AN14321

使用MCX C444 MCU上的段式液晶显示器（SLCD）控制器

第1版—2024年7月15日 **应用笔记**

文档信息

信息	内容
关键词	AN14321、MCX C、SLCD
摘要	本文介绍了通过驱动一个SLCD器件S401M16KR（一个0.17英寸的四位七段定制LCD面板）来使用片上SLCD控制器的方法。

1 介绍

我们随处可见定制的段式液晶显示器（SLCD）技术。例如：

- 用于测量游泳池PH值的产品。
- 用于测量矿井中特定气体的监测仪。
- 用于检查儿童是否发烧的温度计。

SLCD是最古老的显示技术之一。由于其价格低廉且功耗最低，它仍然是最受欢迎的技术之一。

段式LCD显示器，也称为静态显示器或纯玻璃显示器，由两片氧化铟锡（ITO）玻璃和夹在中间的扭曲向列流体组成。静态显示器是一种段式显示屏，每个段都有一个引脚。段是指可单独开启和关闭的任何线、点或符号。

恩智浦MCX C444 MCU集成了SLCD控制器模块，可支持最多8个背板和47个前板，例如8×47或4×51。本文介绍了通过驱动SLCD器件S401M16KR（一个0.17英寸的四位七段定制LCD面板）来使用片上SLCD控制器的方法。

2 硬件

2.1 S401M16KR SLCD器件

S401M16KR SLCD器件可在面板上显示四位数字。每位数字由七段和一个点或冒号显示，如图1所示。

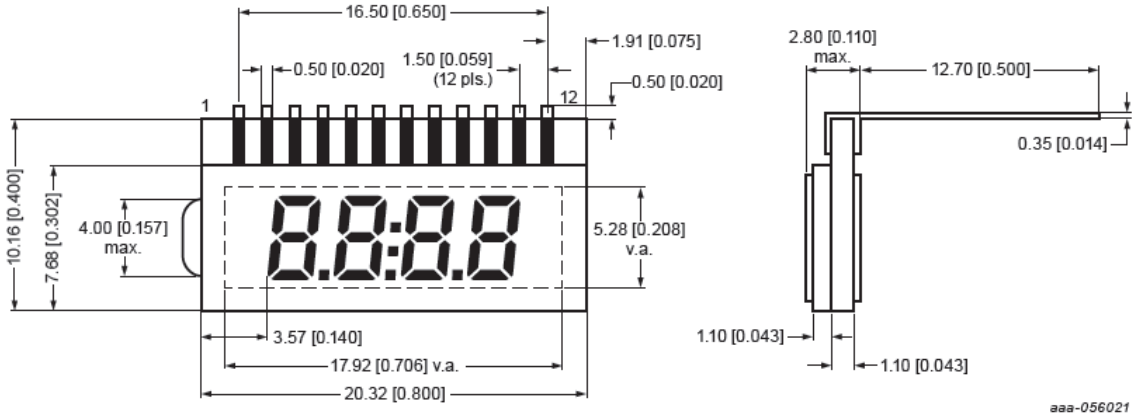

图1. S401M16KR SLCD器件

S401M16KR SLCD器件包含四个COM引脚和八个数据引脚作为控制信号。COM引脚和数据引脚控制一个矩阵，指示在特定时间内哪些段是开启的，哪些段是关闭的，如表1所示。

表1. S401M16KR SLCD器件

引脚	1	2	3	4	5	6	7	8	9	10	11	12
COM0	COM0	/	/	/	1D	DP1	2D	DP2	3D	DP3	4D	COL
COM1	/	COM1	/	/	1E	1C	2E	2C	3E	3C	4E	4C
COM2	/	/	COM2	/	1G	1B	2G	2B	3G	3B	4G	4B
COM3	/	/	/	COM3	1F	1A	2F	2A	3F	3A	4F	4A

COM引脚会在每个步骤逐个开启。在每个步骤中，由其各自的COM引脚激活，八个数据引脚输出控制电平信号以开启和关闭各个段。每个COM的段是逐行开启和关闭的。当包含四个步骤的循环快速运行时，某些段就会同时开启，作为一个整体显示视图（即使它们不在矩阵的同一行中）。

将控制信号视为一个激活矩阵，请参见表2。

表2. 控制信号的激活矩阵

nCS	D0	D1	D2	D3	D4	D5	D6	D7
COM0	1D	1DP	2D	2DP	3D	3DP	4D	4DP
COM1	1E	1C	2E	2C	3E	3C	4E	4C
COM2	1G	1B	2G	2B	3G	3B	4G	4B
COM3	1F	1A	2F	2A	3F	3A	4F	4A

