

STM32L462 SDMMC DMA 多次循环读写

关键字: STM32L462, SDMMC, DMA

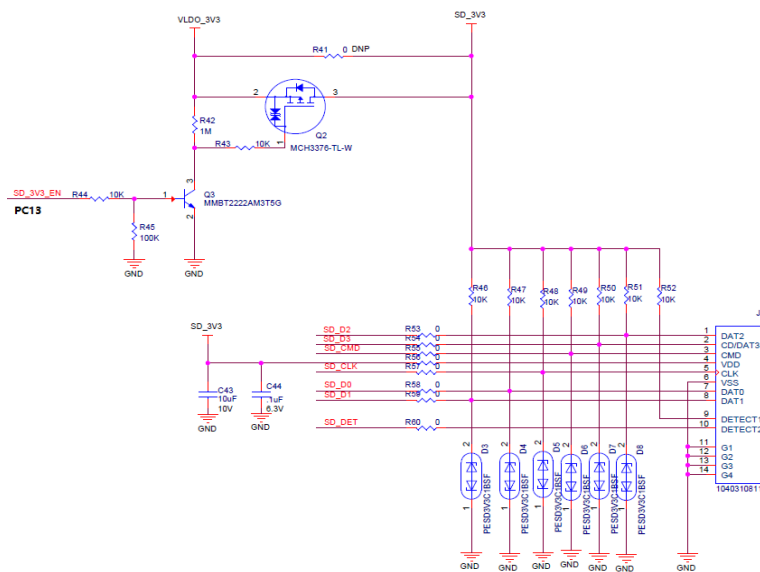
1. 引言

某客户在项目开发中用到 STM32L462 的 SDMMC 接口去进行 SD 卡的读写，发现用 SDMMC 中断、Polling 查询的方式都可以进行连续的读写交替循环操作，但是用 DMA 的方式进行该操作时，发现不能进行多次的读写。

2. 原因分析

客户提供了它的硬件电路板和部分原理图：

图1. 客户 SDMMC 接口电路图



2.1 客户现象复现:

2.1.1 CubeMX 的配置

CubeMX V6. 3. 0 中关于 SDMMC 外设的配置如下:

图2. SDMMC 在 CubeMX 中的配置

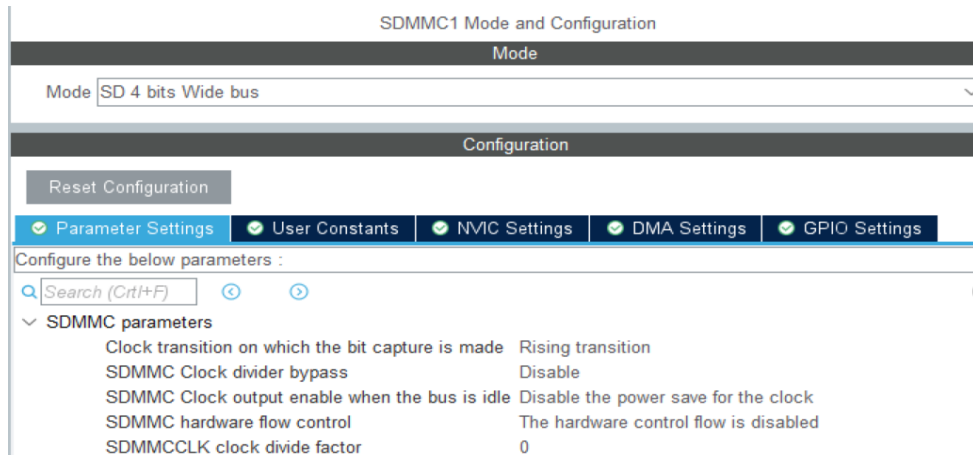


图3. SDMMC 中断的和优先级别的配置

Parameter Settings	User Constants	NVIC Settings	DMA Settings	GPIO Settings
NVIC Interrupt Table				
SDMMC1 global interrupt	<input checked="" type="checkbox"/>	5	Preemption Priority	0
DMA2 channel4 global interrupt	<input checked="" type="checkbox"/>	6		0
DMA2 channel5 global interrupt	<input checked="" type="checkbox"/>	6		0

