TB3178

How to Perform Faster Mathematical Calculation in Cortex-M0+ Microcontrollers

Introduction

Various applications in the industrial and home appliance markets require mathematical operations for different sets of algorithms and calculations. Cortex™-M0+ based microcontrollers contain instructions for addition, subtraction, and multiplication. The Cortex-M0+ architecture does not have an assembly instruction for the division operation, and the division logic can vary based on different compilers. The ARM Cortex-M0+ based microcontroller (MCU) has a configurable option to use the fast multiplier for multiplication. Based on the configurable option, the multiplication operation may vary from a single cycle instruction, up to 32 cycles.

The SAMC21, a Cortex-M0+ MCU, is a perfect fit for applications which require mathematical calculations. The SAMC21 MCU has the fast single cycle multiplier option for multiplication, and has a new peripheral called the Division and Square Root Accelerator (DIVAS), which allows for rapid division and square root operation.

1. Concept

The Application Binary Interface (ABI) for the ARM® Architecture is a collection of standards, some open and some specific to the ARM architecture. The ABI regulates the inter-operation of binary files and development tools in a spectrum of ARM-based execution environments. Compilers that have support for ARM MCUs need to comply with these standards. One of these standards is the Run-time ABI for the ARM Architecture. This standard specifies the helper function for ABI to support C, C++, and arithmetic operations. For division, the compiler replaces division and modulo operators with their library code (i.e., using repeated subtraction as a solution for division). This library code adds hundreds of bytes to code memory, and the MCU consumes anywhere from 50 to 400 clock cycles depending on the size of the operands. DIVAS can be used by the compiler, by overloading the runtime ABI helper methods to use DIVAS features. DIVAS shows better performance than compiler division (i.e., 50 clock cycles less for the division of 65535/3). DIVAS supports integer square root operation without any additional library dependencies.

Note: The modulo operator uses division to retrieve the remainder, and therefore needs to be overloaded. DIVAS performance results may vary based on *dividend* and *divisor* values.

2. Solution/Implementation

DIVAS supports 32-bit Integer division only. The Run-time ABI helper method for the division is overloaded for compilers to understand that division should use the DIVAS feature. As per the Run-time ABI standard, the 32-bit integer division functions return the quotient in `r0`, or both quotient and remainder in `{r0, r1}`.

In the following example, the 2-value-returning functions are described using ARM-specific prototype notation.

