SJSU SAN JOSÉ STATE UNIVERSITY

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Department of Computer Engineering

Real-Time Embedded System
Co-Design
CMPE 146 Section 1
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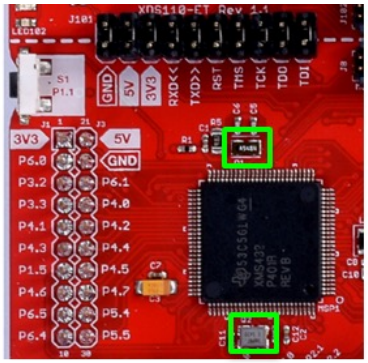
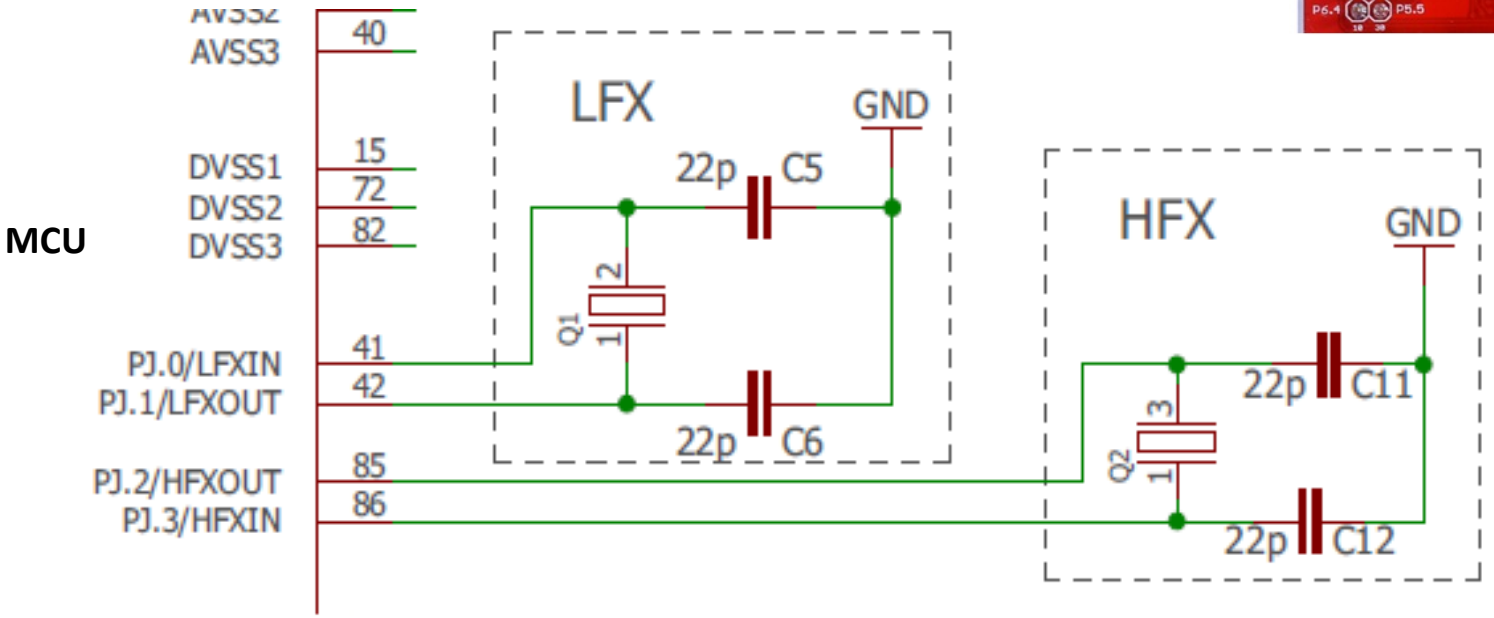
MCU Clock System

External Oscillators to MCU

- Two quartz crystal oscillator modules connected to MSP432 on LaunchPad
  - HFX: High-frequency oscillator at 48 MHz
  - LFX: Low-frequency oscillator at 32 kHz
- Crystal oscillator provides very high accuracy and stability
  - Oscillation frequency can be manufactured precisely
  - Quartz crystal is quite temperature insensitive
    - ~0.001% over the operating range
  - Stability is in the range of 0.005%