对于每个数字位置，不同的数字由不同的段组合而成。图2以直接分段的方式显示了0-9的数字。

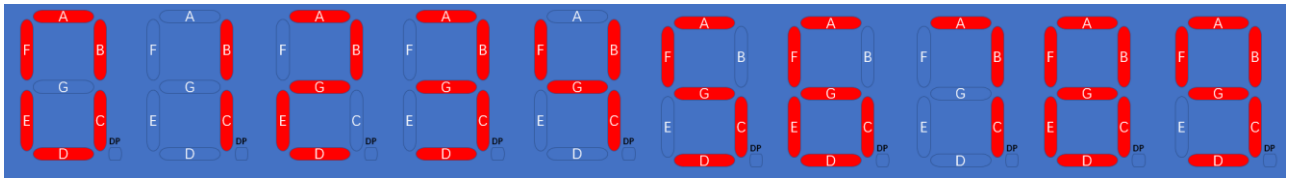

图2. SLCD数字

表3介绍了相关信息。

表3. SLCD数字信息

编号	段	COM0 (.D)	COM1 (CE)	COM2 (BG)	COM3 (AF)
0	ABCDEF	*D (0 × 1)	CE (0 × 3)	B* (0 × 2)	AF (0 × 3)
1	BC	*D (0 × 1)	CE (0 × 3)	B* (0 × 2)	AF (0 × 3)
2	ABDEG	*D (0 × 1)	CE (0 × 3)	B* (0 × 2)	AF (0 × 3)
3	ABCDG	*D (0 × 1)	CE (0 × 3)	B* (0 × 2)	AF (0 × 3)
4	BCFG	*D (0 × 1)	CE (0 × 3)	B* (0 × 2)	AF (0 × 3)
5	ACDFG	*D (0 × 1)	CE (0 × 3)	B* (0 × 2)	AF (0 × 3)
6	ACDEFG	*D (0 × 1)	CE (0 × 3)	B* (0 × 2)	AF (0 × 3)
7	ABC	*D (0 × 1)	CE (0 × 3)	B* (0 × 2)	AF (0 × 3)
8	ABCDEFG	*D (0 × 1)	CE (0 × 3)	B* (0 × 2)	AF (0 × 3)
9	ABCDFG	*D (0 × 1)	CE (0 × 3)	B* (0 × 2)	AF (0 × 3)
无	—	*D (0 × 1)	CE (0 × 3)	B* (0 × 2)	AF (0 × 3)
点	DP	*D (0 × 1)	CE (0 × 3)	B* (0 × 2)	AF (0 × 3)

如表3所示，可以得到其代码，在每个由特定的COMx引脚激活的周期内显示不同的数字。在源文件中有以下代码数组：

```
#define SLCD_ON_SHOW_COUNT 11u

const uint8_t SLCD_NUMBER_TABLE[][SLCD_COMx_COUNT] =
{
```

```
    /* COM0, COM1, COM2, COM3 */
    { 0x1, 0x3, 0x2, 0x3 }, /* SLCD_ON_SHOW_NUMBER_0 */
    { 0x0, 0x2, 0x2, 0x0 }, /* SLCD_ON_SHOW_NUMBER_1 */
    { 0x1, 0x1, 0x3, 0x2 }, /* SLCD_ON_SHOW_NUMBER_2 */
    { 0x1, 0x2, 0x3, 0x2 }, /* SLCD_ON_SHOW_NUMBER_3 */
    { 0x0, 0x2, 0x3, 0x1 }, /* SLCD_ON_SHOW_NUMBER_4 */
    { 0x1, 0x2, 0x1, 0x3 }, /* SLCD_ON_SHOW_NUMBER_5 */
    { 0x1, 0x3, 0x1, 0x3 }, /* SLCD_ON_SHOW_NUMBER_6 */
    { 0x0, 0x2, 0x2, 0x2 }, /* SLCD_ON_SHOW_NUMBER_7 */
    { 0x1, 0x3, 0x3, 0x3 }, /* SLCD_ON_SHOW_NUMBER_8 */
    { 0x1, 0x2, 0x3, 0x3 }, /* SLCD_ON_SHOW_NUMBER_9 */
    { 0x0, 0x0, 0x0, 0x0 }, /* SLCD_ON_SHOW_NONE */
    { 0x2, 0x0, 0x0, 0x0 }, /* SLCD_ON_SHOW_DP */
};
```

