Here is a **README** file for your **STM32F401RE On-Chip Temperature Sensor with USART2** project. You can save it as **README.md** (for GitHub) or **README.docx** (for Word).

**STM32F401RE On-Chip Temperature Sensor (ADC1 CH18) with USART2 Output**

This project reads the **on-chip temperature sensor** of the **STM32F401RE** using **ADC1 Channel 18** and prints the **temperature (°C)** over **USART2** to a **serial terminal (Tera Term / PuTTY)**.

✅ **Temperature updates every 1 second**  
✅ **Uses TIM2 as a trigger for ADC1 conversions**  
✅ **Sends results via USART2 (9600 baud) to a serial terminal**

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**1. Overview**

* **MCU**: STM32F401RE (Nucleo-F401RE)
* **ADC**: **ADC1 Channel 18 (Internal Temperature Sensor)**
* **ADC Trigger**: TIM2 (1 Hz)
* **Serial Communication**: USART2 (PA2, TX)
* **Baud Rate**: 9600

**Formula (from STM32F4 Reference Manual)**

Temperature(°C)=(VSENSE–V25)Avg\_Slope+25Temperature (°C) = \frac{(VSENSE – V25)}{Avg\\_Slope} + 25

* **V25** = **0.76V**
* **Avg\_Slope** = **2.5mV/°C**

**2. Hardware Setup**

| **Peripheral** | **STM32F401RE Pin** | **Description** |
| --- | --- | --- |
| **Internal Temp Sensor** | **ADC1 Channel 18** | Measures on-chip temperature |
| **USART2 TX** | **PA2** | Sends data over ST-Link Virtual COM Port |

**💡 No External Hardware Required!**

The **on-chip temperature sensor** and **USART2 (ST-Link)** are used, so you only need **USB power and a terminal program**.

**3. Software Explanation**

**🟢 TIM2 (1 Hz ADC Trigger)**

* TIM2 triggers ADC1 conversions **every 1 second**.
* Uses **CH2 as a trigger source for ADC1**.

**🟢 ADC1 (Temperature Sensor)**

* **Uses Channel 18 (internal sensor)**.
* **Enabled via ADC->CCR register**.
* **Samples at 15 ADC cycles for accuracy**.

**🟢 USART2 (Serial Output)**

* **TX (PA2) sends data to the ST-Link Virtual COM Port**.
* **Uses printf() to print temperature readings**.

**🟢 Data Flow**

TIM2 (1Hz) → Triggers ADC1 CH18 → Reads Temperature → Sends to USART2 → Serial Monitor

**4. Project Structure**

.

├── Inc/

│ └── stm32f4xx.h // CMSIS/Device headers

├── Src/

│ └── main.c // Contains ADC1, TIM2, and USART2 logic

└── README.md // This file

**5. Building and Uploading**

**Using Keil uVision / STM32CubeIDE**

1. **Open Keil uVision or STM32CubeIDE**
2. **Create a new project** for STM32F401RE
3. **Copy main.c into the Src/ directory**
4. **Compile and Flash the project** to **Nucleo-F401RE**

**6. Usage**

**1️⃣ Flash the code to the STM32F401RE**

* Use **Keil uVision** or **STM32CubeIDE**.

**2️⃣ Open a Serial Terminal**

* **Tera Term** / **PuTTY** / **RealTerm**
* Select the **"STMicroelectronics STLink Virtual COM Port"**.
* **Set Baud Rate to 9600, 8N1** (8 data bits, No parity, 1 stop bit).

**3️⃣ Observe Temperature Readings**

✅ Every second, you will see:

ADC: 1820, Temp: 32.45°C

ADC: 1815, Temp: 32.20°C

✅ The temperature will **change slightly** depending on MCU activity and ambient temperature.

**7. Troubleshooting**

**🔴 No Serial Output?**

✅ Ensure that the **ST-Link Virtual COM Port** is installed on your PC.  
✅ Check that **PA2 is configured as AF7 (USART2 TX)**.  
✅ Verify USART2 is enabled (USART2->CR1 |= (1U << 13);).

**⚠️ ADC Reads Incorrect Temperature?**

✅ Make sure that **VBAT sensing is disabled** (ADC->CCR &= ~(1U << 22);).  
✅ Increase **sampling time** (ADC1->SMPR1 = (3U << 24);) for better accuracy.

**⏳ Want Faster ADC Updates?**

✅ Decrease **TIM2 Auto-Reload Value (TIM2->ARR)** to sample **faster than 1 Hz**.

**8. License**

This project is licensed under the **MIT License**.  
You are free to **modify, distribute, and use** the code.

**9. References**

📄 [STM32F401RE Datasheet](https://www.st.com/en/microcontrollers-microprocessors/stm32f401re.html)  
📄 [STM32 Reference Manual (RM0368)](https://www.st.com/resource/en/reference_manual/dm00096844.pdf)  
📄 [ADC Programming Guide](https://www.st.com/resource/en/programming_manual/dm00245755.pdf)

**🚀 Summary**

✅ **Reads STM32F401RE's on-chip temperature sensor (ADC1 CH18)**  
✅ **Uses TIM2 to trigger ADC1 conversion every 1 second**  
✅ **Sends temperature data over USART2 at 9600 baud**  
✅ **No external hardware required!**

📡 **Enjoy real-time temperature monitoring on STM32F401RE! 🎯**