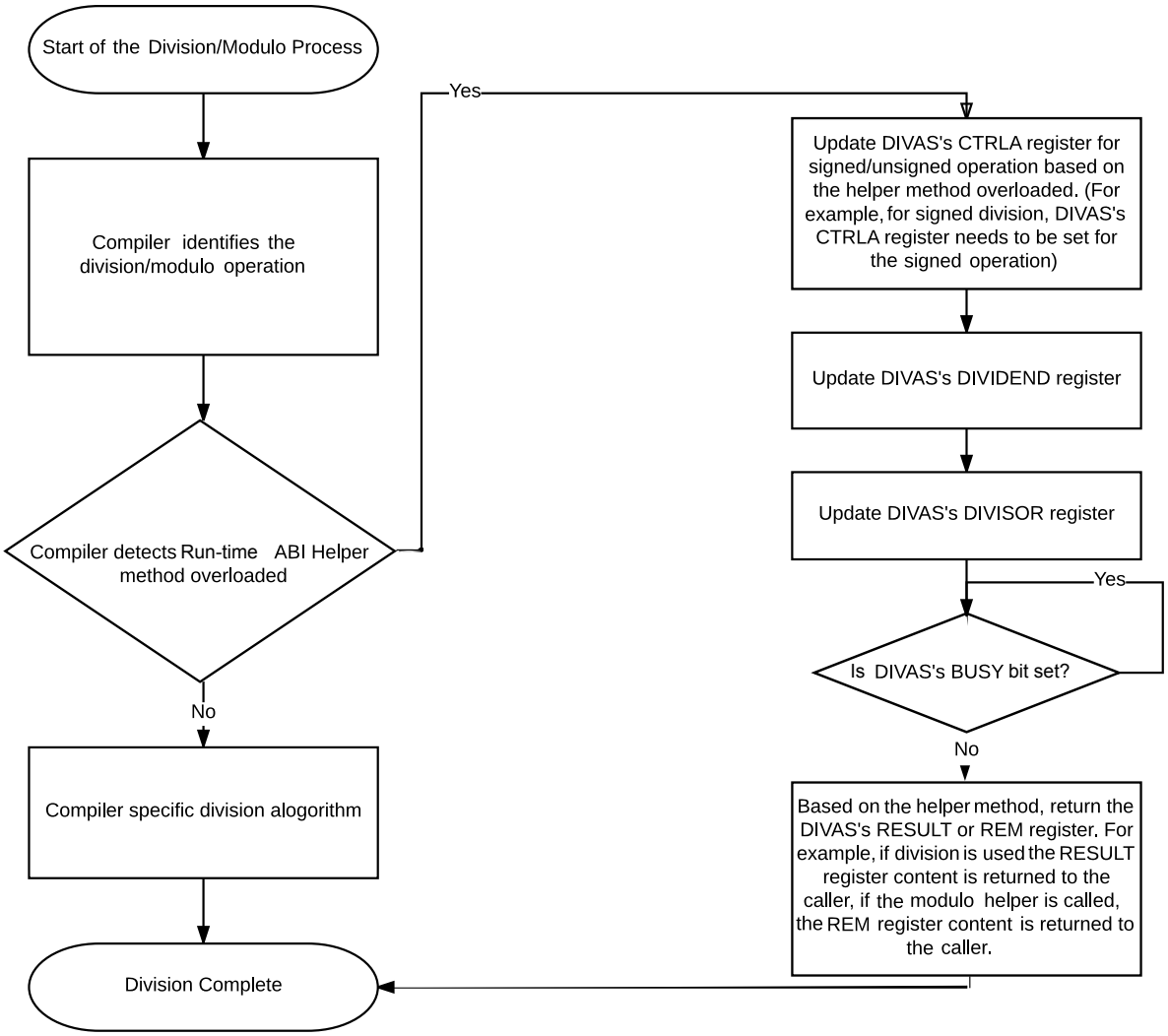
Note: Some compilers may use 64-bit signed/unsigned integers as the return type, instead of the `idiv` or `uidiv` structure.

```
int __aeabi_idiv(int numerator, int denominator);
unsigned __aeabi_uidiv(unsigned numerator, unsigned denominator);
typedef struct { int quot; int rem; } idiv_return;
typedef struct { unsigned quot; unsigned rem; } uidiv_return;
__value_in_regs idiv_return __aeabi_idivmod(int numerator, int denominator);
__value_in_regs uidiv_return __aeabi_uidivmod(unsigned numerator, unsigned denominator);
```

Note:

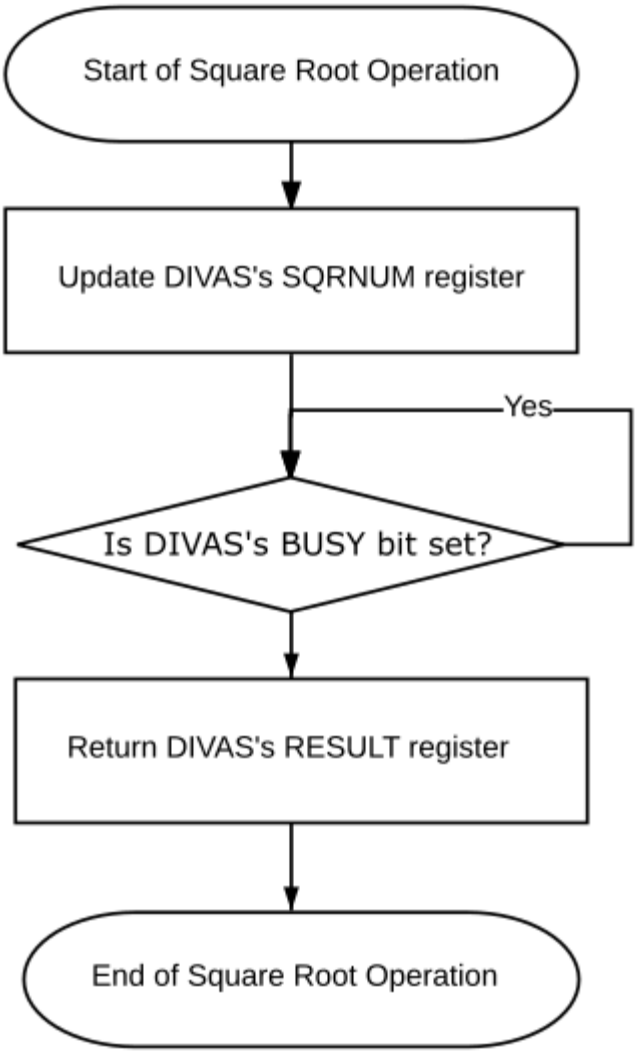
The ASFv3 framework provides support for the DIVAS driver. The DIVAS ASF APIs contain APIs for integer division, modulo, and square root. Set the symbolic definition `DIVAS_OVERLOAD_MODE` to *true* to help overloaded ABI helper methods in the ASF driver for DIVAS to perform the intrinsic division operations. The driver that contains the run-time ABI helper methods are overloaded with DIVAS ASF driver APIs.

Figure 2-1. DIVAS Division Operation



Functions may use the DIVAS Square root feature, instead of using the math library's float operation based function call.

Figure 2-2. DIVAS Square Root Operation



DIVAS can be useful in the following application scenarios:

- Run-time calibration of the ADC and Oscillators for fine tuning performance of ADC/Oscillator output in industrial and motor control applications.
- Industrial control applications, which require faster PID loop.

Tip:

Division by zero: Cortex-M0+ is the ARMv6-M architecture which does not include a divide instruction, therefore, there is no hardware exception for that. The user can validate for verifying *denominator* to be zero and based on which can raise a software user exception using the raise API or provide a default value (zero or the *dividend*) as output. Please refer to https://www.gnu.org/software/libc/manual/html_node/Signaling-Yourself.html for information on signal/raise APIs, which are supported by GCC compiler.

The Division may cause signed bit overflow: When dividend -2147483648 (bit pattern 0x80000000) is divided by denominator of value -1, the output number 2147483648 has no value in signed representation. The above is a special case, and implementation can be user defined based on the application need (i.e., Can return the *dividend* or a default value.).

Division/modulo operation from both ISR and main context: If division occurs from both ISR and main context, the overloaded methods should be protected by an interrupt lock. The implementation should then contain a global interrupt disable and a global interrupt enable method at the start and end of every overloaded method.

Floating point division and long division: The ARM Cortex-M0+ does not have a floating-point unit (FPU), and DIVAS supports 32-bit integer division only. The compiler continues to use its library code to perform floating point division and long (64-bit) division instead of using DIVAS.

3. Relevant Resources

- http://www.atmel.com/Images/Atmel-42465-Using-DIVAS-on-SAMC-Microcontroller_ApplicationNote_AT6486.pdf
- Application Binary Interface for the ARM® Architecture http://infocenter.arm.com/help/topic/com.arm.doc.ihi0036b/IHI0036B_bsabi.pdf
- Run-time ABI for the ARM® Architecture (http://infocenter.arm.com/help/topic/com.arm.doc.ihi0043d/IHI0043D_rtabi.pdf)
- http://asf.atmel.com/docs/latest/samc20/html/group__asfdoc__sam0__divas__group.html
- https://www.gnu.org/software/libc/manual/html_node/Program-Error-Signals.html

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ISBN: 978-1-5224-2418-5

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