EE3220 System-on-Chip Design

Tutorial Note 3

ARM-based 32-bit MCUs Debug & UART

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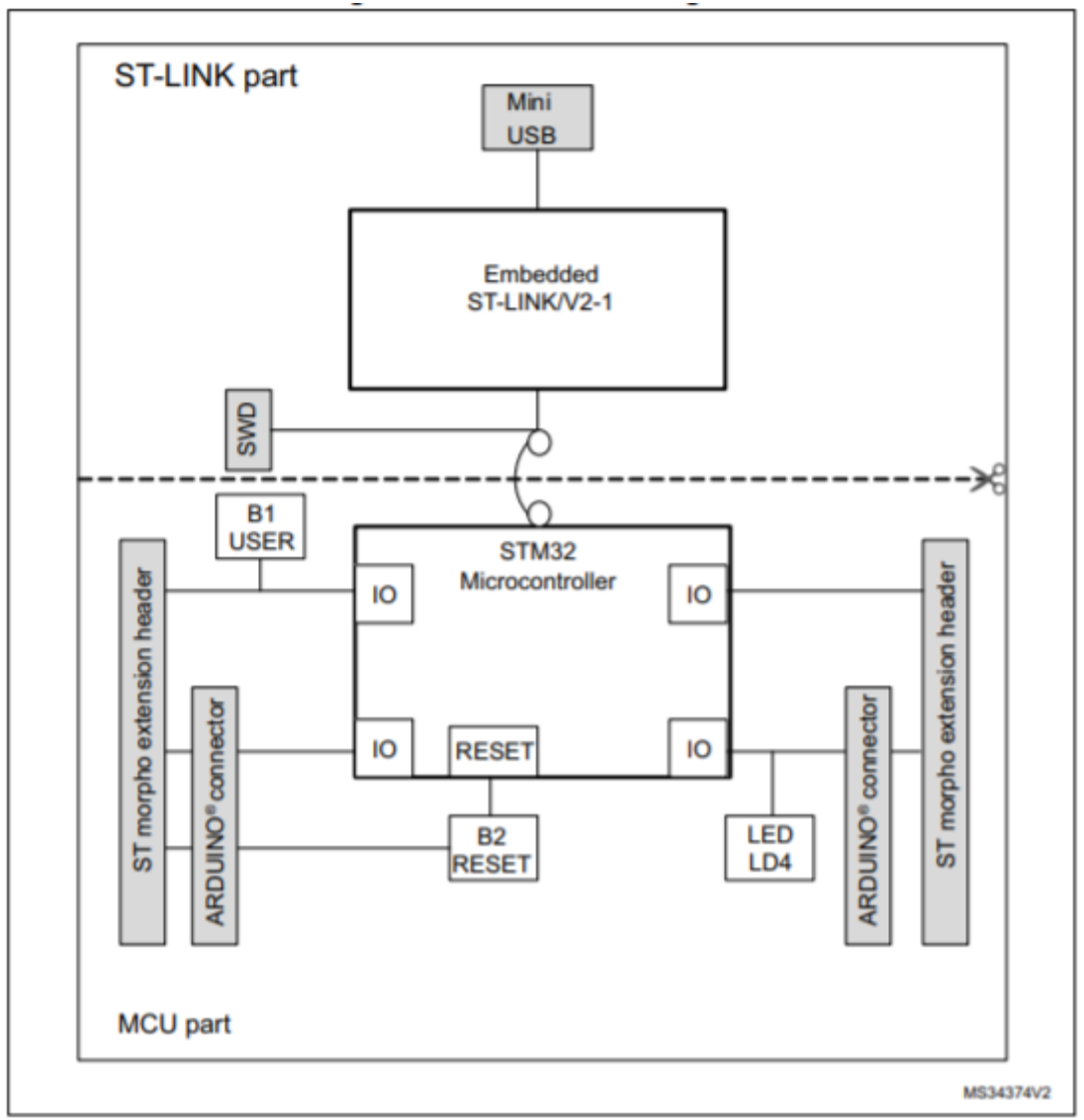
Objective

- In this tutorial, you will be able to learn:
  - The basic feature and design tools of ARM Cortex-M architecture.
  - Debug system architecture and experiment with Keil Studio.
  - Serial communication bus– UART and USART.