注:

此数组的每位数字仅包含两个引脚。一个四位的并行显示可以用八个引脚扩展。下面一节介绍四位数字的用法。

2.2 FRDM-MCXC444开发板

在FRDM-MCXC444开发板上，SLCD器件通过引脚连接到MCU。其原理图如图3所示。

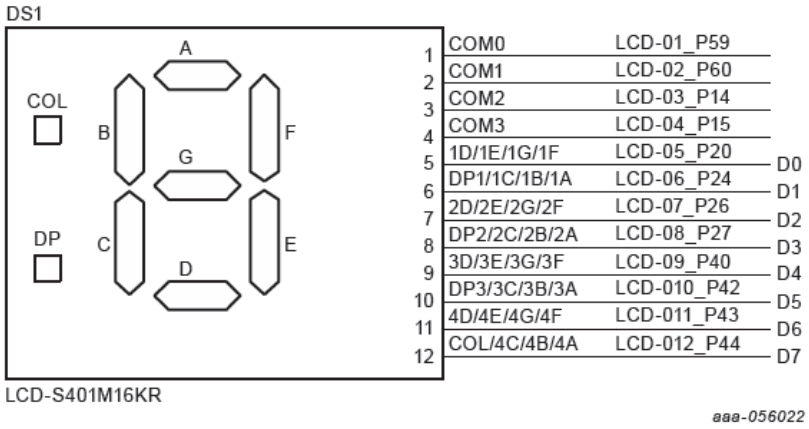

图3. SLCD的连接

表4所示为关于引脚设置的功能信息。

表4. 引脚设置的功能信息

功能ID	SLCD引脚	MCU引脚	ALT	注释
LCD-01	P59	PTE20	ALT0	COM0
LCD-02	P60	PTE21	ALT0	COM1
LCD-03	P14	PTB18	ALT0	COM2
LCD-04	P15	PTB19	ALT0	COM3
LCD-05	P20	PTC0	ALT0	D0
LCD-06	P24	PTC4	ALT0	D1
LCD-07	P26	PTC5	ALT0	D2
LCD-08	P27	PTC6	ALT0	D3

表4. 引脚设置的功能信息（续）

功能ID	SLCD引脚	MCU引脚	ALT	注释
LCD-09	P40	PTD0	ALT0	D4
LCD-10	P42	PTD2	ALT0	D5
LCD-11	P43	PTD3	ALT0	D6
LCD-12	P44	PTD4	ALT0	D7

数据信号可视为总线，由八个独立的引脚组成，命名为D0到D7。为了控制这些信号进行了编码，这样每个引脚的发出信号被视为通过总线发出的完整数据。

为了像总线一样操作所有的控制信号，在源代码中将信号索引排列成两个数组：

```
/* Define the sync bus and the data bus. */
#define SLCD_COMx_COUNT 4u
#define SLCD_DATA_BUS_WIDTH 8u
  /* Define the pins for sync bus and data bus. */
const uint8_t SLCD_PIN_COMx[SLCD_COMx_COUNT] =
{
    59, /* COM0. */
    60, /* COM1. */
    14, /* COM2. */
    15 /* COM3. */
};
const uint8_t SLCD_PIN_DATA[SLCD_DATA_BUS_WIDTH] =
{
    20, /* D0. */
    24, /* D1. */
    26, /* D2. */
    27, /* D3. */
    40, /* D4. */
    42, /* D5. */
    43, /* D6. */
    44 /* D7. */
    };
```

