons the installation must not remain at the train between several experimental phases. It has to be installed and removed after the experiment quickly and easily. Once the CAN bus was favoured for event driven data acquisition, in an area with many moving parts a wireless solution seemed to be profitable.

To avoid the inconveniences of radio waves as the sensitivity to disturbances caused by the vehicle or other sources, infrared light seemed to be more reliant in areas covered from daylight and sufficient for the short distance requirements. Good benefit was expected from decoupling the bus electrically to avoid ground loops and to pass the signals through closed windows. Consequently the practicability was investigated theoretically and a functional example has been implemented.

2. Basic approach

A first approach to use the wireless optical medium was to adapt the principles of wired optical data transmission as available in many commercial devices and described already in [4]. This method is characterised by the transmission and reception of the light signal from a glass fibre. The signal is transmitted directly to the RX and TX Pins of the CAN controller.

In terms of wireless communication this could be adopted by focussing many optical transceivers to a diffuse reflector assuming it as the central optical medium (figure 1).

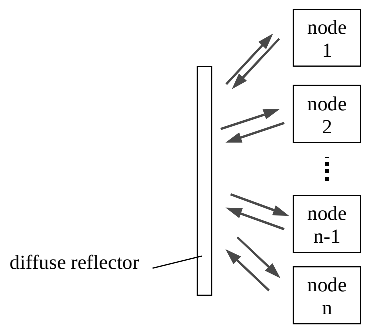

figure 1 – centred arrangement

This method is limited by the obvious geometric constraints, hence a spatially more independent way needed to be developed. In opposite to the above mentioned constellation, the nodes should be mounted sequentially. All signals have to be read from the neighbour(s) at one side and have to be transmitted to the neighbour(s) on the other side. An infrared CAN repeater network would cope with this task, covering the centred formation too.

A scheme of a chain of infrared CAN modules is shown in figure 2. Combined variations such as tree formations should be possible. Circles may be advantageous if a beam is temporarily covered.

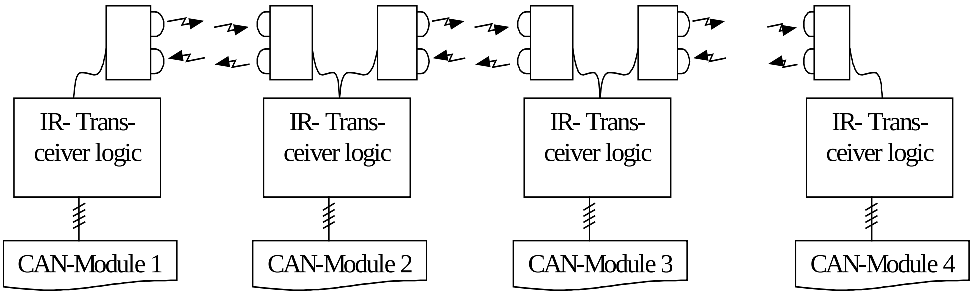

figure 2 - repeater chain constellation

The Transceiver is connected to the CAN controller and consists of the transceiver logic and one or more IR transmitter and receiver diodes. The number of diodes has no impact on the logic, since they are connected to the same signals. Some few diodes become necessary to increase the intensity of light and to adjust the infrared light beams to the direction of the adjacent receivers. More than two directions are possible.

3. The IR-CAN repeater principle

There are two tasks the IR-transceiver logic has to treat with: Synchronisation of all nodes and bus timing for the data transfer. For simplicity the synchronisation is assumed to be done only once at the beginning of a telegram, provided that the accuracy of all oscillators involved is sufficiently high.

Observing the behaviour of the repeater chain the procedure of CAN data transmission can be described by three main phases for each Bit:

1. Synchronisation gap: The transceiver transmits the assumed signal from the CAN controller to the infrared bus. It emits light for a dominant bit or no light for a recessive bit.
   The device is not yet watching nor repeating the infrared bus level.
2. Repetition segment: If the wished signal is a dominant one, the transceiver continues sending. Otherwise the transceiver watches for infrared light and repeats it, if a dominant level was found. In this phase the detected signal is passed through to the CAN controller.
3. Hold segment: The transceiver holds the bit level until all nodes have finished their bit time and passes it to the CAN controller without observing the current state of the infrared line.

