

4060 - T29: Real Time Networking Student Log

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January - April 2024

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1 Introduction

Intro The following is a log or perhaps a journal of my efforts in COMP 4060 - T29 - Real Time Networking. I will break the document into sections for each Month and subsections for each week. Each day will contain a paragraph explaining what I had accomplished.

2 January

2.1 January 8-12

Jan 8 I did some preliminary reading of the documents provided on CAN networks. I only spent about an hour reading, little notes.

Jan 11 Dug into the data sheets. Started examining the UART drivers we need to build. Probably 30 mins or so taken aside. Industrial Project has hit the fan a bit and taken up more time. I set up a calendar for the group as we all have fairly tight schedules right now.

2.2 January 15-19

Jan 15 We had an hour-long group meeting today. We discussed the pace of the project we would like to achieve. Send off an email to confirm some items and inform the Supervisor of our meeting availability. I started to dig into blinky again with the updated code. To my grief, I have switched to VScode and started to try and get the debugging working with the help of the other group members. I spent another hour or so getting the debugging to work in VScode, I stopped once I had the debugger open, openOCD via VScode. I started to get a little frustrated and had to finish my industrial project proposal so I stopped for the evening. I will discuss with the group for advice and continue later this week.

Jan 17 Today I spent around 4 hours deep-diving CAN and making notes on it. Then I proceeded to try and get debugging working one last time before asking for help. If I cannot accomplish this by Friday I will reach out. I spent approx 1.5 hours on this, but more time was spent reading about it than coding.

Jan 18 Spent approximately 1 hour reading into the Curiosity Nano's CAN controller. I think I understand the requirements for setting up and how the INIT and CONFIG registers work together.

2.3 January 19-23

JAN 22 I spent about an hour and a half finishing my CAN notes which are visible in the Notes section. I have done some looking into coding the CAN controller of the curiosity nano.

- https://github.com/MikroElektronika/mikrosdk_click_v2/tree/master/clicks/canfd3 Here is the CAN FD 3 example code. I gave it a quick browse for something valuable but was mainly looking for CAN controller init code keeping it in my back pocket though
- https://microchip-mplab-harmony.github.io/reference_apps/apps/sam_e51_cnano/same51n_mikroe_click/readme.html I also gave themse projects a quick brows for the same as above, but I don't think any use the CAN controller just UART.
- https://microchip-mplab-harmony.github.io/reference_apps/apps/sam_e54_xpro/same54_can_usb_bridge/readme.html#hardware-used I do however think there is something useful here. It uses the same micro controller so it should have INIT, read/write code, ect. This will take some digging though. Today I put in approximately 3.5 hours into researching and documenting.

JAN 24 I tinkered more with debugging for about an hour or two this morning. It seems to be somewhat working but I am still not getting proper debugging and have no output from the debug calls. I will give it one last go. I think we will plan a group in person meeting, maybe input from the other students will help. I maybe just need to keep fresh eyes on it and stop getting frustrated and understand it better, but config files are frustrating to me. In a more productive note, I have started some framework for my drive code. I am going to clean up some of my I2C code for my gyro so I have a device to poll data from and send over the CAN network. This way I can make sure I understand the new systimer and clock speed a little better with something I understand. I suspect I will have to use some prescalers to compensate for the 60 times faster clock. I will do a commit at end of day and upload this as a pdf.

2.4 January 26 - February 1

JAN 29 Today I continued my efforts of attempting to get the CAN0 controller initialized. I got some preliminary coding done with it. I sort of got confused with some of the usage documentation and searched for some reference code online. I am having serious troubles finding anyone who has used the CAN controller on a SAM E5 device and the same sam.h dependency. I continued by porting over more of my I2C code. In total I worked on this for about 2.5 hours today. GitHub will have a commit by end of day along with updated pdf. VS Code configs continue to delay progress, but not majorly. We have scheduled a virtual meeting for Wednesday January 31st.

JAN 31 Today we had a group meeting. The minutes will be in the notes. Jacob helped me debug my debugger issues and it appears to be a bunch of version issues. I think its time to setup a Docker. I think Landon may have one. I spent about an hour in the meeting and and additional hour working on the silly version stuff.