3 基本用法

MCX C444上的SLCD控制器很容易使用。在启用时钟并设置引脚复用功能后，对于没有闪烁和故障检测功能的基本用法，仅需要一个控制寄存器，即LCD通用控制寄存器（LCD_GCR）来初始化控制器。下面提供了一组典型设置：

```
      /* Setup slcd controller. */
LCD->GCR = LCD_GCR_DUTY(3)       /* Selects the duty cycle of the LCD controller
 driver. 3: 4 COMx
lines. */
         | LCD_GCR_LCLK(2)       /* Clock divider for clock source. 0-7 */
         | LCD_GCR_SOURCE(0)     /* LCD clock source. 1:use MCGIRCLK. 0:OSC32K
 */
         | LCD_GCR_LCDEN(0)      /* Disable the controller during setting. */
         | LCD_GCR_LCDSTP(0)     /* Keep LCD module alive in STOP modes. */
         | LCD_GCR_LCDDOZE(1)    /* Keep LCD module alive in DOZE mode. */
         | LCD_GCR_FFR(0)        /* Select the frame rate mode. 0:standard frame
 rate. */
```

```
          | LCD_GCR_ALTSOURCE(0)  /* Select the alternate clock source. no
 available when using default
clock source.*/
          | LCD_GCR_ALTDIV(0)     /* Clock divider for alternate clock source. no
 available when using
default clock.*/
          | LCD_GCR_FDCIEN(0)     /* Enables an LCD interrupt event when fault
 detection is completed.
*/
          | LCD_GCR_PADSAFE(0)    /* Force safe state on LCD pad control, locking
 all LCD control bits.
*/
          | LCD_GCR_VSUPPLY(0)    /* Select the power voltage supply. 0: from
 internal Vdd. */
          | LCD_GCR_LADJ(1)       /* Configures SLCD to handle different LCD
 glass capacitance.*/
          | LCD_GCR_CPSEL(1)      /* Selects the LCD controller charge pump or a
 resistor network to
supply the LCD voltages V_LLx.  */
          | LCD_GCR_RVTRIM(8)     /* Regulated Voltage Trim. no available when
 disabled.*/
          | LCD_GCR_RVEN(0)       /* Regulated Voltage Enable. disabled. */
          ;
```

MCU的引脚必须映射到SLCD控制总线的COMx信号和Dx信号上。

- COMx信号的映射配置为背板引脚。
- Dx信号的映射配置为面板引脚。
- 所用的引脚通过LCD引脚使能寄存器(LCD_PEN0，LCD_PEN1)、LCD背板使能寄存器(LCD_BPEN0，LCD_BPEN1)进行初始化，同时LCD_PENx使能所有正在使用中的引脚，LCD_BPENx选择它们作为面板或背板。
- LCD_WF8Bx寄存器用于每个引脚的信号时序。

下面介绍LCD_WF8Bx寄存器的用法：

- LCD_WF8Bx数组中的每个寄存器对应一个LCD信号引脚。该数组的索引也是针对SLCD模块的功能引脚的。例如，LCD_WF8B[59]对应于SLCD模块的信号引脚LCD_P59。
- LCD_WF8Bx寄存器中的每个位对应于步骤1，而位的索引也对应步骤1。例如，LCD_WF8B[59]中的位2在整个周期（包括四步骤或8步骤）的步骤2中相应的LCD_P59信号。

在软件中，数据信号的控制与硬件略有不同。软件首先对并行引脚进行数据搜索，然后整理数据时序。然而，硬件则首先搜索每个引脚的数据时序，然后将并行引脚组装成8位宽的总线。因此，在源代码工程中设计了一个转换函数。

```
/**
* @brief Set the data on SLCD control bus
* @param com_idx The index of step (COMx), 0-3.
* @param show_dat The display code to the bus for current step.
*/
void slcd_set_bus_data(uint8_t com_idx, uint8_t show_dat)
{
    uint8_t bit_mask = (1u << com_idx);
    for (uint8_t i = 0u; i < SLCD_DATA_BUS_WIDTH; i++)
    {
        if (show_dat & 0x1)
       {
```

```
            LCD->WF8B[SLCD_PIN_DATA[i]] |= bit_mask;
        }
        else
        {
            LCD->WF8B[SLCD_PIN_DATA[i]] = ~bit_mask;
        }
         show_dat >>= 1u;
    }
}
```

创建了一个API函数，以将段码组装到四位数字的显示矩阵中。使用此API，就无需进行复杂的矩阵转换。只需告诉MCU想要显示的数字及其位置，软件就会自动处理所有转换。

```
/* keep the unchanged displaying code in the matrix. */
static uint8_t slcd_on_show_numbers[SLCD_COMx_COUNT];

/**
* @brief Set the displaying number in the digital position of SLCD device.
* @param index The index of digital position, 0-3.
* @param number The value of showing number, 0-10, while 10 is "none".
* @param en_dp Enable showing the dop in current digital positon, true or false.
*/
void slcd_set_number(uint8_t index, uint8_t number, bool en_dp)
{
    uint8_t tmp8 = 0u;
    for (uint8_t i = 0u; i < SLCD_COMx_COUNT; i++)
    {
        tmp8 = slcd_on_show_numbers[i] & (~(0x3 << (2 * index))); /* clear old
 setting code.*/
        tmp8 |= (SLCD_NUMBER_TABLE[number][i] << (2 * index)); /* add new
 setting code. */
        if (en_dp)
        {
            tmp8 |= SLCD_NUMBER_TABLE[SLCD_ON_SHOW_NUMBER_DP][i] << (2 *
 index); /* add new setting
for dot point. */
        }
        slcd_on_show_numbers[i] = tmp8;
        slcd_set_bus_data(i, slcd_on_show_numbers[i]);
      }
}
```