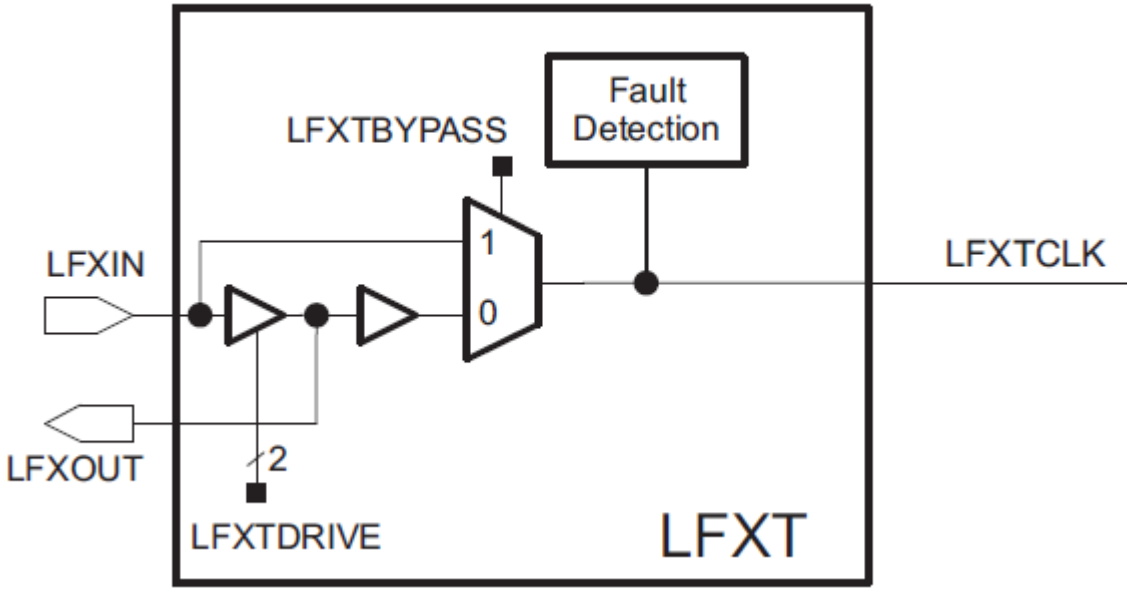




LaunchPad MSP-EXP432P401R

Low-Frequency Base Clock (ext. osc. 1)

- LFXTCLK
  - Low-frequency oscillator or external clock source in the 32-kHz or below range
  - In bypass mode, driven with an external square wave signal
- Disabled by default
  - LFXIN and LFXOUT pins are set to be used as GPIOs
- Can generate interrupt if fault is detected