3 February

3.1 February 5-9

FEB 5 I spent some time attempting Landons docker but I quickly abandoned that when I had the realization that python source has a make command to do an altinstall alongside the main install. This finally got gdb working, but my debug still does not work. It no longer hangs as it did before but I am getting no response back from the device. Perhaps my USB cable actually is bad. I will attempt a few other to see if this fixes the problem. Only about an hour spent today with no major coding. Intellisense still broken and I hate VS code.

FEB 7 I finally have all my old code ported over. I am now testing. I suspect the new sysTimer settings have complicated things. The button no longer works. I quickly re-installed the very cool named project kyber and tested the button with my old code. It works "flawlessly" in the sense of it works as it did before. Button works, gyro communicates. I have even tried directly copying and not reformatting my code, again does not work. Must investigate settings more but won't let it slow me down for now. Here is my game plan:

- Finish CAN drivers
- Get I2C get gyro data on a schedule
- Attempt to send gyro data over CAN

As far as continuing to debug my old code, I am going to attempt to set up another timer and PWM it to see exactly how fast the timers are moving. The force is with me, debug is now working, I tried some more stuff and eventually put in a new usb cable, not sure if that was it. Maybe my uhhhhh usb cable was "bad" or "crap" or other less civil synonyms. I can now remove this burden from my todo list. I can now use this for debugging my button and other code. Had group meeting. Finished up some code before I called it for the day and changed focus.

FEB 25 Back into the swing of it. I have continued to follow the sample code I have followed. Today I fixed the circular reference in my I2C code. I made some circular references when I was separating my I2C code from my just gyro code. I re-merged them for now as I wanted to see if the I2C is still working with the systimer. I can't get messages like I used to in my project but I suspect its a baud rate issue. I did a small amount of tinkering to see if it was a quick fix. Unfortunately I didn't manage to send anything other than a start signal. I will tinker with this more another time. I shifted my focus to the CAN controller for an 3 hours. I followed along with the example code that Jacob had shown me at our Jan 31st meeting. I also discussed some of the topics with Jacob on discord. I started to use the value assignment functions from sam.h as they are significantly better at bit bashing the registers all at once. I set the quanta

with small values for testing. I have also turned on the feed back loop. The data analyzer isn't showing me anything interesting yet. I have tried to use the debugger to set my base ram location for messages, but have not managed to get the same address back. Jacob and I have agreed to a discord discussion on Wednesday, we wait for Landon's response. The debugger is proving very valuable. I will pick Jacobs brain more on this ram issue if I can't figure it out before then. Today in total I worked on the project for approximately 4.5 hours.

4 NOTES

4.1 CAN Overview

Controller Area Network (CAN) is a standard for micro-controller and device communication. It uses messages, and was originally designed as a multiplexing method. The physical layer utilises twisted pairs (CAN+ and CAN-). Messages are framed with IDs which dictate priority. Logical 0 is Dominant and logical 1 is recessive. This means IDs that have larger values (1's in high bit places) are lower priority. Arbitration is done via first bit with a 1. All nodes see transmission.

Nodes All nodes can send and receive, but not at the same time. The priority is determined by the frame ID. Messages are transmitted using non-return-to-zero (NRZ) format

All nodes require the following:

- Some controller :CPU/Microprocessor/host processor/micro controller
 - Decides what messages mean and what to transmit
 - Handles talking to other devices
- CAN Controller
 - Receiving: Stores bits until entire message is received, then can trigger interrupt for retrieval
 - Transmitting: If the host, can send messages via CAN controller in a serial manner.
- Transceiver (ISO 11898-2/3) Medium Access Unit (MAU)
 - Receiving: converts at the CAN bus level for CAN controller use, protective layer for CAN controller.
 - Transmitting: converts bit stream from CAN controller to the CAN bus

4.2 CAN: IDs and arbitration

ID Arbitration When nodes transmit they see all messages including their own. If they transmit a 1 and see 0 they quit and lose arbitration. This is because 0 is dominant and they then know they do not have priority. Because of this, whenever there is a collision the lower ID will win. When a collision does happen. The recessive message waits for the dominant message + 6-bit clocks then attempts again This means the first frame to transmit a 1 is the loser, thus highest priority id frame is all 0s followed by 00...001

IDs as priorities Using ID for the type of data, or the sending node ignores the fact ID is also used as message priority. This leads to poor real-time performance. CAN bus is limited to around 30% to ensure deadlines if you don't build around the priority. Otherwise, you can achieve 70 to 80% CAN bus usage and have reliable deadlines.