The sample point can be set after the complete repetition of the IR-level of all members. Then the CAN-Module compares detected signal to its own signal. In the arbitration phase of the telegram the controller will decide whether to cease sending or to continue.
Figure 3 shows the signal propagation through a chain of IR-CAN repeaters or nodes. For the 5th node the bit timing inside the controller is added. It can be seen, that the sample point of the controller has to be adjusted between 60% and 80% of the bit time.

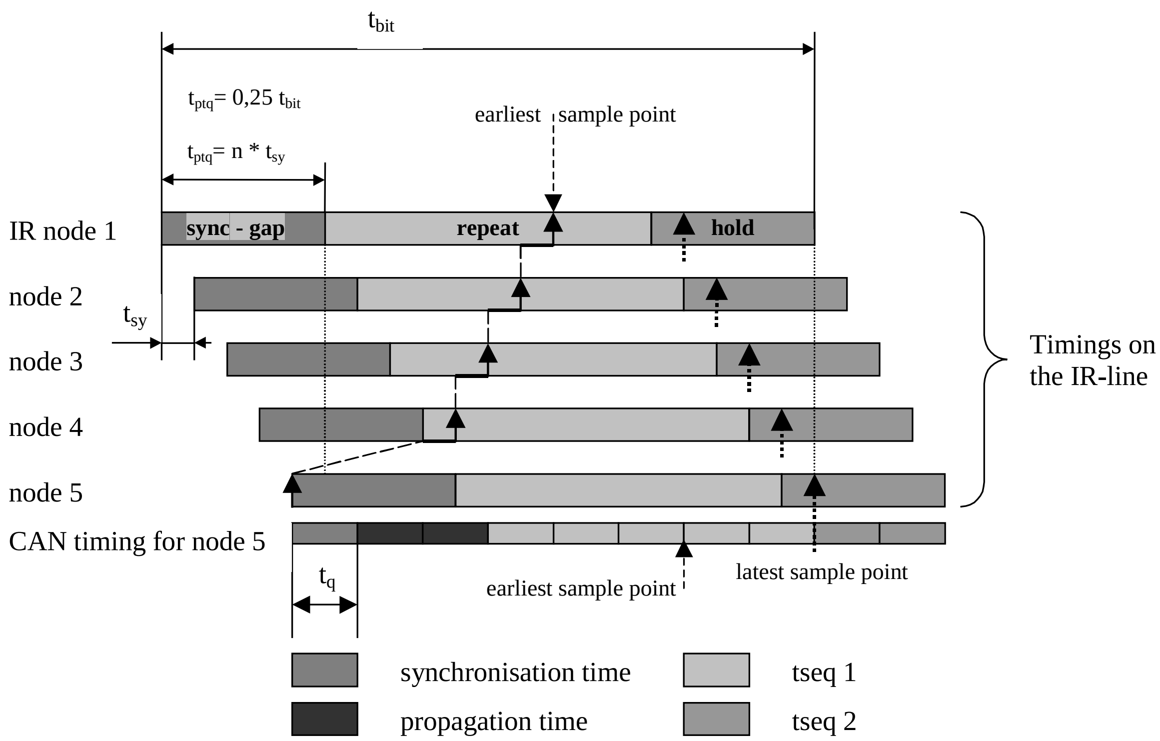

figure 3 bit timing diagram

The maximum baud rate depends on the longest path of signal propagation and on the latency time within each single transceiver that equals the synchronisation time t_{sy}. This time depends on the oscillator clock frequency, the time for logic operation and the time to activate the optical transceiver. The minimal bit time can be calculated by the equation:

$$t_{bit\_min} = (4*n-2)\ t_{sy}$$

To simplify the logic and to add some time for compensation of the oscillator jitter, the equation can be reduced to

$$t_{bit} = (4*n) * t_{sy}$$

leading to the following calculated baud rates:

number of nodes on longest path [n]	number of t_{sy} for complete signal propagation	max. baud rate example for propagation t_{sy} <= 250ns (500ns)
2	8	<= 500 kbit/s (250 kbit/s)
3	12	<= 333 kbit/s
4	16	<= 250 kbit/s (125 kbit/s)
up to 8	32	<= 125 kbit/s
up to 50	200	<= 20 kbit/s (10 kbit/s)
up to 100	400	<= 10 kbit/s

table 1 calculated baud rates

Theoretically there exist no maximum of nodes, but there are geometrical constraints when focussing many nodes to one reflecting area as well as economical limits, once the baud rate decreases continually when increasing the number of nodes.

