The University of Texas experience with µClinux, the TCM-BF537, and C++

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Motivation

- Because of the diverse requirements of the UT satellite projects, a general purpose flight software running on a mature, reliable operating system was needed.

What is µClinux?

- Originally a fork of the Linux kernel to run on microcontrollers without a memory management unit (MMU).
- Major parts were integrated with main line Linux kernel for a number of processor architectures since version 2.5.46.
- Now a Linux distribution called uClinux-dist which contains a customized build system for the Linux kernel, various patches, and a large collection of userspace applications.

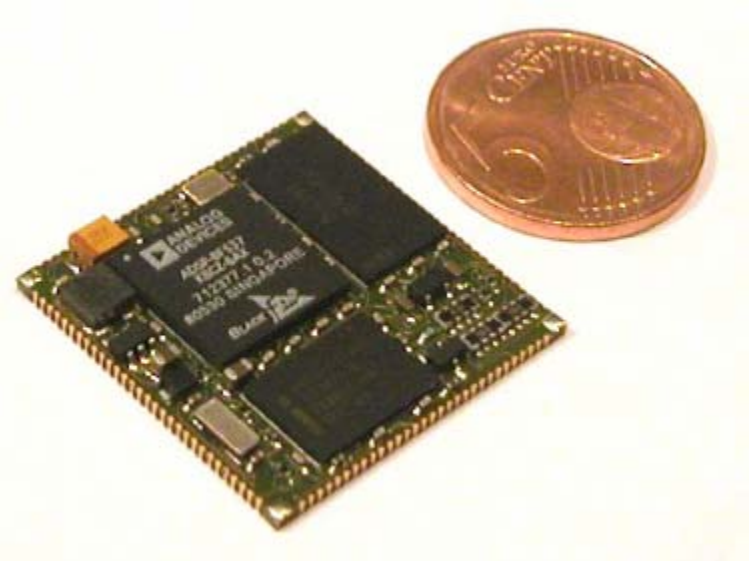
Why use µClinux?

- Programmers can focus on developing actual satellite software without worrying too much on hardware implementation/differences, leading to portable code.
  - Supports many peripheral devices like cameras, memory, bus drivers, etc. out of the box
  - Easily extensible through kernel modules or userspace code.
  - Allows flexibility with hardware requirements and choices.

What is the TCM-BF537?

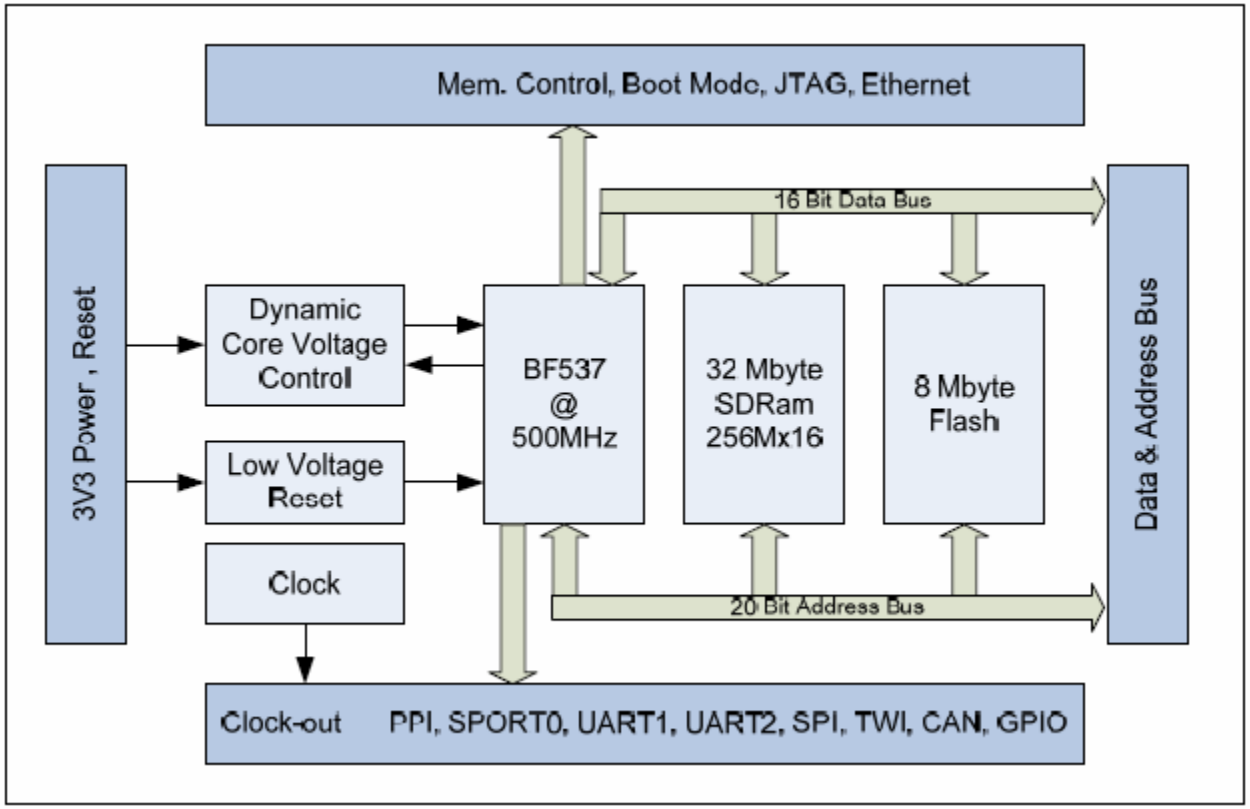
- A module developed by Bluetechnix aka Tinyboards that contains
  - the Blackfin BF537, a powerful processor (500MHz) developed by Analog Devices
  - 32 MB of SDRAM
  - 8 MB of Flash ROM
- Can connect to many peripheral devices over common buses like UART, SPORT, I^2C, SPI, etc
- Blackfin processor fully supported by µClinux.
- Not limited to TCM-BF537

What is the TCM-BF537?



