**Below is the README content reformatted as a Word-style document.**

You can copy everything between the asterisks (\*\*\* ...) into a new blank Microsoft Word file. Adjust formatting (fonts, headings, table styles, etc.) as desired.

**8-bit LCD Interface on STM32F401RE (Direct Register Access)**

This document demonstrates how to interface a standard 16×2 (or similar) character LCD with an STM32F401RE microcontroller using **8-bit parallel mode** via direct register access. The example code displays the word **"Hello"** on the LCD, then clears the display repeatedly.

**Table of Contents**

1. [Overview](https://chatgpt.com/c/67ac9336-5850-8000-b005-1be99daeb42b#Overview)
2. [Project Structure](https://chatgpt.com/c/67ac9336-5850-8000-b005-1be99daeb42b#Project-Structure)
3. [Hardware Connections](https://chatgpt.com/c/67ac9336-5850-8000-b005-1be99daeb42b#Hardware-Connections)
4. [Getting Started](https://chatgpt.com/c/67ac9336-5850-8000-b005-1be99daeb42b#Getting-Started)
5. [How It Works](https://chatgpt.com/c/67ac9336-5850-8000-b005-1be99daeb42b#How-It-Works)
6. [Customizing](https://chatgpt.com/c/67ac9336-5850-8000-b005-1be99daeb42b#Customizing)
7. [Troubleshooting](https://chatgpt.com/c/67ac9336-5850-8000-b005-1be99daeb42b#Troubleshooting)
8. [License](https://chatgpt.com/c/67ac9336-5850-8000-b005-1be99daeb42b#License)
9. [References](https://chatgpt.com/c/67ac9336-5850-8000-b005-1be99daeb42b#References)

**1. Overview**

* **MCU**: STM32F401RE (e.g., Nucleo-F401RE board)
* **LCD**: Character LCD (HD44780-compatible or equivalent)
* **Interface**: 8-bit data bus + 3 control signals
* **Libraries**: CMSIS/Startup files for the STM32F4 series (direct register access, no HAL drivers)

In this setup:

* **PC0–PC7** connect to **LCD D0–D7**.
* **PB5** connects to **RS** (Register Select).
* **PB6** connects to **R/W** (Read/Write).
* **PB7** connects to **EN** (Enable).

The code provides functions to:

* Initialize the LCD.
* Send LCD commands (with and without polling).
* Write data (characters) to the LCD.
* Poll the "busy flag" (BF) for timing.
* Provide a simple millisecond delay routine.

**2. Project Structure**

A minimal folder layout might look like this:

.

├─ Inc/

│ └─ stm32f4xx.h (or stm32f401xe.h, depending on your CMSIS package)

│

├─ Src/

│ └─ main.c (contains the LCD code)

│

└─ README.docx (this file)

Depending on your development environment (Keil uVision, STM32CubeIDE, etc.), the directory structure can differ. The essential files are:

* **main.c** (the direct register access code for the LCD).
* The **CMSIS/Device** headers for STM32F401RE.

**3. Hardware Connections**

The table below shows an example wiring setup between the STM32F401RE (Nucleo board) and the LCD.

| **LCD Pin** | **Description** | **STM32 Pin** | **Notes** |
| --- | --- | --- | --- |
| D0 | Data Bit 0 | PC0 |  |
| D1 | Data Bit 1 | PC1 |  |
| D2 | Data Bit 2 | PC2 |  |
| D3 | Data Bit 3 | PC3 |  |
| D4 | Data Bit 4 | PC4 |  |
| D5 | Data Bit 5 | PC5 |  |
| D6 | Data Bit 6 | PC6 |  |
| D7 | Data Bit 7 | PC7 |  |
| RS | Reg Select | PB5 |  |
| R/W | Read/Write | PB6 | Usually tied LOW if only writing to LCD |
| EN | Enable | PB7 |  |
| VSS | LCD Ground | GND |  |
| VDD | +5 V or +3.3 V | 3.3 V or 5V | Check your LCD module’s VCC requirements |
| VO | Contrast Pin | Pot or Resistor divider | Adjust contrast (often 10 kΩ pot) |
| A (LED+) | Backlight + | 3.3 V or 5 V | Depends on LCD’s backlight voltage |
| K (LED-) | Backlight – | GND |  |

**Note**: Some LCD modules require 5 V; if yours cannot run at 3.3 V, use a level shifter or supply 5 V where appropriate.