Overview of NUCLEO F401-RE

- **Common features**
- – STM32 microcontroller in LQFP64 package
- – 1 user LED shared with ARDUINO®
- – 1 user and 1 reset push-buttons
- – 32.768 kHz crystal oscillator
- – Board connectors:
- ◦ ARDUINO® Uno V3 expansion connector
- ◦ ST morpho extension pin headers for full access to all STM32 I/Os
- – Flexible power-supply options: ST-LINK, USB VBUS, or external sources
- – On-board ST-LINK debugger/programmer with USB re-enumeration
- capability: mass storage, Virtual COM port and debug port
- – Comprehensive free software libraries and examples available with the
- STM32Cube MCU Package
- – Support of a wide choice of Integrated Development Environments (IDEs)
- including IAR Embedded Workbench®, MDK-ARM, and STM32CubeIDE
- **Board-specific features**
- – External SMPS to generate Vcore logic supply
- – 24 MHz HSE
- – Board connectors:
- ◦ External SMPS experimentation dedicated connector
- ◦ Micro-AB or Mini-AB USB connector for the ST-LINK
- ◦ MIPI® debug connector
- – Arm® Mbed Enabled™ compliant



Development tools

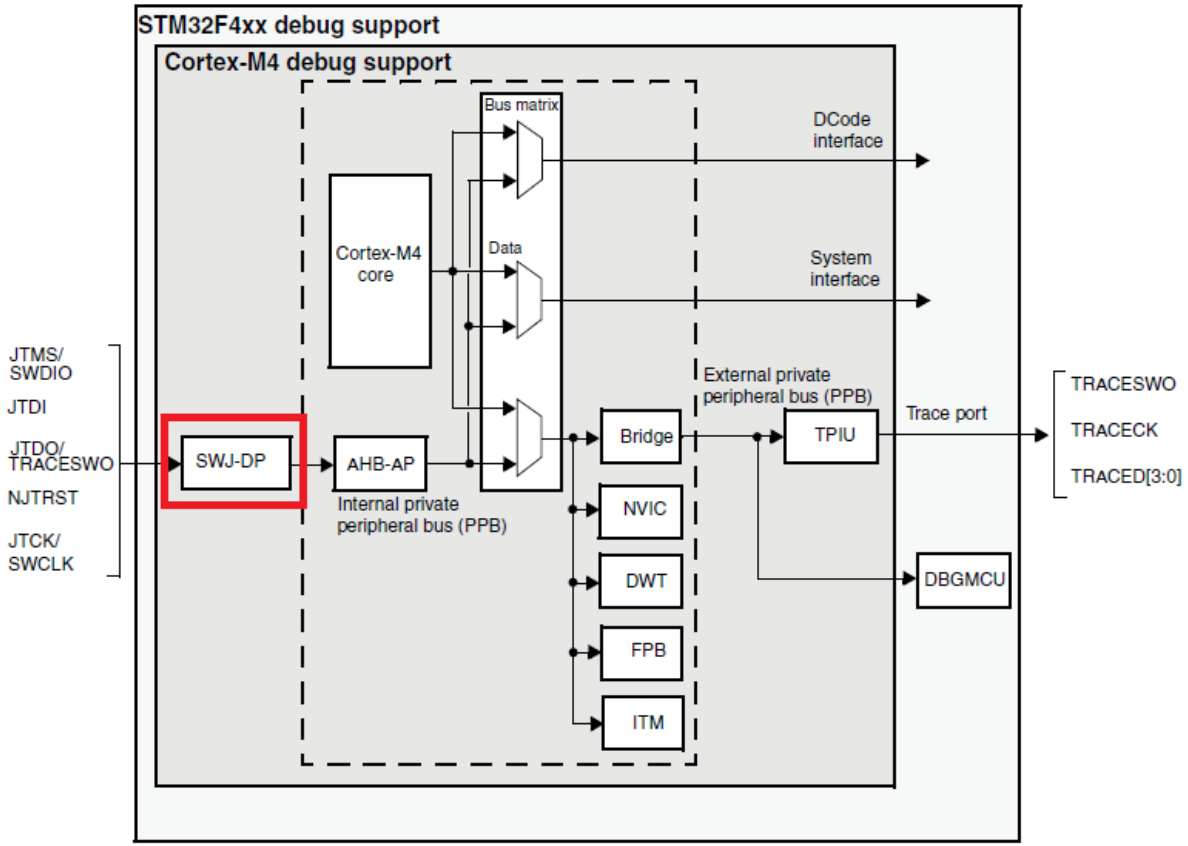
- The board is supported by many tools and IDEs many vendors
  - ARM Development Studio (licensed)
  - ARM® Mbed online
  - ARM Keil Studio Cloud
  - STM32CubeIDE (free)
  - IAR Systems - IAR Embedded Workbench® (licensed)
  - Keil®: MDK-ARM(a) (licensed)
  - GCC-based IDEs
  - CrossWorks
  - SEGGER Embedded Studio (commercial with free-trial)
  - SW4STM32 (free)
  - TrueSTUDIO (free)
  - MATLAB® and Simulink® (licensed)