SDMMC DMA 的配置如下：DMA Request Settings 发送和接收都一样，Normal 模式。

图4. SDMMC DMA 配置

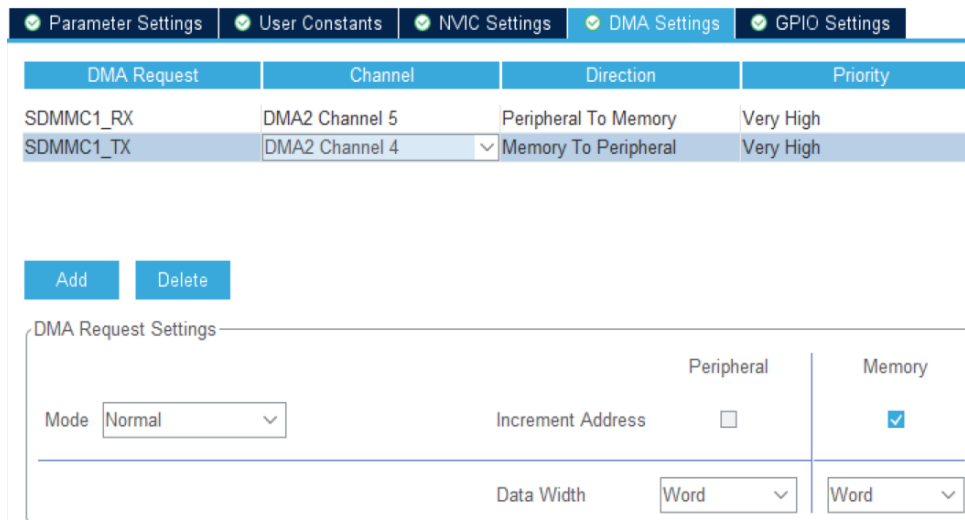


图5. SDMMC 的引脚的配置

Pin Name	Signal on Pin	GPIO out...	GPIO mode	GPIO Pull...	Maximu...	Fast Mode	User Label	Modified
PC8	SDMMC1_D0	n/a	Alternate ...	Pull-up	Very High	n/a		<input checked="" type="checkbox"/>
PC9	SDMMC1_D1	n/a	Alternate ...	Pull-up	Very High	n/a		<input checked="" type="checkbox"/>
PC10	SDMMC1_D2	n/a	Alternate ...	Pull-up	Very High	n/a		<input checked="" type="checkbox"/>
PC11	SDMMC1_D3	n/a	Alternate ...	Pull-up	Very High	n/a		<input checked="" type="checkbox"/>
PC12	SDMMC1_CK	n/a	Alternate ...	Pull-up	Very High	n/a		<input checked="" type="checkbox"/>
PD2	SDMMC1_CMD	n/a	Alternate ...	Pull-up	Very High	n/a		<input checked="" type="checkbox"/>

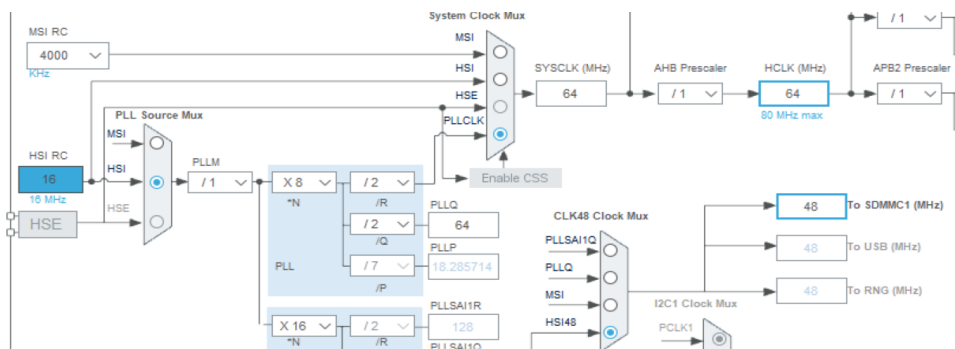
这里结合客户的原理图，还要配置一下 PC13 即给 SD 卡供电的引脚，要不然，后面调试 SD 卡时，MX_SDMMC1_SD_Init();初始化过不了。

图6. PC13 引脚的配置

Pin Name	Signal on Pin	GPIO outp...	GPIO mode	GPIO Pull...	Maximum ...	Fast Mode	User Label	Modified
PC13	n/a	High	Output Pu...	No pull-up ...	Low	n/a	SD_3V3_E...	<input checked="" type="checkbox"/>

其他的配置保持默认，系统时钟源选择 HSI 经过 PLL 锁相环，SYSCLK=64MHz，SDMMC1 的时钟为 48MHz，分频系数 SDMMCCLK clock divide factor 为 0，但是参考手册公式， $SDMMC_CK = SDMMCCLK / [CLKDIV + 2]$ 。所以 SDMMC_CK 频率这里是 24MHz。

