OVERVIEW

The following application note describes the interface of a LCD text display to a 8051 microcontroller system. This application note comes with the µVision2 project **LCD_Display.UV2** that includes C source code of the interface software and a complete simulation script for simulator based testing. In this example, we are using the LCD-Controller ST6077. However, the interface to other text displays is similar.

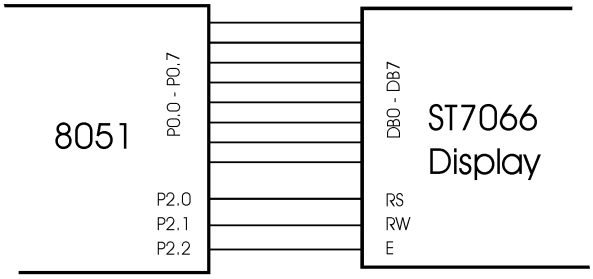
µVision2 provides full integration of the C51 compiler and debugger. Today applications need to be tested before real hardware becomes available. Therefore µVision2 offers both: a simulator that seamless simulates the complete peripherals of countless 8051 derivatives, and a target debugger that allows software testing in real hardware with a target monitor or emulator.

If you open the µVision2 project **LCD_Display.UV2** you can easily follow the steps described in this application note.

HARDWARE INTERFACE

This section gives an overview about the connection and communication between the ST6077 LCD display device and the 8051 microcontroller. Details are provided in the datasheet **st6077v151.pdf** that comes in the file **APNT_161.ZIP**.

The schematic below shows you how the devices are connected:



The data bus of the ST7066 is connected to the 8051 Port P0. The three control pins RS, RW, and E are connected to the 8051 I/O Port P2.0 – P2.1. These connections are reflected in the software interface.

Overview of the display pins	
DB0 – DB7	8bit data bus
RW	Selects Read or Write mode 0: Read 1: Write
RS	Select Registers 0: Instruction register (for write) / address counter (for read)

	1: Data Register (read and write)
E	Enables data read/write (This has to follow each command)

SOFTWARE INTERFACE

The file **LCD_interface.C**, that comes with the µVision2 project **LCD_Display.UV2** is the source code that handles all basic input/output to the LCD text display. You may use this file as template for your own 8051 display driver.

```
/*----------------------------------------------------------------------------
LCD_interface.C
Copyright 2001 Keil Software, Inc.
----------------------------------------------------------------------------*/
#include <reg51.h>
#include <stdio.h>
#include <intrins.h>

sbit  P20_PIN = P2^0;              // I/O Pin for P2.0
sbit  P21_PIN = P2^1;              // I/O Pin for P2.1
sbit  P22_PIN  = P2^2;              // I/O Pin for P2.2

#define LINE1_ADDR 0x00      // Start of line 1 in the DD-Ram
#define LINE2_ADDR 0x40      // Start of line 2 in the DD-Ram

/* Display-Commands */
#define CLEAR_DISPLAY 0x01   // Clear entire display and set Display Data Address to 0
#define DD_RAM_PTR    0x80   // Address Display Data RAM pointer
#define DISP_INIT     0x38   // 8 bit 2 lines
#define INC_MODE      0x06   // Display Data RAM pointer incremented after write

/*
* ReadInstrReg: Read from Instruction Register of LCD Display Device
*/
static unsigned char ReadInstrReg (void)  {
  unsigned char Instr;
  P0 = 0xff;            // DATA PORT is input
  P20_PIN = 0;          // select instruction register
  P21_PIN = 1;          // read operation
  P22_PIN = 1;          // give operation start signal
  _nop_ (); _nop_ ();   // wait
  Instr = P0;           // read Instruction
  P22_PIN = 0;
  return(Instr);
}

/*
 * WriteInstrReg: Write to Instruction Register of LCD Display Device
 */
static void WriteInstrReg (unsigned char Instr)  {
  P20_PIN = 0;          // select instruction register
  P21_PIN = 0;          // write operation
  P22_PIN = 1;          // give operation start signal
  _nop_ (); _nop_ ();   // wait
  P0 = Instr;           // write instruction
  P22_PIN = 0;
  P0 = 0xff;            // DATA_PORT is input [prevent I/O-Port from damage]
}

/*
 * ReadDataReg: Read from Data Register of LCD Display Device
```

```
 */
static unsigned char ReadDataReg (void)  {
  unsigned char val;
  P0 = 0xff;           // DATA_PORT is input
  P20_PIN = 1;         // select data register
  P21_PIN = 1;         // read-operation
  P22_PIN = 1;         // give operation start signal
  _nop_ (); _nop_ ();  // wait
  val = P0;            // read Instruction
  P22_PIN = 0;
  return (val);
}

/*
 * WriteDataReg: Write to Data Register of LCD Display Device
 */
static void WriteDataReg (unsigned char val)  {
  P20_PIN = 1;          // select data register
  P21_PIN = 0;          // write operation
  P22_PIN = 1;          // give operation start signal
  _nop_ (); _nop_ ();   // wait
  P0 = val;             // write value
  P22_PIN = 0;
  P0 = 0xff;            // DATA_PORT is input [prevent I/O-Port from demage]
}

char putchar (char c)  {
  unsigned char line;
  if (c == '\n')  {
    line = ReadInstrReg ();
    if (line & LINE2_ADDR)  {       // is already in line 2
      WriteInstrReg (LINE1_ADDR | DD_RAM_PTR);   // place to start of line 1
    }
    else  {
      WriteInstrReg (LINE2_ADDR | DD_RAM_PTR);   // place to start of line 2
    }
  }
  else  {
    WriteDataReg (c);
  }
  return (c);
}

/*
 * Waits for some time so the 7066 can do the last command
*/
void wait (unsigned int time) {
  int i;
    for (i = 0; i < time ;i++){
    }
  }
}

/*
 * Clear_Display: Write 0x20 to Display RAM
 */
static void Clear_Display (void)  {
  WriteInstrReg (CLEAR_DISPLAY);
  wait (1);
}
```

