CAN-CTRL
CAN 2.0 & CAN-FD Bus Controller Megafunction

Implements a CAN protocol bus controller that performs serial communication according to all current and imminent specifications: CAN 2.0A, 2.0B, the upcoming ISO CAN FD and the original Bosch protocol non-ISO CAN-FD standards.

The CAN protocol uses a multi-master bus configuration for the transfer of frames between nodes of the network and manages error handling with no burden on the host processor. The megafunction enables the user to set up economic and reliable links between various components. It appears as a memory-mapped I/O device to the host processor, which accesses the CAN megafunction to control the transmission or reception of frames.

The CAN megafunction is easy to use and integrate featuring programmable interrupts, data and baud rates; a configurable number of independently programmable acceptance filters; and a generic processor interface or optionally an AMBA APB, or AHB-Lite interface. It implements a flexible buffering scheme, allowing fine-tuning of the megafunction size to satisfy the requirements of each specific application.

The number of receive buffers is synthesis-time configurable from 2 to 31. Two types of transmit buffers are implemented: a high-priority primary transmit buffer (PTB) and a lower-priority secondary transmit buffer (STB). The PTB can store one message, while the number of included buffer slots for the STB is synthesis-time configurable from 0 to 16 slots. An optional wrapper instantiating multiple CAN controllers eases integration in cases where multiple bus-nodes need to be controlled by the same host processor.

The megafunction implements functionality similar to the Philips SJA1000 working with its PelICAN mode extensions, providing error analysis, diagnosis, system maintenance and optimization features.

The CAN megafunction is extensively verified and proven in multiple production designs.

Applications

The CAN-CTRL megafunction can be integrated in devices that use CAN or higher-layer, CAN-based communication protocols. In addition to traditional automotive applications, such devices are used in industrial (e.g. the CANopen and DeviceNet protocols), aviation (e.g. the ARINC-825 and CANaerospace protocols), marine (e.g. the NMEA 2000 protocol) and other applications.

Block Diagram

Features

CAN Bus Specifications
- CAN 2.0A & 2.0B (ISO 11898)
- Optional CAN-FD support
  - Non-ISO CAN FD (compliant to original Bosch protocol)
  - ISO CAN-FD (compliant to upcoming ISO 11898-1)

Enhanced Functionality
- Error Analysis features enabling diagnostics, system maintenance and system optimization
  - Last error type capture
  - Arbitration lost position capture
  - Programmable Error Warning Limit
- Listen-Only Mode enables CAN bus traffic analysis and automatic bit-rate detection
- Loop back mode for self testing
- Optional ECC memories support

Flexible Message Buffering and Filtering
- Configurable number of receive buffers, 2 to 31
- One high-priority transmit buffer
- Configurable number of lower-priority transmit buffers, 0 to 16
- Configurable number of independently programmable 29-bit acceptance filters, 1 to 16
- Loop-back mode for self testing
- Optional ECC memories support

Easy to Use and Integrate
- Programmable data rate up to 1 Mbit/s with CAN 2.0 and several Mbit/s with CAN-FD option
- Programmable baud rate prescaler: 1/2 up to 1/256
- Single Shot Transmission Mode for lower software overhead and fast reloading of transmit buffer
- Programmable interrupt sources
- Generic 8-bit host-controller interface and optional 8/16/32-bit AMBA-APB or 32-bit AHB-Lite interface
- Buffers can be implemented as Flip-Flops or RAM
- A single host can control multiple CAN bus nodes via an optional Multi-CAN wrapper

Zero Risk
- Link to commercial bus drivers (e.g., PCA82C250T by Philips)
- Multiple times production proven

Efficient and Portable Design
- Available in RTL, and portable to ASIC and FPGA technologies
Functional Description

The CAN bus megafunction is founded on the basic CAN protocol principle and meets all constraints of the CAN 2.0B and CAN-FD specifications.