BLUE TECHNIX

TCM-BF537 Functional Specification



Example 1: I²C

- The Blackfin has a two-wire interface (TWI) that can be used to drive an I²C bus.
- µClinux has a driver that implements an I²C controller and the SMBus protocol using the Blackfin's TWI or by bit-banging two GPIO pins.
- Separate drivers are written that use the I²C HAL to communicate with a specific device.
- The University of Texas has implemented a high-level C++ userspace driver for the ClydeSpace powerboard and the KatySat radio.

Example 2: Serial

- Like with I^2C, Linux has a HAL for serial-like devices.
- The µClinux drivers for the Blackfin's UART and SPORT ports are implemented as teletype (tty) devices.
- The Dragon GPS and KatySat radio drivers simply use the Linux tty interface to read/write bytes and set the baud rate of the line.
- Once again, the software interface is the same even if you are on an x86 PC or a Motorola processor.

Downsides of µClinux

- higher memory consumption
- relatively longer boot time
- higher interrupt latency by default (preventing real-time operation)
  - does not hinder most CubeSat missions even in navigation and control operations as lag times are usually large.

C++

- C++ promotes writing modular, maintainable code with simplified interfaces.
- Benefits of object oriented language include abstraction, encapsulation, inheritance, and polymorphism.
- Applying object oriented principles with C is possible (like in Linux), but not intuitive.

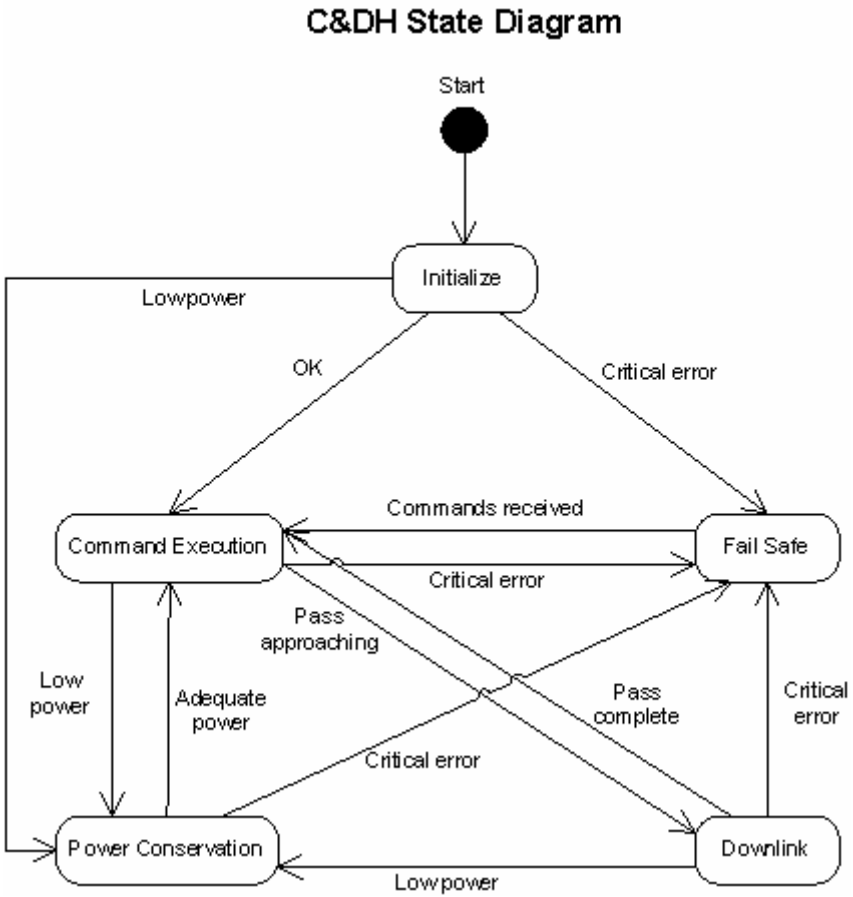
Blackbird

- The University of Texas's attempt to create reusable and extensible satellite software for nano- and pico-satellites.
- Written in C++ and assumes a Linux runtime environment.
- Currently runs on a Bluetechnix TCM-BF537 core module loaded with µClinux.

Blackbird Components

- A ModeManager implements typical flow control based on the return values of the currently running Mode (i.e. the Transition).
- A Mode turns on and off independent Activities.
- An Activity implements different subsystem algorithms and interacts with Devices.
- A Device provides an interface for Activities and implements it by using Linux device drivers and other hardware abstraction features.

Blackbird State Machine



POSIX Threads

- Allows Blackbird's Activity classes to run in an independent matter, but still interact closely with Modes via signals.
- Implementing multitasking in a single-threaded system can become tedious and non-intuitive.
- However, introduces new problems with mutexes, deadlocks, and race conditions.

Update on UT satellite programs

- FASTRAC
  - Manifested to launch December 2009
- Texas 2-Step
  - Post CDR phase
- PARADIGM
  - Manifested to launch April 2009 (STS-127)
  - Currently undergoing ETU development/testing
  - First satellite to use Blackbird

Resources and Questions

- http://blackfin.uclinux.org
- http://docs.blackfin.uclinux.org
- http://vulcan.ae.utexas.edu