Debug system overview

- The STM32F401RE is built around a Cortex®-M4 with FPU core which contains hardware extensions for advanced debugging features:
  - The debug extensions allow the core to be stopped either on a given instruction fetch (breakpoint) or data access (watchpoint).
  - When stopped, the core's internal state and the system's external state may be examined.
  - Once examination is complete, the core and the system may be restored and program execution resumed.
- Two interfaces for debug are available:
  - Serial wire
  - JTAG debug port

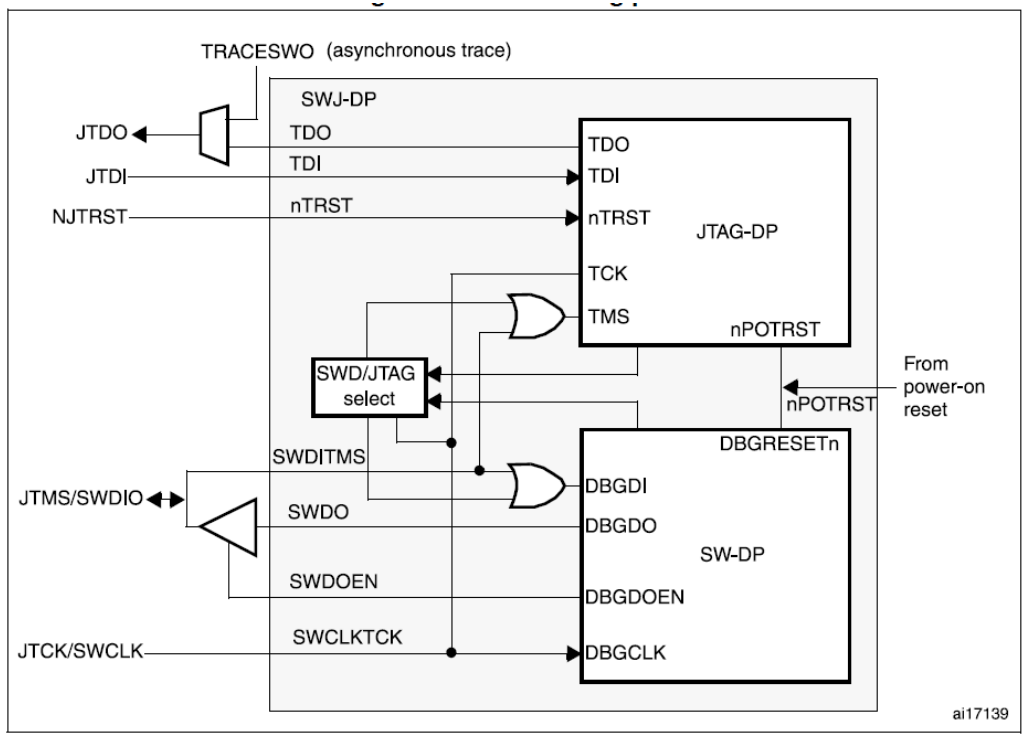
STM32 MCU and Cortex®-M4 debug block

- The Arm® Cortex®-M4 with FPU core provides integrated on-chip debug support. It is comprised of:
  - SWJ-DP: Serial wire / JTAG debug port
  - AHP-AP: AHB access port
  - ITM: Instrumentation trace microcell
  - FPB: Flash patch breakpoint
  - DWT: Data watchpoint trigger
  - TPUI: Trace port unit interface
  - ETM: Embedded Trace Macrocell