4.3 CAN: Bit timing

Nominal Bit Time: Time it takes to send bit components:

Synchronization Synchronization is important to the CAN protocol. It prevents errors and allows for arbitration's to occur. Recolonization occurs every single recessive to dominant transmission during the frame. In order to sync the nominal bit time is segmented into quanta and then certain aspects can be altered to allow for synchronization. The nominal bit time is broken down in the following way. Each are assigned a number of quanta. For example a system where we break our nominal bit time into 10 quanta.

Sync (1 quanta)

Propagation (3 quanta)

Phase segment 1 (3 quanta)

Phase segment 2 (3 quanta)

Synchronization occurs as follows.

1. **Bus Idle** -> wait for first recessive to dominant transition
2. **Hard synchronization**
3. **Resync** occurs on every recessive to dominant transition during the frame (message?)
 - a. CAN controller expects this at multiple of nominal bit time.
 - b. Else It adjust nominal bit time accordingly.

Resync and Adjustment process:

- Produce a number of quanta to divide the bits' segments into time slices.
 - The number of quanta can vary based on the controller
 - The quantity of quanta a segment is assigned can vary depending on system needs
- On out-of-sync (before or after) transition controller calculates the time difference, to compensate:
 - If we need to lengthen we do so to phase 1
 - If we need to reduce time we do so in phase 2.
- As a result of either a or b, we have adjusted the timing of the receiver to the transmitting node and synchronized them.

- We continuously do so at every recessive to dominant transition to keep synchronization
 - This reduces errors induced by noise (random error)
 - Allows for resync to nodes that lost arbitration back to the one that won previously.
 -

4.4 CAN Protocol Layers:

- Application layer
- Object layer
- Transfer layer
- Physical layer

We are building the transfer layer?

4.4.1 CAN Transfer layer:

- Most of the CAN standard applies to this layer, it is what receives messages from the physical layer and into the object layer for use in the application.
- Transfer layer is responsible for:
 - Synchronization
 - Bit timing
 - Message framing
 - Arbitration
 - Acknowledgement
 - Error Detection
 - Signalling
 - Confinement
- To accomplish the previous responsibilities, it performs the following tasks:
 - Fault confinement
 - Error detection
 - Message Validation
 - Arbitration
 - Message framing

- Transfer rate and timing
- Information routing

Physical layer

- Pinout:
 - Pin 2: CAN- (Low)
 - Pin 3: GND
 - Pin 7: CAN+ (High)
 - Pin 9: CAN V+ (power)

4.5 CAN Frames:

- Two types of frame format
 1. Base frame format
 - i. 11- bits for identifier
 - ii. IDE bit dominant
 2. Extended frame format
 - i. 11- bit identifier + 18-bit extension = 29-bit identifier
 - ii. IDE bit recessive
- There are four types of frames.
- Regardless of type all begin with a start of frame (SOF) bit to signal start of frame transmission.
- Frame types:
 1. Data Frame: a frame containing node data for transmission .
 2. Remote frame: requests transmission of an identifier
 3. Error frame: frame type for any node detecting an error.
 4. Overload frame: a buffer/delay for data or remote frame.

