# Assignment 5 – Power Modes and Clock Sources in STM32

This assignment discusses the power management architecture of STM32 microcontrollers, highlighting differences between general-purpose (STM32F1) and ultra-low-power (STM32L4) families. It explains how various power modes, clock sources, and peripheral configurations affect energy efficiency and system performance. It also describes how DMA and peripheral autonomy help reduce CPU activity and improve battery life in embedded systems.

## 1. Power Modes in STM32

STM32 microcontrollers offer multiple power modes to balance performance and energy efficiency. Each mode defines which system components remain active, how quickly the device wakes up, and the overall current consumption.

### STM32F1 Family (General Purpose)

• Run Mode – The CPU and all peripherals are active; highest power consumption.
• Sleep Mode – The CPU clock is stopped, but peripherals remain operational; wake-up occurs via interrupts.
• Stop Mode – Most clocks are halted except LSE or LSI; registers and RAM are preserved; wake-up latency is moderate.
• Standby Mode – The lowest power state; all logic is powered down except the RTC backup domain; RAM is lost.

### STM32L4 Family (Ultra-Low-Power)

• Run Mode – Multiple performance levels allow dynamic frequency and voltage scaling.
• Sleep / Low-Power Sleep – CPU halted, selected peripherals remain active.
• Stop 0 / Stop 1 / Stop 2 – Gradually disables oscillators and voltage regulators to minimize current consumption while retaining RAM.
• Standby / Shutdown – All power domains except backup RAM and RTC are off; ideal for very long idle periods.

The STM32L4 provides finer control over regulator and oscillator domains, enabling current consumption in the microamp range, significantly lower than the STM32F1 series.

## 2. Clock Sources in STM32

Clock sources determine the timing precision, startup delay, and power draw of the microcontroller. The main clock sources include:

• HSE (High-Speed External) – External crystal or oscillator; highly accurate but power-hungry.
• HSI (High-Speed Internal) – Built-in RC oscillator; moderate accuracy, fast startup.
• MSI (Multi-Speed Internal, L-series only) – Configurable from 100 kHz to a few MHz; excellent for low-power modes.
• LSE (Low-Speed External) – 32.768 kHz crystal used for RTC; extremely low power and

accurate.
• LSI (Low-Speed Internal) – Internal RC (~37 kHz) with poor accuracy but minimal current.
• PLL (Phase-Locked Loop) – Multiplies the base frequency to higher speeds; consumes more power.

## 3. Combining Clock Sources for Low-Power Operation

During long low-activity periods, combining a low-power internal clock (MSI/HSI) with the LSE for RTC is ideal. LSE maintains accurate timekeeping while the rest of the system remains in low-power states. This configuration achieves high precision with minimal energy usage.

Typical configuration:
- LSE drives the RTC for accurate timing.
- MSI/HSI used for quick wake-up tasks.
- PLL enabled only when high-performance processing is required.

## 4. Peripheral Clock Management (RCC)

The RCC (Reset and Clock Control) allows independent enabling and disabling of peripheral clocks. Disabling unused peripheral clocks reduces dynamic power consumption and noise.

Example:
__HAL_RCC_SPI1_CLK_DISABLE();
__HAL_RCC_ADC1_CLK_DISABLE();

## 5. GPIO Configuration for Low Power

Unused GPIO pins must be configured correctly to prevent floating inputs that cause unwanted current flow. To minimize leakage, unused pins should be set as analog inputs or as inputs with defined pull-up or pull-down resistors.

## 6. DMA and Peripheral Autonomy

Using DMA (Direct Memory Access) and hardware-triggered peripheral operations reduces CPU intervention. For example, a timer can trigger ADC conversions, and DMA transfers the results directly to memory. This keeps the CPU in Sleep or Stop mode longer, reducing overall system power consumption.

## 7. Conclusion

Effective power management in STM32 designs relies on the intelligent use of power modes, proper clock source selection, and efficient peripheral management. The STM32L4 family’s advanced low-power modes enable exceptional energy savings, while combining internal oscillators with the LSE ensures accurate timekeeping even in deep sleep states. Clock gating, correct GPIO settings, and DMA-based operation further optimize energy efficiency, making these techniques essential for battery-operated and IoT systems.