

APPLICATION NOTE 2935

## Design Considerations for CAN Bus and Asynchronous Serial

*This application note gives guidance on system CPU crystal selection for DS80C400 and DS80C390 microcontrollers when using asynchronous serial and CAN.*

### Introduction

When designing a system that requires both CAN bus and asynchronous serial interfaces on a DS80C390 or DS80C400 processor, the designer can encounter problems choosing a CPU crystal that allows use of standard bit rates on both interfaces. The CAN bus requires less than 0.5% error, while an asynchronous serial interface requires 2.5% error or less. Common serial baud-rate crystals such as 11.0592MHz, 14.7456MHz, and 18.432MHz will not allow high-bit-rate CAN transmission without violating CAN bus bit-error guidelines. To find the compromise for both interfaces, the designer must first understand how each I/O block generates its bit clock.

### CAN Bus Timing

Bit rates for the CAN controller are generated from the microcontroller system clock and are affected by the on-board crystal multiplier (doubling and quadrupling do affect the input clock to the CAN controller). The clock signal is first divided by two and then by the baud-rate prescaler (BPR), which determines the time quantum ( $t_{qu}$ ). The CAN specification requires that each bit time be composed of between  $8t_{qu}$  and  $25t_{qu}$ . After passing through the BPR, the clock signal is divided once again by the user-specified divisor, which is composed of  $t_{SEG1}$  and  $t_{SEG2}$  plus  $t_{SYNC\_SEG}$  of  $1t_{qu}$ . For more detailed information, refer to Section 19 of the [High-Speed Microcontroller User's Guide: DS80C390 Supplement](#).

The bit rate is determined by the following equation:

$$CANbitrate = \frac{f_{MULT}}{2 \times BPR \times (t_{SYNC\_SEG} + t_{SEG1} + t_{SEG2})}$$

$$8 \leq (t_{SYNC\_SEG} + t_{SEG1} + t_{SEG2}) \leq 25$$

$$1 \leq BPR \leq 256$$

$$reload = \frac{f_{MULT}}{2 \times CANbitrate}$$

Now, we calculate the reload and actual bit rate:

$$\text{actualCANbitrate} = \frac{f_{MCLK}}{2 \times \text{round}(\text{reload})}$$

All useful frequencies will have an error of less than 0.005.

**Example of unusable crystal for 1Mbps CAN bit rate:**

$$\begin{aligned} \text{reload} &= 36.864\text{E}6 / (2 \times 1\text{E}6) = 18.432 \\ \text{actual bit rate} &= 36.864\text{E}6 / (2 \times 18) = 1024000 \\ \text{error} &= (1024000 - 1000000) / 1000000 = 0.024 \end{aligned}$$

**Example of acceptable crystal for 1Mbps CAN bit rate:**

$$\begin{aligned} \text{reload} &= 36\text{E}6 / (2 \times 1\text{E}6) = 18 \\ \text{actual bit rate} &= 36\text{E}6 / (2 \times 18) = 1000000 \\ \text{error} &= (1000000 - 1000000) / 1000000 = 0.0 \end{aligned}$$

$$(t_{\text{SEG1}} + t_{\text{SEG2}} + t_{\text{SYNC\_SEG}}) = 18 / \text{BPR}$$

Remembering that  $t_{\text{SYNC\_SEG}}$  is always 1, and choosing 1 for BPR gives:

$$(t_{\text{SEG1}} + t_{\text{SEG2}}) = 17$$

The designer picks the appropriate TSEG values from this constraint.

## Async Serial Using Timer 2

Bit rates for Serial Port 0 using Timer 2 are calculated while Timer 2 is in 16-bit autoreload mode. Timer 2 runs off the crystal inputs and is not affected by any crystal multiplier settings. For more detailed information, refer to Section 12 of the [High-Speed Microcontroller User's Guide](#).

The bit rate is determined by the following equations:

$$\text{Serialbitrate} = \frac{f_{osc}}{32 \times \text{reload}}$$

$$\text{reload} = \frac{f_{osc}}{32 \times \text{Serialbitrate}}$$

$$\text{actual} = \frac{f_{osc}}{32 \times (\text{round}(\text{reload}))}$$

All useful frequencies will have an error of less than 0.025.