The putchar function is the basic output routine that is used for simple character output. These function is used by the function printf. In addition we have implemented the function Clear_Display.

The following test code allows you to check the implementation.

```
void main (void)  {
  unsigned char c;
  for (c = 'A'; c < 'H'; c++)  {  // Put the characters A to H to the display
    putchar (c);
  }
  printf ("Hello \n");            // Puts 'Hello' to the display using printf()
  Clear_Display ();               //Clear the display and reset cursor
  for (c = 0; c < 10; c++)  {
    printf ("This is Display Line %bd\n", c);  // another printf() testing
  }
  while (1);  //never stop
.
```

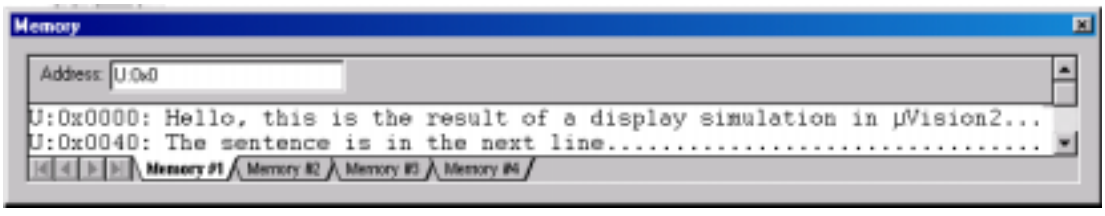
Function Overview of the Software Interface	
ReadInstrReg ()	Returns the instruction in the instruction register.
WriteInstrReg (*Instr*)	Writes the instruction I*nstr* out to the instruction register. Nothing is returned.
ReadDataReg ()	Returns the value in the Data Register.
WriteDataReg (*val*)	Writes the value *val* to the Data Register.
putchar (*c*)	Behaves like a normal putchar value. The value in c is written to the display and returned if it was successful.
Clear_Display ()	Clears the entire Display by filling the Data Ram with blanks.

The test code does not use all interface functions, but they are implemented for completeness.

µVISION2 SIMULATION

The following section shows you how to simulate the LCD text display with µVision2.

The µVision2 simulator provides several ways to simulate a text display. One of the easiest methods is to use the µVision2 memory window as ASCII display. In addition to the standard microcontroller memory, µVision2 offers four user defined memory spaces that are accessed with the prefixes **S:**, **T:**, **U:**, and **V:**. We are using the **U:** memory space as display memory for the LCD text display. The µVision2 memory window is used in ASCII mode. You may resize the window, so that it reflects the size of your LCD display as shown below.