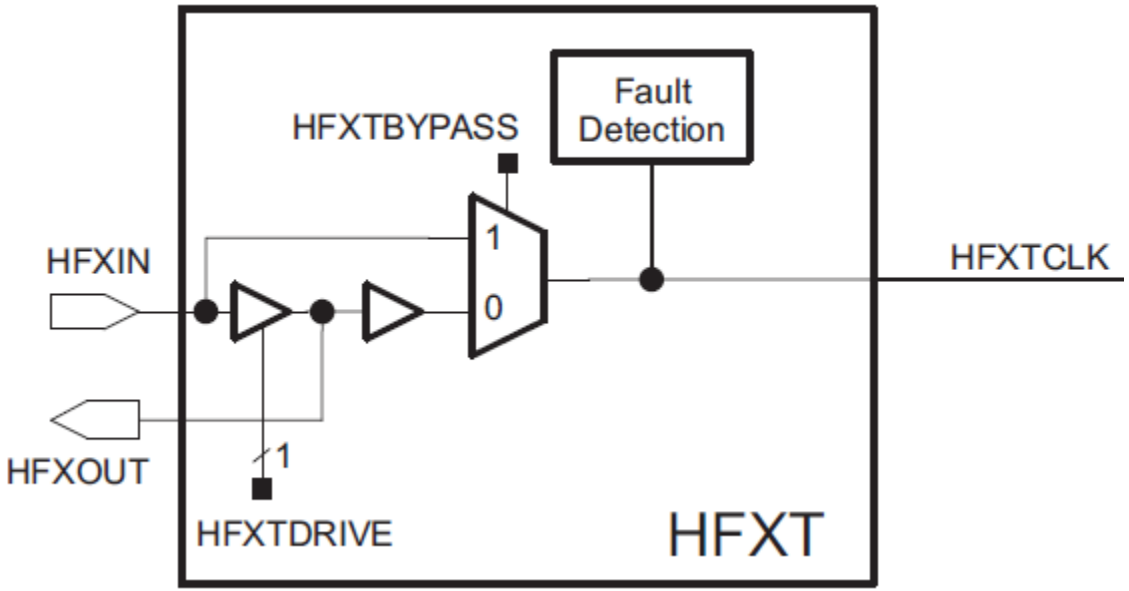


MSP432 MCU

Diagram source: TI MSP432P4xx SimpleLink Microcontrollers Technical Reference Manual, Figure 6-1.

High-Frequency Base Clock (ext. osc. 2)

- HFXTCLK
  - High-frequency oscillator in the 1-MHz to 48-MHz range
  - In bypass mode, HFXTCLK can be driven with an external square wave signal
- Disabled by default
  - HFXIN and HFXOUT pins are set to be used as GPIOs
- Can generate interrupt if fault is detected



MSP432 MCU

Diagram source: TI MSP432P4xx SimpleLink Microcontrollers Technical Reference Manual, Figure 6-1.

MCU Internal Oscillators

Five internal sources

- VLO
  - Very-low-power low-frequency oscillator
  - 9.4-kHz typical frequency
- REFO
  - Low-power low-frequency oscillator
  - Selectable 32-kHz or 128-kHz typical frequencies
- MODOSC
  - Low-power oscillator
  - 25-MHz typical frequency
- SYSOSC
  - Regular oscillator
  - 5-MHz typical frequency
- DCO
  - Digitally controlled oscillator (DCO) generating programmable frequencies

MCU Base Clock - VLOCLK (int. osc. 1)

- Very-low-power low-frequency oscillator (VLO)
- 9.4-kHz typical frequency
- A low-cost ultra-low-power clock source for applications that do not require an accurate time base
  - 50-nA current consumption (typical)
- Oscillator can be powered down when clock is not needed
- Used in low-power mode

MCU Base Clock - REFOCLK (int. osc. 2)

- Low-power low-frequency oscillator (REFO)
- Selectable 32-kHz or 128-kHz typical frequencies
- A low-cost ultra low-power clock source for applications that do not require a crystal-accurate time base
  - More accurate than VLO
  - 0.6-µA (32 kHz) or 1-µA (128 kHz) current consumption (typical)
- REFO is turned on whenever HFXT oscillator is enabled for use
  - Used to check the stability of the HFXTCLK
  - Can generate clock fault signal
- Fail-safe clock source for LFXTCLK
- Used in low-power mode
- Oscillator can be powered down when clock is not needed

MCU Base Clock - MODCLK (int. osc. 3)