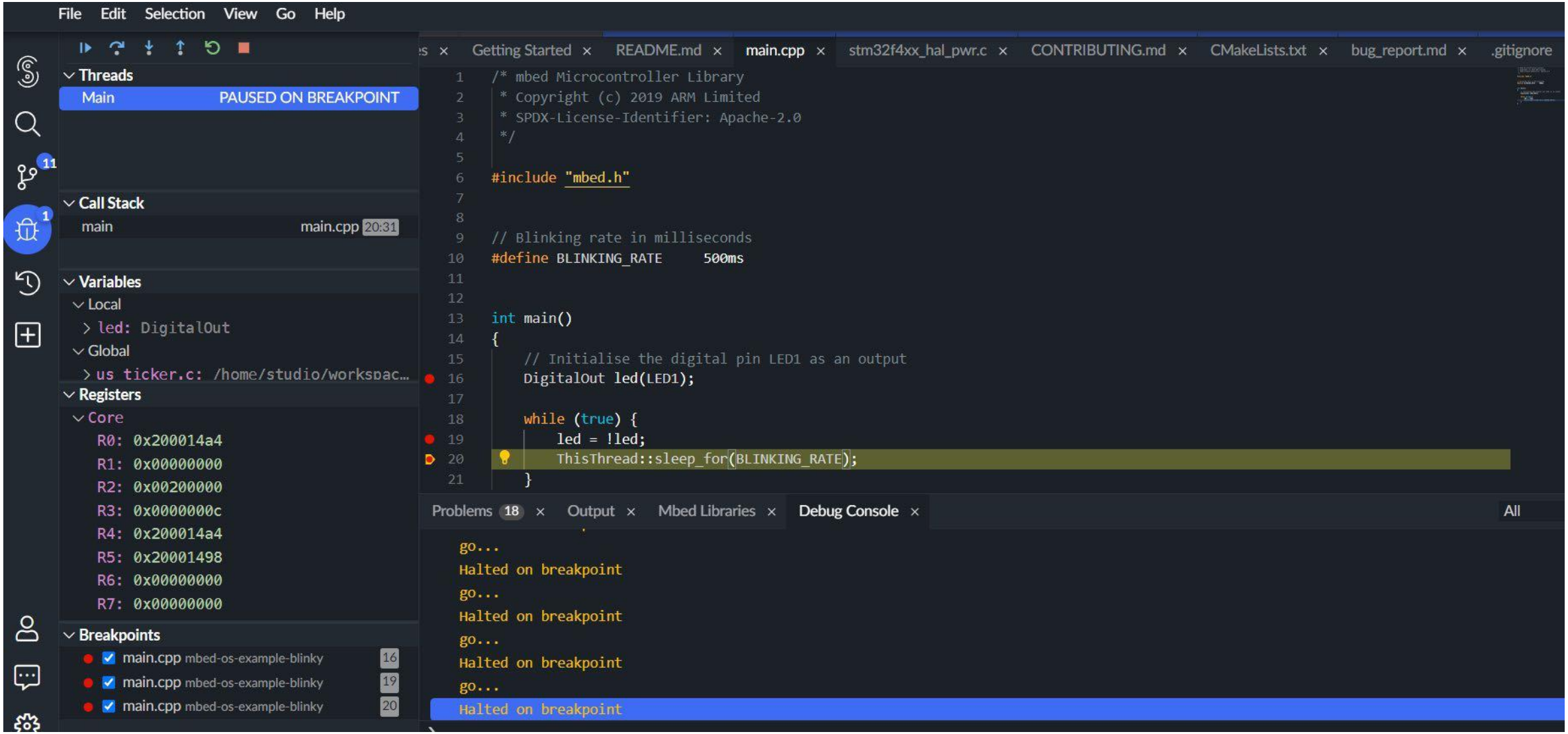
SWJ debug port

- The core of the STM32F401RE integrates the Serial Wire / JTAG Debug Port (SWJ-DP). It is an Arm® standard CoreSight debug port that combines a JTAGDP (5-pin) interface and a SW-DP (2-pin) interface.
  - The JTAG Debug Port (JTAG-DP) provides a 5-pin standard JTAG interface to the AHP-AP port.
  - The Serial Wire Debug Port (SW-DP) provides a 2-pin (clock + data) interface to the AHP-AP port.



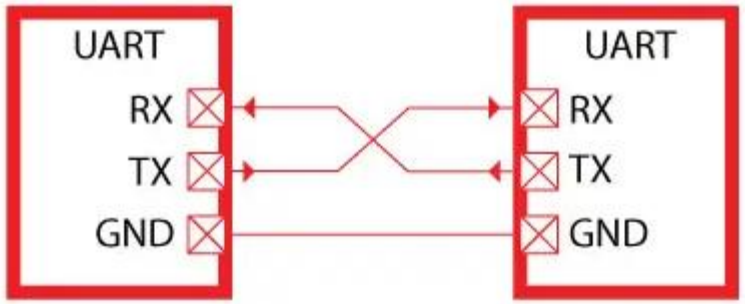
- In STM32F401RE, debug is performed using 2 pins only instead of 5 required by the JTAG (JTAG pins could be re-use as GPIO with alternate function): the JTAG TMS and TCK pins are shared with SWDIO and SWCLK, respectively, and a specific sequence on the TMS pin is used to switch between JTAG-DP and SW-DP.