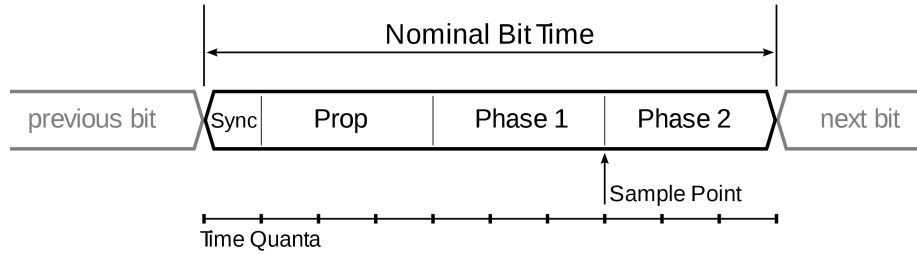


Figure 1: CAN Bit Timing: Wikipedia

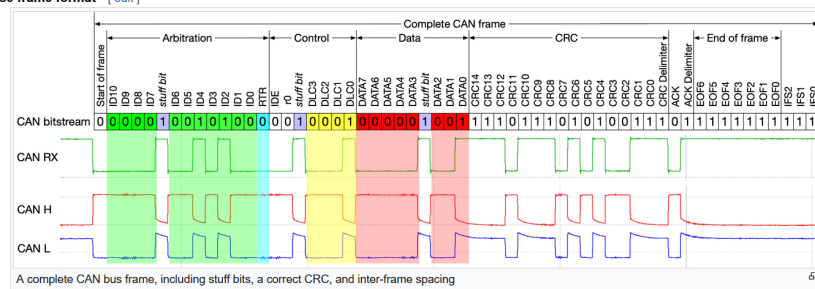
Data frame [\[edit \]](#)

The data frame is the only frame for actual data transmission. There are two message formats:

- Base frame format: with 11 identifier bits
- Extended frame format: with 29 identifier bits

The CAN standard requires that the implementation must accept the base frame format and may accept the extended frame format, but must tolerate the extended frame format.

Base frame format [\[edit \]](#)



The frame format is as follows: The bit values are described for CAN-LO signal.

Field name	Length (bits)	Purpose
Start-of-frame	1	Denotes the start of frame transmission
Identifier (green)	11	A (unique) identifier which also represents the message priority
Stuff bit	1	A bit of the opposite polarity to maintain synchronisation; see § Bit stuffing
Remote transmission request (RTR) (blue)	1	Must be dominant (0) for data frames and recessive (1) for remote request frames (see Remote Frame , below)
Identifier extension bit (IDE)	1	Must be dominant (0) for base frame format with 11-bit identifiers
Reserved bit (r0)	1	Reserved bit. Must be dominant (0), but accepted as either dominant or recessive.
Data length code (DLC) (yellow)	4	Number of bytes of data (0–8 bytes) ^[a]
Data field (red)	0–64 (0–8 bytes)	Data to be transmitted (length in bytes dictated by DLC field)
CRC	15	Cyclic redundancy check
CRC delimiter	1	Must be recessive (1)
ACK slot	1	Transmitter sends recessive (1) and any receiver can assert a dominant (0)
ACK delimiter	1	Must be recessive (1)
End-of-frame (EOF)	7	Must be recessive (1)
Inter-frame spacing (IFS)	3	Must be recessive (1)

Figure 2: Data frame: Wikipedia



University of Manitoba

Meeting Minutes

Date and Time	Jan 31st 2024 @ 9:00 am
Venue	Discord - Lounge
Participants	Andrew Marinic & Jacob Janzen
Absent	Landon Colburn

Minutes of the Meeting

Item	Notes and Discussion	Group
1	I need help with my debugger still	Andrew
2	Jacob helped me find that I was missing an outdated version of libncurses	Group 11
3	We tracked down, and Andrew resolved	Group 11
4	Discussing CAN and figuring out if INIT resets CCE sort of like the PORT Toggle.	Andrew & Jacob
5	Found reference material https://github.com/majbthrd/SAMC21demoCAN	Jacob
6	CAN baud rate, do we need it?	Andrew
7	Start at 0	Jacob
8	Jacob found info about how the CCE get set in the source code on line 420 of mcan.c https://github.com/majbthrd/SAMC21demoCAN/blob/master/mcan.c#L408	Jacob
9	Conclusion that it needs to be set manually and that INIT needs to be set to 0 and not 1 like toggle	Jacob
10	Have you looked at fast CAN? should we be implementing that?	Andrew
11	Starting with normal CAN, but agree we should look into, Click controller uses it	Jacob
12	Have you looked into the resistors? They should go into the CANH and CANL?	Andrew
13	Showed their setup and how they put in their resistors, reminded Andrew about using the +/- for CANH and CANL	Jacob
14	Discussion about TX/RX but neither at that step	Andrew & Jacob
15	Discussion about ideas for what our piece of CAN network will do Andrew wants to use Gyro Jacob wants to use RNG sfu	Andrew & Jacob
16	Wrap up discussion, discuss next meeting. Finished at 9:45 am	Andrew & Jacob