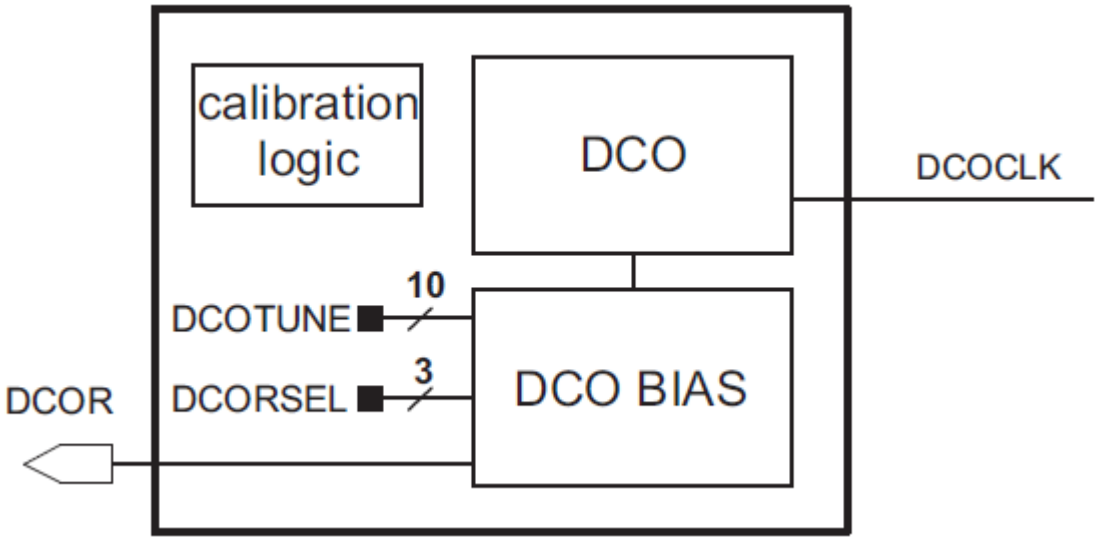
- Internal low-power oscillator (MODOSC)
- 25-MHz typical frequency
- 50-µA current consumption (typical)
- Oscillator can be powered down when clock is not needed
- Can be used in both active and low-power modes

MCU Base Clock - SYSCLK (int. osc. 4)

- Regular oscillator (SYSOSC)
- 5-MHz typical frequency
- 30-µA current consumption (typical)
- For general-purpose timing for certain modules that do not require the stringent accuracy and start-up requirements of MODOSC
  - Start-up time for high-accuracy clocks could be longer
- SYSOSC is used by the system for
  - Memory controllers (flash and SRAM) state machine clock
  - Fail-safe clock source for HFXTCLK
  - Power control manager (PCM) and power supply system (PSS) state machine clock
  - Serial communication peripherals

MCU Base Clock - DCOCLK (int. osc. 5)

- An integrated digitally controlled oscillator (DCO)
- Six ranges, factory calibrated for the center frequencies
  - Each range overlaps with its neighboring ranges
  - On MSP432P401R, 1 to 52 MHz outputs, 8-MHz range
- Frequency can be changed during runtime
  - A settling time (<10 µs) is required before final selected frequency is obtained
- Used in both active and low-power modes



MSP432 MCU

Diagram source: TI MSP432P4xx SimpleLink Microcontrollers Technical Reference Manual, Figure 6-1.