4. Test Implementation

The test implementation bases on the application of IrDA-transceivers [3] that are originally dedicated do semi-duplex data transfer up to 4 Mbit/s, for transmission and reception of the Infrared CAN signal. The logic was designed to fulfil the time limits of ¼ of the maximum Baud rate of 1Mbit/s using a 10ns programmable logic device (PLD). The 16 MHz oscillator reduced the time clock jitter to less than ±32 ns. The baud rate is adjusted using jumpers for easy handling. Each node got one or two optical transceiver modules with flexible coupling to the logic unit. In this way it can be lined up to the adjacent transceiver individually. For connection to more than two CAN nodes a white paper as a diffuse reflector shield turned out favourable. A scheme of the complete interface shows figure 4.

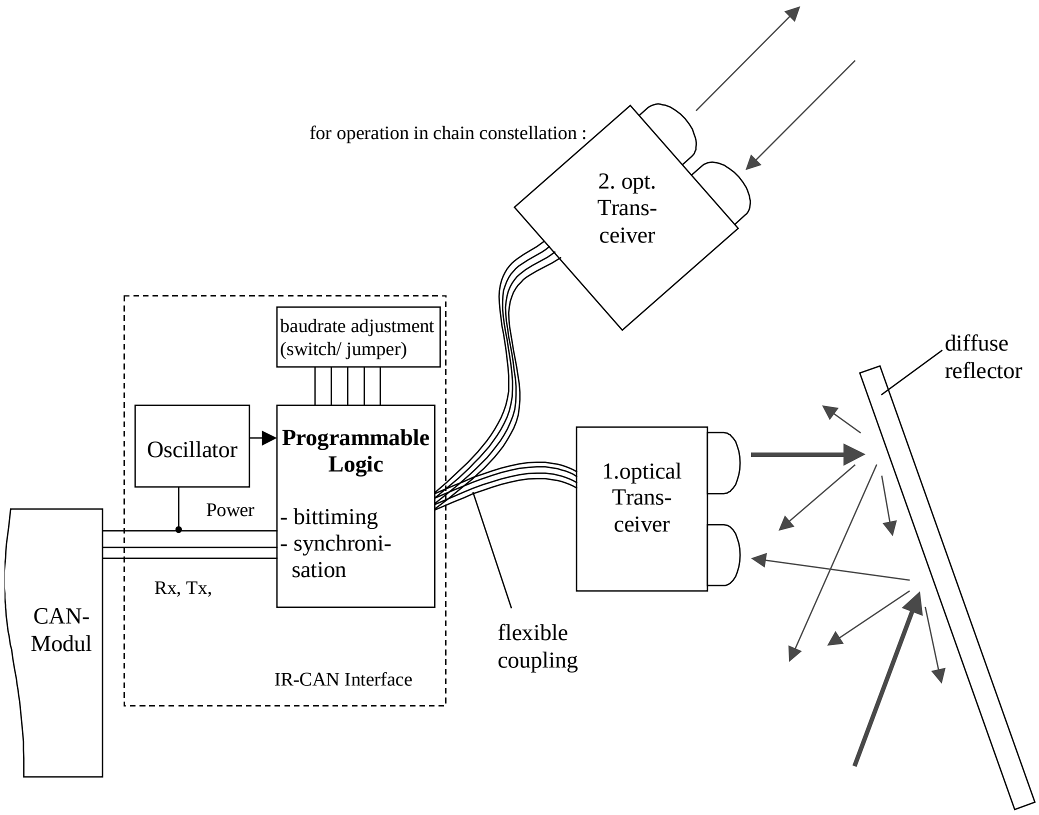

figure 4 test implementation of IR-CAN transceiver

The optical receiver (IrDA) appeared as the limiting factor. As a whole t_{sy} <= 350ns were measured. Hence 250 kbit/s for two nodes and for centred configuration of 3 nodes could be verified using a white sheet of paper as reflector. For 3 nodes in a chain, 250 kbit/s failed as expected.

Save performance could be shown up to 20 cm of distance between the transceivers. Since other emitting diodes show different behaviour this relatively short distance might be increased using other types of emitters.

Further tests as performance at daylight conditions will be continued in autumn 2000. Therefore the implemented net will be coupled to a second, wired CAN network using a Controller board with two CAN modules. Different scenarios as data acquisition through closed windows will be tested.