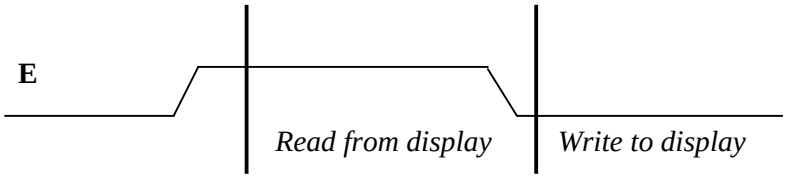


The following µVision2 script defines debug functions and other required settings to simulate the LCD text display.

The MAP command reserves 80 Bytes of the user-memory **U:**. The size is identical to your display size. In this example:

*2 rows * 0x40 characters = 0x80 character with 1 Byte each*

The debug function **Simulate_Display** is triggered on a write to Port 2 (P2). This behavior is defined with the **BreakSet** command on the last line of the µVision2 script. This command *connects* the control lines of the LCD text display controller to the simulated 8051 device. Any write event on Port 2 (P2) calls the function **Simulate_Display**. Depending on the previous Port 2 (SD_oldPORT2) state, a LCD display read or write command is performed as explained in the following diagram.



- Read from LCD display: **E** (P2.2) signal changes from low to high.
- Write to LCD display: **E** (P2.2) signal changes from high to low.

The signal **RS (Port 2.0)** selects the instruction register or the display RAM of the LCD device. The signal **RW (Port 2.1)** defines a read or write command to the LCD device.

```
define unsigned char SD_oldPORT2;
define unsigned char SD_cursor;


MAP U:0, U:0x80 READ WRITE   // This line maps the user memory.
// U:0 as start address in the memory window shows it

/*
 * Simulate the 'Clear Display' command
 */
func void SD_clear (void)  {
  unsigned char i;
  for (i = 0; i < 0x80; i++)  {
   _WBYTE (U:0+i, 0x20);
   // Writes blanks to the whole user memory ( display memory )

  }
  SD_cursor = 0;   // Sets the cursor to the origin
}


/*
 * Process all commands of the LCD display controller
 */
func void Simulate_Display (void)  {

  if (!(SD_oldPORT2 & 0x04) && (PORT2 & 0x04))  {   // LCD read: E changes to high
    if ((PORT2 & 0x03) == 0x02)  {   // read flag register
      PORT0 = (SD_cursor & 0x7F);    //return DD RAM pointer to port 0 of the 8051
    }
```

```
  }

  if ((SD_oldPORT2 & 0x04) && !(PORT2 & 0x04))  {   // LCD write: E changes to low
    if ((PORT2 & 0x03) == 0)  {      // write to command register
      if (PORT0 == 0x01)  {          // command is 'Clear Display'
        SD_clear ();                 // call the 'Clear Display' simulation
      }
    if (PORT0 & 0x80)  {             // Set DDRAM address (cursor position)
        SD_cursor = (PORT0 & 0x7F);  // set DD RAM pointer
      }
    }
    if ((PORT2 & 0x03) == 0x01)  {   // command is 'Write to RAM'
     _WBYTE (U:0+SD_cursor, PORT0);  // write to DD RAM (user memory @ U:0xXX)
      SD_cursor++;                   // Advance cursor position by 1
    }


    if (PORT2 & 0x02)  {             // read mode
      PORT0 = 0xFF;                  // display data goes to high
    }
  }

  SD_oldPORT2 = PORT2;               // store E for change detection
}


BS WRITE PORT2, 1, "Simulate_Display ()"
```

The debug function **Simulate_Display** analyses some of the states of the LCD display device. To simplify the debug function, we have only implemented the commands that are used by the C51 software interface. The variable **SD_cursor** holds the cursor position in the DDRAM (diplay memory) and is used as *pointer* to the user memory **U:**.

CONCLUSION

Implementing an LCD text interface is straight forward with the Keil development tools. It is even possible to simulate the whole target system with µVision2 without scarifying execution speed. The simulation model described in this application note may be adapted to most other LCD text display controllers.

This application note uses the µVision2 debug functions as peripheral interface. **Application Note 154 "Implementing µVision2 DLL´s for Simulating User Defined Hardware"** describes an interface that is able to simulate complex peripherals which require accurate timing and/or several input/output variables.