Primary System Clocks

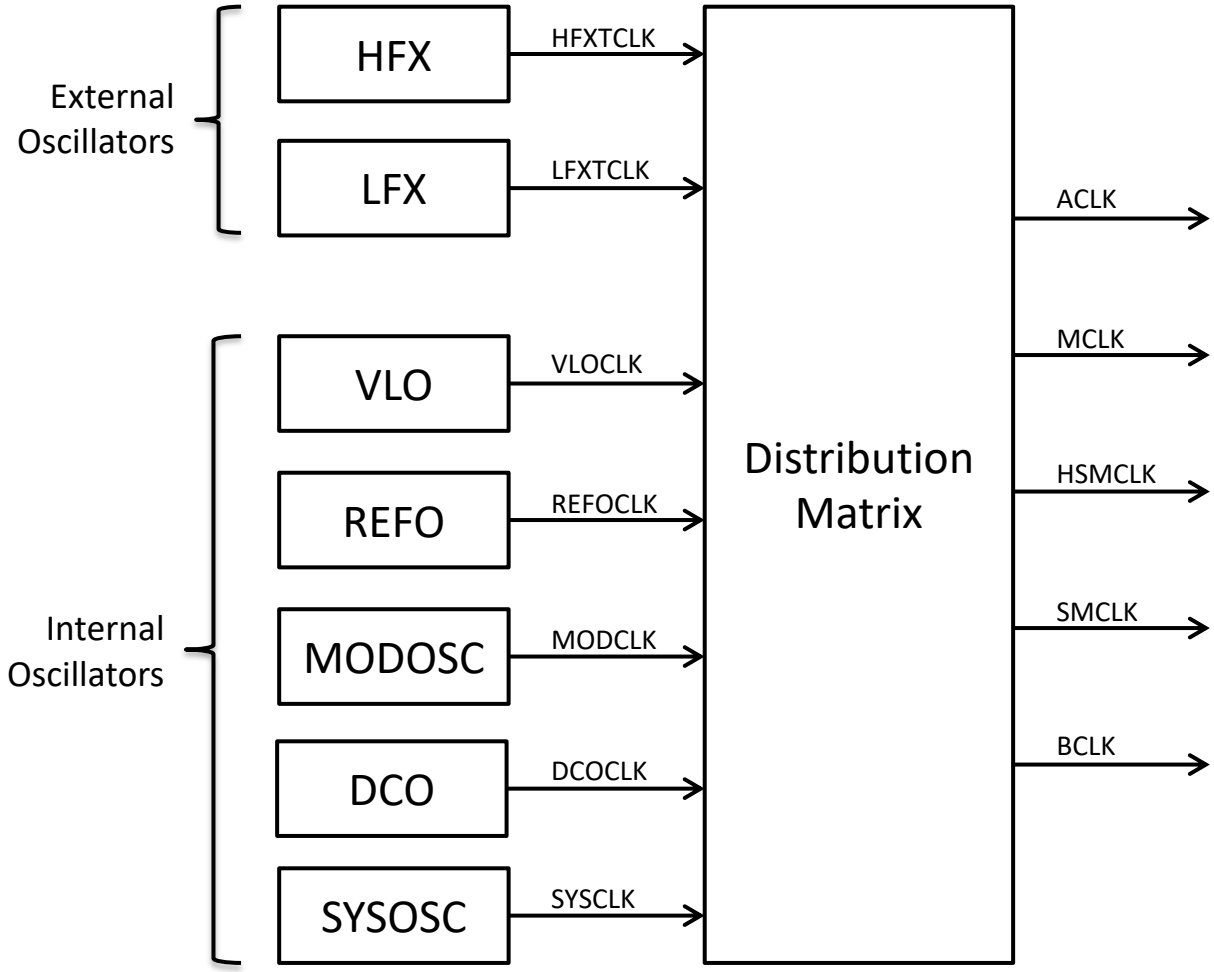
Five primary system clocks are derived from one of the base clocks

- ACLK: Auxiliary Clock
  - Base clock sources: LFXTCLK, VLOCLK, REFOCLK
  - Can be divided by 1, 2, 4, 8, 16, 32, 64, or 128
  - Software selectable by individual peripheral modules
  - Restricted to maximum frequency of operation of 128 kHz
- MCLK: Master Clock
  - Base clock sources: LFXTCLK, VLOCLK, REFOCLK, DCOCLK, MODCLK, HFXTCLK
  - Can be divided by 1, 2, 4, 8, 16, 32, 64, or 128
  - Used by the CPU and peripheral module interfaces
- HSMCLK: Subsystem Master Clock
  - Base clock sources: LFXTCLK, VLOCLK, REFOCLK, DCOCLK, MODCLK, HFXTCLK
  - Can be divided by 1, 2, 4, 8, 16, 32, 64, or 128
  - Software selectable by individual peripheral modules

Primary System Clocks (cont'd)

- SMCLK: Low-speed Subsystem Master Clock
  - Base clock source: HSMCLK
  - Can be divided by 1, 2, 4, 8, 16, 32, 64, or 128
  - Limited in frequency to half of the rated maximum frequency of HSMCLK
  - Software selectable by individual peripheral modules
- BCLK: Low-speed Backup Domain Clock
  - Base clock sources: LFXTCLK, REFOCLK
  - Used primarily in the backup domain (real-time clock, watchdog timer, 6-KB SRAM)
  - Restricted to a maximum frequency of 32 kHz

Clock System Summary



Clock System Main Features

- Clock system can be configured or reconfigured by software at any time during program execution
- Dedicated clock distribution to peripherals
  - Peripheral requests clock sources from the clock system through dedicated signal lines
  - Clock system distributes clocks through dedicated clock lines to peripheral
  - As a result, it reduces dynamic power to peripherals that do not require a particular clock
- Clock variety supports wide range of applications based on requirements of
  - Power
  - Speed
  - Cost
  - Clock accuracy
- Clock dividers provide flexibility to fine tune individual clock requirements
- Failsafe mechanism for higher reliability