在应用程序的`main()`函数中，用于在目标SLCD上显示变化的数字的源代码如下：

```
int main(void)
{
    bool en_dp;

    /* init board hardware. */
    BOARD_InitPins();
    BOARD_BootClockRUN();
    BOARD_InitDebugConsole();

    PRINTF("slcd basic example.\r\n");
    /* init the clock and pins for slcd, setup the controller for slcd. */
    slcd_init();
```

```
    en_dp = false;
    while (1)
    {
        for (uint8_t i = 0u; i < SLCD_ON_SHOW_COUNT; i++)
        {
            GETCHAR();

            slcd_stop(); /* stop the slcd controller before updating displaying.
 */
            slcd_set_number(0, i , en_dp);
            slcd_set_number(1, (i+1)%SLCD_ON_SHOW_COUNT, en_dp);
            slcd_set_number(2, (i+2)%SLCD_ON_SHOW_COUNT, en_dp);
            slcd_set_number(3, (i+3)%SLCD_ON_SHOW_COUNT, en_dp); slcd_start();
        }
        en_dp = !en_dp;
    }
}
```

下载工程并在FRDM-MCXC444开发板上运行。这些数字会显示在SLCD上，如图4所示。

图4. FRDM-MCXC444开发板的SLCD

如需了解完整的可运行源代码工程`slcd_basic`，请参阅AN14321SW。

4 低功耗模式下的用法

在带有SLCD控制器的MCU上，SLCD控制器特别支持一些附加的低功耗STOP模式。在这些模式下，几乎所有的硬件都被关闭以节省能量。SLCD控制器控制其引脚来刷新SLCD设备，以保持其面板上的显示。

除了VLLS0模式外，SLCD几乎可以在所有电源模式下工作。有关详细信息，请参阅《用户手册》中的**电源管理**章节。

表5. 低功耗模式下的SLCD

模块	VLPR	VLPW	Stop	VLPS	LLS	VLLSx
段式LCD	CPO中的FF异步操作	FF	PSTOP2中的异步操作FF	异步操作	异步操作	VLLS0中的异步操作OFF

保持SLCD在低功耗模式下工作的关键设置如下：

- 时钟源：确保 SLCD 控制器的时钟源在目标低功耗模式下仍然运行。例如，如果 SLCD 控制器的时钟源是 32K OSC，则在每种模式下都应启用此时钟源，即使低至 VLLSx 模式。

- 引脚复用：确保 SLCD 控制器使用的引脚配置为模拟功能（ALT0），并且其他（数字）功能的引脚在 VLLSx 模式下被锁定（电压电平不能更改）。只有当 SLCD 控制器的引脚处于活动状态时，SLCD 控制器才会输出波形，SLCD 面板才会继续显示数字。
- SLCD 控制器的低功耗模式：通过将 `LCD_GCR[LCDSTP]`位和 `LCD_GCR[LCDDOZE]`位设置为 0，可启用 SLCD 控制器的低功耗支持，以保持 SLCD 控制器在 STOP 和 WAIT 模式下仍能工作。

在完成上述参数设置后，设置SLCD控制器进行显示，然后进入低功耗STOP模式。在低功耗STOP模式下，SLCD面板上的显示是开启的，因为SLCD控制器仍在输出刷新波形。

在图5所示的示例工程中，在VLLS3模式下，RTC和SLCD控制器运行时，FRDM-MCX C444开发板上的测量电流低至约19µA。

图5. SLCD的低功耗显示

如需了解完整的可运行源代码工程`slcd_low_power`，请参见AN14321SW。

5 结语

本文档介绍了MCX C444 MCU的片上SLCD控制器的基本使用方法，并提供了基于FRDM-MCXC444开发板的示例工程。SLCD控制器可通过适当的硬件配置来控制SLCD器件自动在其面板上显示内容。即使在低功耗模式下，SLCD控制器仍能以极低的能耗工作。这表明，带有片上SLCD控制器的MCX C444适用于对能耗敏感的应用领域。

6 参考资料

- https://focuslcds.com/segment-lcd/

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8 修订历史

表6汇总了本文档的修订情况。

表6. 修订历史

文档ID	发布日期	说明
AN14321 v.1	2024年7月15日	首次公开发布

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