**4. Getting Started**

1. **Clone or Copy** the source files into your development environment.
2. **Open** the project in your IDE of choice (e.g., Keil uVision, STM32CubeIDE).
3. **Verify** you have the correct CMSIS/Device configuration for the **STM32F401RE**.
4. **Confirm** the clock is set to **84 MHz** (default on the Nucleo-F401RE).
5. **Wire** the LCD pins to the corresponding GPIO pins on the MCU as shown above.
6. **Build** and **flash** the project to the board.

When powered, the LCD should initialize and display the word **"Hello"** repeatedly, clearing in between.

**5. How It Works**

1. **Initialization**
   * The LCD\_init() function sets up the GPIO directions for LCD control and data pins.
   * It sends several 0x30 commands (without polling) because the LCD’s busy flag is not yet readable immediately after power-up.
   * Then it configures 8-bit mode, clears the screen, and enables the display/cursor.
2. **Sending Commands & Data**
   * **LCD\_command()** polls the busy flag (BF, D7) before sending a command.
   * **LCD\_data()** also polls BF, then writes a character (ASCII code) to the data port.
   * **LCD\_command\_noPoll()** is only for the initial steps when the BF can’t be read.
3. **Repeated Display**
   * In the while(1) loop of main(), the code prints **"Hello"**, waits 500 ms, clears the LCD (command 0x01), waits again, and repeats.
4. **Delays**
   * The delayMs() function is a simple software loop calibrated for an ~84 MHz clock. For more precise timing, use **SysTick** or a hardware timer.

**6. Customizing**

* **Change the text**: Modify the sequence of LCD\_data() calls in the main loop to display any text you like.
* **Move cursor**: Use LCD\_command(0xC0) to set the cursor to the second line on a 2×16 display.
* **Adjust delays**: If the LCD is slow or you need more margin, increase the delay. To improve accuracy, use a hardware timer.
* **Remap pins**: Change the pin assignments in PORTS\_init() if needed.

**7. Troubleshooting**

* **No text visible**:
  1. Check contrast on pin VO.
  2. Confirm correct wiring of RS, RW, EN, and data pins.
  3. Ensure the LCD is powered at a suitable voltage (3.3 V or 5 V).
* **Garbled or random characters**:
  1. Double-check that the LCD is in 8-bit mode.
  2. Verify the initialization sequence (timing might need adjustments).
  3. Check for loose wiring or incorrect pin connections.
* **Partial text or missing characters**:
  1. Ensure all 8 data lines are firmly connected.
  2. Polling BF might be failing if the LCD lines aren’t correctly set to input mode during reads.
  3. Use longer delays if the LCD is not responding in time.

**8. License**

This project is provided under the [MIT License](https://opensource.org/licenses/MIT). Feel free to modify, use, or distribute as needed.

**9. References**

* **STM32F401RE Reference Manual (RM0368)**: [ST.com resource](https://www.st.com/resource/en/reference_manual/dm00096844.pdf)
* **HD44780 LCD Controller Datasheet**: Various sources (e.g., SparkFun)
* **Nucleo-F401RE Board Info**: [ST official page](https://www.st.com/en/evaluation-tools/nucleo-f401re.html)

**End of Document**

**Instructions**:

1. Select all text (including the headings).
2. Paste into a new Microsoft Word document.
3. Save as .docx.
4. Adjust formatting (fonts, headings, spacing) as needed.