🔑 Synchronization Primitives in FreeRTOS

1. Binary Semaphore

- Works like an ON/OFF flag.
- Commonly used for **task-to-task** or **ISR-to-task signaling**.
- Example: An ISR “gives” the semaphore when data is ready, and a task “takes” it to process the data.

2. Counting Semaphore

- Similar to binary, but the semaphore value can be greater than 1.
- Useful for **counting events** or managing access to a pool of identical resources.
- Example: Controlling access to a pool of 5 buffers.

3. Mutex (Mutual Exclusion Semaphore)

- Protects a **shared resource** (like UART, I2C, or a global variable) so only one task uses it at a time.
- Has a **priority inheritance mechanism** to avoid *priority inversion*.

4. Recursive Mutex

- A special kind of mutex that allows the **same task** to “take” the mutex multiple times (as long as it gives it back the same number of times).
- Useful in cases where a function that takes a mutex is called by another function that already holds it.

5. Event Groups

- A collection of bits that tasks can **wait on**.
- Tasks can wait for one or more bits to be set before continuing.
- Useful for synchronization of multiple events.
- Example: A task waits until both “WIFI_CONNECTED” and “SENSOR_READY” flags are set.

6. Task Notifications (Direct-to-Task Notifications)

- Lightweight and faster than semaphores.
- Each task has a built-in **notification value** (like a private semaphore or mailbox).
- Tasks can block waiting for a notification, and ISRs or tasks can send notifications.
- Often recommended instead of binary semaphores when possible.

7. Message Queues

- FIFO buffers managed by the kernel.
- Used for **task-to-task** or **ISR-to-task communication**.
- You can send structured data (not just a signal) between tasks.
- Example: A producer task sends sensor readings to a queue, and a consumer task processes them.

8. Stream Buffers

- One-way communication channel for **continuous streams of bytes**.
- Designed for sending data from **ISR to task** (like UART receive)..
- Works like a circular buffer managed by FreeRTOS.

9. Message Buffers

- Similar to stream buffers, but instead of a continuous stream, data is sent as discrete messages (each message has a length)..
- Example: Sending packets of varying sizes between tasks.

Primitive	**Purpose**	**Typical Use Case**
Binary Semaphore	Signaling (task/ISR → task)	ISR signals a task
Counting Semaphore	Counting events / resource pool	Multiple buffers available
Mutex	Exclusive access to a resource	Protect UART/I2C access
Recursive Mutex	Same task can lock multiple times	Nested function calls
Event Groups	Sync multiple events (bit flags)	Wait for WiFi + Sensor ready
Task Notifications	Lightweight semaphore/queue alternative	Fast ISR → task signaling
Message Queue	Send data/messages between tasks	Producer/Consumer
Stream Buffer	Continuous byte stream	UART/ADC data stream
Message Buffer	Discrete variable-length messages	Network packets