5. Outlook

The next most important step is to build a passive coupling device between infrared medium and wired networks.
There might be two main applications for such a device:

1. connect wired CAN nets through a closed window by passive couplers and
2. connect many wired networks at one centred point also using passive couplers as shown in figure 5:

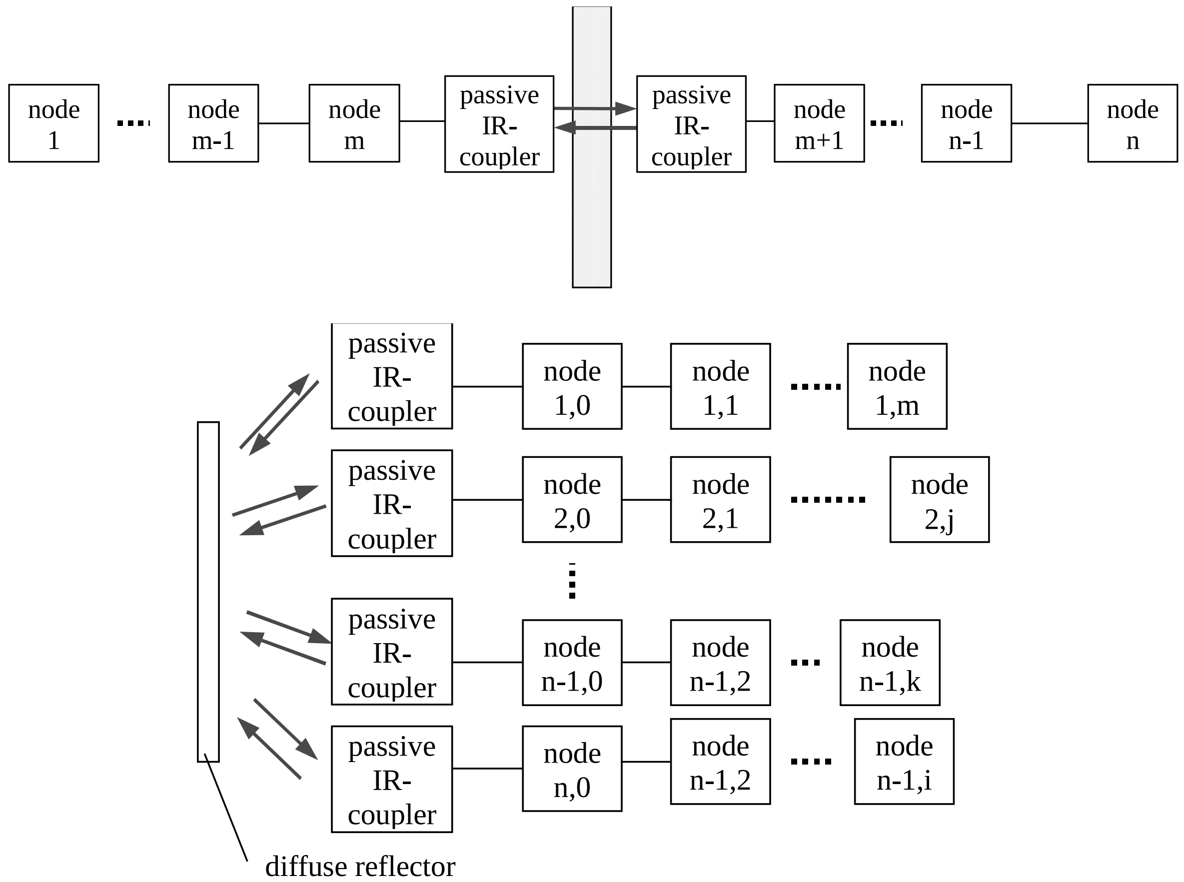

figure 5 planned configurations

Further aims of development will be:
- increase speed and distance covered
- reduce space and energy consumption for battery applications (at least for passive repeaters)
- include features for easy light beam adjusting

References

[1] Hartwich, F., Bassemir, A.: The Configuration of the CAN Bit Timing. Proceedings of 6th International CAN Conference, CiA, Turin, 1999

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[3] IrDA Serial Infrared Physical Layer Specification, Version 1.3, October 1998; http://www.irda.org

[4] Etschberger, K.: Controller Area Network. Hanser Verlag, München, Wien 1994

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