**Example of unusable crystal for 115200 bit/s:**

$$\begin{aligned} \text{reload} &= 16\text{E}6 / (32 \times 115200) = 4.340 \\ \text{actual} &= 16\text{E}6 / (32 \times 4) = 125000 \\ \text{error} &= (125000 - 115200) / 115200 = 0.0851 \end{aligned}$$

#### Example of acceptable crystal for 115200 bit/s:

$$\begin{aligned} \text{reload} &= 18\text{E}6 / (32 \times 115200) = 4.883 \\ \text{actual} &= 18\text{E}6 / (32 \times 5) = 112500 \\ \text{error} &= (112500 - 115200) / 115200 = 0.0234 \end{aligned}$$

## Async Serial Using Timer 1

Bit rates for Serial Ports 0 and 1 using Timer 1 are calculated while Timer 1 is in 8-bit autoreload mode. An added feature of this process is the ability to generate baud rates based on divide-by-4 or divide-by-12 from the external crystal or the system clock. In divide-by-4 mode, the input clock is generated from the system clock ( $f_{MULT}$ ), while in divide-by-12, the base frequency of the external crystal will be used ( $f_{osc}$ ). You can also enable a serial baud-rate doubler by setting the appropriate SMOD (SMOD\_0 or SMOD\_1) bit. For more detailed information, refer to Section 12 of the [High-Speed Microcontroller User's Guide](#).

### Timer 1 in Divide-by-4 Mode

The bit rate is determined by the following equations:

$$\text{Serialbitrate} = \frac{2^{SMOD} \times f_{MULT}}{128 \times \text{reload}}$$

$$\text{reload} = \frac{2^{SMOD} \times f_{MULT}}{128 \times \text{Serialbitrate}}$$

$$\text{actual} = \frac{2^{SMOD} \times f_{MULT}}{128 \times \text{round}(\text{reload})}$$

All useful frequencies will have an error of less than 0.025

#### Example of unusable crystal:

$$\begin{aligned} \text{reload} &= 20\text{E}6 / (64 \times 115200) = 2.713 \\ \text{actual} &= 20\text{E}6 / (64 \times 3) = 104167 \\ \text{error} &= (104167 - 115200) / 115200 = 0.096 \end{aligned}$$

#### Example of acceptable crystal:

$$\begin{aligned} \text{reload} &= 22\text{E}6 / (64 \times 115200) = 2.984 \\ \text{actual} &= 22\text{E}6 / (64 \times 3) = 114583 \\ \text{error} &= (114583 - 115200) / 115200 = 0.0054 \end{aligned}$$

### Timer 1 in Divide-by-12 Mode

$$\text{Serialbitrate} = \frac{2^{\text{SMOD}} \times \text{fosc}}{384 \times \text{reload}}$$

$$\text{reload} = \frac{2^{\text{SMOD}} \times \text{fosc}}{384 \times (\text{Serialbitrate})}$$

$$\text{actual} = \frac{2^{\text{SMOD}} \times \text{fosc}}{384 \times \text{round}(\text{reload})}$$

All useful frequencies will have an error of less than 0.025

#### Example of unusable crystal for 115200 bit/s:

$$\begin{aligned} \text{reload} &= 18\text{E}6 / (192 \times 115200) = 0.814 \\ \text{actual} &= 18\text{E}6 / (192 \times 1) = 93750 \\ \text{error} &= (93750 - 115200) / 115200 = 0.186 \end{aligned}$$

#### Example of acceptable crystal for 115200 bit/s:

$$\begin{aligned} \text{reload} &= 22\text{E}6 / (192 \times 115200) = 0.995 \\ \text{actual} &= 22\text{E}6 / (192 \times 1) = 114583 \\ \text{error} &= (114583 - 115200) / 115200 = 0.0054 \end{aligned}$$

## Suggested Crystal Values for 115200 Serial and CAN Bus

The following table lists crystal frequencies that allow 115,200bps asynchronous serial using Serial 0 and Timer 2 and a 1Mb CAN bus.

**Note:** These values assume that the designer is not using the system clock multiplier.

CRYSTAL	CAN ERROR (%)	SERIAL ERROR (%)
18000000	0.00	2.34
22000000	0.00	0.54
26000000	0.00	0.76
30000000	0.00	1.73
34000000	0.00	2.48
36000000	0.00	2.34
40000000	0.00	1.36
44000000	0.00	0.54
48000000	0.00	0.16
52000000	0.00	0.76
54000000	0.00	2.34
56000000	0.00	1.27

60000000	0.00	1.73
64000000	0.00	2.12
66000000	0.00	0.54
68000000	0.00	2.48
72000000	0.00	2.34

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Application Note 2935: <http://www.maxim-ic.com/an2935>

### More Information

For technical questions and support: <http://www.maxim-ic.com/support>

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