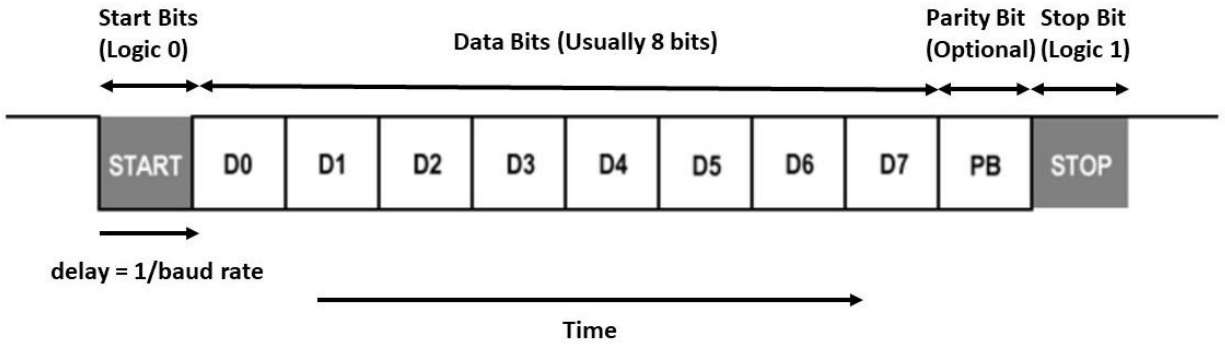
Debug in Keil Studio



UART

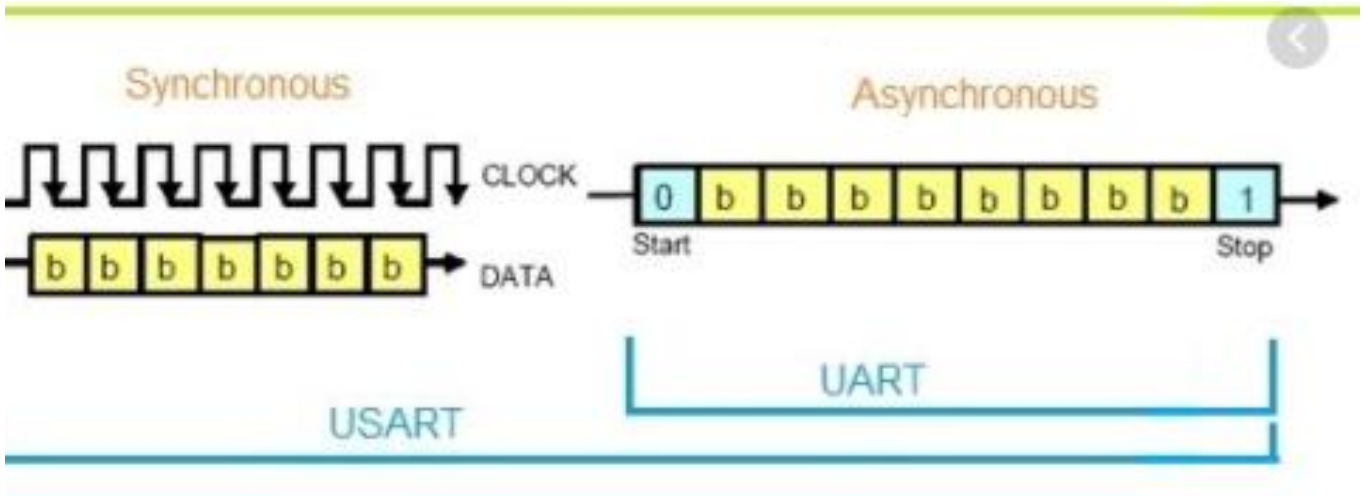
- Universal Asynchronous Receiver Transmitter (UART) is one of the simplest and the most common protocols for serial communication between hardware devices.
- A UART device requires only two wires, one for transmitting and the other for receiving, to support full duplex communication.
- The UART module converts data into a stream of serial bits and transmits in a packet form shown in the following figure. The data stream is transferred at a fixed **baud rate** in both direction.





USART

- USART — a Universal Synchronous/Asynchronous Receiver/Transmitter
  - In synchronous mode, have a reference clock signal to receiver
  - Receiver could not know the baud rate



USART Configure

- Baud rate register (USART_BRR)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Reserved															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DIV_Mantissa[11:0]												DIV_Fraction[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

USART Configure (cont'd)

- Control register 3 (USART_CR3)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Reserved															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Reserved				ONEBIT	CTSIE	CTSE	RTSE	DMAT	DMAR	SCEN	NACK	HDSEL	IRLP	IREN	EIE
				rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

  - Set as 0x0000 if no flow control

USART Configure (cont'd)

- Control register 2 (USART_CR2)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Reserved															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	LINEN	STOP[1:0]		CLKEN	CPOL	CPHA	LBCL	Res.	LBDIE	LBDL	Res.	ADD[3:0]			
	rw	rw	rw	rw	rw	rw	rw		rw	rw	rw	rw	rw	rw	rw

  - STOP[1:0]: STOP bits
  - 00: 1 Stop bit

USART Configure (cont'd)

- Control register 1 (USART_CR1)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Reserved															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OVER8	Reserved	UE	M	WAKE	PCE	PS	PEIE	TXEIE	TCIE	RXNEIE	IDLEIE	TE	RE	RWU	SBK
rw	Res.	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

