

Calculator for CAN Bit Timing Parameters

Adam Haun

ABSTRACT

Controller Area Network (CAN) nodes use user-specified timing parameters to sample the asynchronous bitstream and recover the clock. These parameters are typically based on the frequency of the available reference oscillator. There may be several options available for a given frequency, and some of them will allow a looser oscillator tolerance than others. This application report details the creation of a bit timing calculator to maximize the oscillator tolerance for the CAN modules on TI microcontrollers.

Project collateral discussed in this application report can be downloaded from the following URL:
<http://www.ti.com/lit/zip/sprac35>.

Contents

1	Introduction	1
2	Implementation	2
3	References	2

Trademarks

TMS320C2000 is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

1 Introduction

Calculation of the bit timing parameters requires at least three inputs:

- The desired bit rate, which is common across the entire bus.
- An estimate of the propagation delay between the most distant nodes on the bus
- The CAN module clock frequency, which is used to derive the bitstream sampling clock

The propagation delay comes from two main sources: the speed of electromagnetic propagation along the bus wiring and extra delay due to transceivers, isolation, or other interface circuitry.

A bit timing calculator must provide at least five outputs:

- The baud rate prescaler (BRP), which determines the sampling clock period. A single period is referred to as a time quantum (T_q).
- The propagation delay expressed as a number of time quanta.
- The length of phase segment 1 (PhSeg1) in time quanta. In addition to determining the bit rate, phase segment 1 acts as a buffer that can be lengthened to resynchronize with the bitstream.
- The length of phase segment 2 (PhSeg2) in time quanta. Phase segment 2 is like phase segment 1, but it occurs after the sampling point instead of before. Phase segment 2 can be shortened to resynchronize with the bit stream.
- The synchronization jump width (SJW) in time quanta. This is the maximum time by which the bit sampling period may be lengthened or shortened during each cycle to adjust for oscillator mismatch between nodes.

The calculator described in this document also outputs the number of time quanta per bit, the oscillator tolerance, the sampling point, and timing register values for the eCAN and D_CAN modules used on the TMS320C2000™ series of microcontrollers.

2 Implementation

The calculator first computes the propagation time as a fraction of the bit period. Either the bus length, a physical propagation delay, or both may be specified. The bus propagation speed is assumed to be two thirds of the speed of light, the standard value for twisted pair cable. The resulting delay time is doubled to give a round trip delay.

The number of time quanta per bit (known as the bit time) can range from 8 to 25. There is no analytic formula for determining the optimum bit time in advance, so the calculator tries all of them. The closest integral baud rate prescaler is calculated for each value. The BRP and Tq/bit values are then used to calculate the actual sampling bit rate. Any difference from the desired value is added to the total tolerance later.

The propagation segment is determined from the fraction computed above, rounded up. The remaining time is split between phase segments 1 and 2, with PhSeg2 rounded up and PhSeg1 rounded down.

The synchronization jump width is limited to 4 Tq at most, and cannot be longer than PhSeg1 or PhSeg2. Thus, the SJW is the minimum of these three values.

Oscillator tolerance is derived from two formulas. The first gives the condition for correct evaluation of 13 dominant bits in a row during an error condition, where there is no re-synchronization:

$$df \leq \frac{\min(\text{PhSeg1}, \text{PhSeg2})}{(2 \times (13 \times \text{bit_time} - \text{PhSeg2}))} \quad (1)$$

The second formula gives the condition for full re-synchronization after 10 consecutive bits:

$$df \leq \frac{\text{SJW}}{(2 \times 10 \times \text{bit_time})} \quad (2)$$

The factor of 2 in each formula comes from considering two oscillators on different nodes, each having the worst-case frequency error in opposite directions. The final oscillator tolerance is the minimum of these two values minus any error in the nominal frequency.

Once the tolerances for all possible values of Tq/bit have been calculated, the settings with the best tolerance are chosen. These are reported in the output section of the calculator. The settings are then converted into eCAN and D_CAN register values, which are also reported.

The calculator can report errors based on several conditions:

- The CAN clock frequency must be at least 8 times the bit rate to give the minimum 8 Tq/bit.
- The propagation delay must be short enough to allow reasonable values for the phase segments.
- The ratio between the CAN clock and the bit rate must be close enough to an integer to produce a usable BRP.

The calculator reports a warning when the exact bit rate cannot be derived from the CAN clock frequency. It also reports a warning when the propagation time is more than half the bit time, since this implies that the bus length is too long for the desired bit rate.

3 References

- *Introduction to the Controller Area Network (CAN)* ([SLOA101](#))
- *Controller Area Network Physical Layer Requirements* ([SLLA270](#))
- *Bosch CAN Specification* (www.kvaser.com/software/7330130980914/V1/can2spec.pdf)

IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ("TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>), [evaluation modules](#), and [samples](http://www.ti.com/sc/docs/sampterm.htm) (<http://www.ti.com/sc/docs/sampterm.htm>).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2018, Texas Instruments Incorporated