Several message buffers are used for buffering received or transmitted messages. The number of buffers can be selected before synthesis. Selecting a large number of buffers disables the need for real-time reaction to CAN messages for the host processor, which significantly eases software development of the system application.

The included high-priority primary transmit buffer (PTB) can be used to transmit an important message as fast as possible, even if several lower-priority messages are pending.

The host interface contains all necessary registers for controlling and configuring the megafunction. The host is able to read and write all registers as conventional RAM in memory mapped mode.

The interface to the host is software configurable. All events on the CAN data bus or in the CAN controller megafunction are signaled using an interrupt. Every interrupt source may be individually enabled or disabled. The CAN controller megafunction contains up to sixteen software-programmable 29-bit acceptance filters that can be used to block unwanted CAN messages, which reduces the load to the host controller.

The host controller interface operates in a different clock domain, which can be synchronous or asynchronous to the megafunction clock. The host-interface type is user selectable at synthesis time, and can be either an 8-bit-wide generic processor interface or a 32-bit-wide APB or AHB-lite interface. This enables easy interfacing to many host controller types, facilitating quick integration with a microcontroller. Furthermore, the width of the internal data path and buffers is adjusted depending on the host interface to ensure efficient utilization of the host bus bandwidth.

Implementation Results

CAN-CTRL reference designs have been evaluated in a variety of technologies. The following are sample results optimized for area with a clock constraint of 80 MHz, with 3 receive buffers, 3 transmit buffers and 3 acceptance filters, with and without the CAN-FD option.

### Table 1: Sample implementation data without the CAN-FD option

<table>
<thead>
<tr>
<th>Family Device</th>
<th>LEs/ALMs</th>
<th>Memory</th>
<th>Memory Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclone V 5CGXFC3-7</td>
<td>821</td>
<td>5 M10K</td>
<td>1,344</td>
</tr>
<tr>
<td>Arria V 5AGTMC3-5</td>
<td>822</td>
<td>5 M10K</td>
<td>1,344</td>
</tr>
<tr>
<td>Stratix V 5SGXMA3-2</td>
<td>819</td>
<td>5 M20K</td>
<td>1,344</td>
</tr>
<tr>
<td>Arria 10 10AX048-2</td>
<td>816</td>
<td>5 M20K</td>
<td>1,344</td>
</tr>
<tr>
<td>MAX 10 10M04-7</td>
<td>2,117</td>
<td>4 M9K</td>
<td>1,280</td>
</tr>
</tbody>
</table>

### Table 2: Sample implementation data with the CAN-FD option

<table>
<thead>
<tr>
<th>Family Device</th>
<th>LEs/ALMs</th>
<th>Memory</th>
<th>Memory Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclone V 5CGXFC3-7</td>
<td>1,004</td>
<td>5 M10K</td>
<td>8,960</td>
</tr>
<tr>
<td>Arria V 5AGTMC3-5</td>
<td>1,005</td>
<td>5 M10K</td>
<td>8,960</td>
</tr>
<tr>
<td>Stratix V 5SGXMA3-2</td>
<td>1,002</td>
<td>5 M20K</td>
<td>8,960</td>
</tr>
<tr>
<td>Arria 10 10AX048-2</td>
<td>1,002</td>
<td>5 M20K</td>
<td>8,960</td>
</tr>
<tr>
<td>MAX 10 10M04-7</td>
<td>2,452</td>
<td>5 M9K</td>
<td>8,960</td>
</tr>
</tbody>
</table>

Deliverables

The megafunction includes everything required for successful implementation:

- VHDL or Verilog RTL source code
- Post-synthesis EDIF (netlist licenses)
- Testbenches
  - Behavioral tests
  - Post-synthesis verification
- Simulation scripts
- Synthesis scripts
- Documentation

Support

The megafunction as delivered is warranted against defects for ninety days from purchase. Thirty days of phone and email technical support are included, starting with the first interaction. Additional maintenance and support options are available.

Verification

The megafunction has been rigorously verified and has been production proven multiple times.