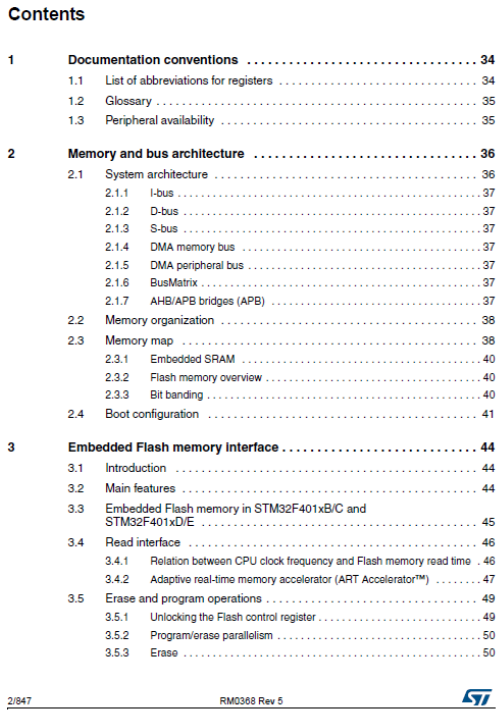
- Bit 2 RE: Receiver enable
  - 0: Receiver is disabled
  - 1: Receiver is enabled and begins searching for a start bit ← enable RX
- Bit 3 TE: Transmitter enable
  - 0: Transmitter is disabled
  - 1: Transmitter is enabled ← enable TX
- Bit 12 M: Word length.
  - 0: 1 Start bit, 8 Data bits, n Stop bit
  - 1: 1 Start bit, 9 Data bits, n Stop bit
- Bit 13 UE: USART enable
  - 0: USART prescaler and outputs disabled
  - 1: USART enabled
- Bit 7 TXEIE: TXE interrupt enable
  - 0: Interrupt is inhibited
  - 1: An USART interrupt is generated whenever TXE=1 in the USART_SR register ← After NVIC setting done

For more details

- Go to board website read more reference document.
  - https://www.st.com/en/microcontrollers-microprocessors/stm32f401re.html#documentation

- Reference document.
  - RM0368 Reference manual

    https://www.st.com/resource/en/reference_manual/dm00096844-stm32f401xb-c-and-stm32f401xd-e-advanced-arm-based-32-bit-mcus-stmicroelectronics.pdf



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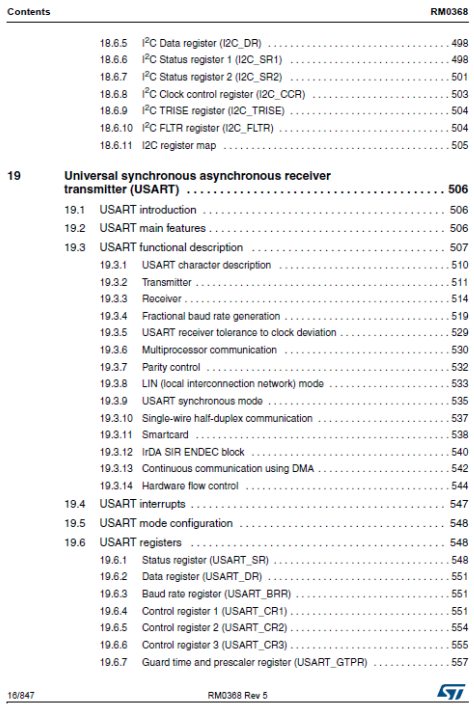

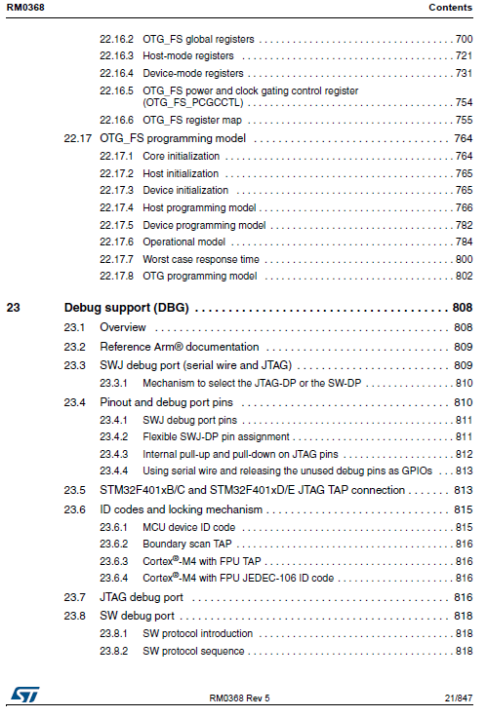

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