图7. 时钟树配置



CubeMX 配置好后，直接生成代码。

2.1.2 添加测试代码

代码生成后，添加如下的测试代码及相关调用函数：

图8. 相关的代码

```

main.c x
65
66  /* Private user code ----- */
67  /* USER CODE BEGIN 0 */
68  #define BLOCK_SIZE          512          // SD卡块大小
69  #define NUMBER_OF_BLOCKS    1          // 每条记录的BLOCK数量
70  #define WRITE_READ_ADDRESS  0x00000000 // 测试读写地址
71
72  #define SD_TRANSFER_OK      ((uint8_t)0x00)
73  #define SD_TRANSFER_BUSY    ((uint8_t)0x01)
74  #define SD_TRANSFER_ERROR   ((uint8_t)0x02)
75
76  __attribute__((aligned(4))) uint8_t Buffer_Block_WR[BLOCK_SIZE*NUMBER_OF_BLOCKS]; // 写数据缓存
77  __attribute__((aligned(4))) uint8_t Buffer_Block_RD[BLOCK_SIZE*NUMBER_OF_BLOCKS]; // 读数据缓存
78
79  uint32_t Temp_Offset = 0;
80
81  HAL_StatusTypeDef sdSta;
82
83  __IO uint32_t writestatus, readstatus = 0;
84
85  volatile uint32_t main_count = 0;
86
87  void Fill_Buffer(uint8_t *pBuffer, uint32_t BufferLength, uint32_t Offset);
88  uint8_t BSP_SD_ReadBlocks_DMA(uint32_t *pData, uint32_t ReadAddr, uint32_t NumOfBlocks);
89  uint8_t BSP_SD_WriteBlocks_DMA(uint32_t *pData, uint32_t WriteAddr, uint32_t NumOfBlocks);
90  uint8_t BSP_SD_GetCardState(void);
91  HAL_StatusTypeDef SD_DMAConfigRx(SD_HandleTypeDef *hsd);
92  HAL_StatusTypeDef SD_DMAConfigTx(SD_HandleTypeDef *hsd);
93
94  /* USER CODE END 0 */
    
```

```

main.c x
MX_GPIO_Init()
294
295 /* USER CODE BEGIN 4 */
296 //填充缓冲区数组
297 void Fill_Buffer(uint8_t *pBuffer, uint32_t BufferLength, uint32_t Offset)
298 {
299     uint32_t index = 0;
300     /* 填充数据 */
301     for (index = 0; index < BufferLength; index++)
302     {
303         pBuffer[index] = index + Offset;
304     }
305 }
306 /* USER CODE END 4 */
    
```

```

main.c x
309 /**
310  * @brief Gets the current SD card data status.
311  * @param None
312  * @retval Data transfer state.
313  */
314 uint8_t BSP_SD_GetCardState(void)
315 {
316     HAL_SD_CardStateTypeDef card_state;
317     card_state = HAL_SD_GetCardState(&hsd1);
318
319     if (card_state == HAL_SD_CARD_TRANSFER)
320     {
321         return (SD_TRANSFER_OK);
322     }
323     else if ((card_state == HAL_SD_CARD_SENDING) ||
324             (card_state == HAL_SD_CARD_RECEIVING) ||
325             (card_state == HAL_SD_CARD_PROGRAMMING))
326     {
327         return (SD_TRANSFER_BUSY);
328     }
329     else
330     {
331         return (SD_TRANSFER_ERROR);
332     }
333 }
334
335 /**
336  * @brief Tx Transfer completed callback
337  * @param hsd: SD handle
338  * @retval None
339  */
340 void HAL_SD_TxCpltCallback(SD_HandleTypeDef *hsd)
341 {
342     writestatus = 1;
343 }
344
345 /**
346  * @brief Rx Transfer completed callback
347  * @param hsd: SD handle
348  * @retval None
349  */
350 void HAL_SD_RxCpltCallback(SD_HandleTypeDef *hsd)
351 {
352     readstatus = 1;
353 }
    
```

另外在中断函数的里面，可以添加如下代码，加一个判断。

图9. 中断函数添加的代码

```

main.c  stm32l4xx_it.c  x
221 void DMA2_Channel4_IRQHandler(void)
222 {
223     /* USER CODE BEGIN DMA2_Channel4_IRQn 0 */
224
225     /* USER CODE END DMA2_Channel4_IRQn 0 */
226     if((hsdl.Context == (SD_CONTEXT_DMA | SD_CONTEXT_WRITE_SINGLE_BLOCK)) ||
227        (hsdl.Context == (SD_CONTEXT_DMA | SD_CONTEXT_WRITE_MULTIPLE_BLOCK)))
228     {
229         HAL_DMA_IRQHandler(&hdma_sdmmc1_tx);
230     }
231     /* USER CODE BEGIN DMA2_Channel4_IRQn 1 */
232
233     /* USER CODE END DMA2_Channel4_IRQn 1 */
234 }
235
236 /**
237  * @brief This function handles DMA2 channel5 global interrupt.
238  */
239 void DMA2_Channel5_IRQHandler(void)
240 {
241     /* USER CODE BEGIN DMA2_Channel5_IRQn 0 */
242
243     /* USER CODE END DMA2_Channel5_IRQn 0 */
244     if((hsdl.Context == (SD_CONTEXT_DMA | SD_CONTEXT_READ_SINGLE_BLOCK)) ||
245        (hsdl.Context == (SD_CONTEXT_DMA | SD_CONTEXT_READ_MULTIPLE_BLOCK)))
246     {
247         HAL_DMA_IRQHandler(&hdma_sdmmc1_rx);
248     }
249     /* USER CODE BEGIN DMA2_Channel5_IRQn 1 */
250
251     /* USER CODE END DMA2_Channel5_IRQn 1 */
252 }
    
```

图10. 主函数中测试代码

```

main.c  x
main()
125 while (1)
126 {
127     Fill_Buffer(Buffer_Block_WR, BLOCK_SIZE*NUMBER_OF_BLOCKS, Temp_Offset++);
128
129     if (HAL_SD_Erase(&hsdl, 0x00000000, WRITE_READ_ADDRESS+1000) != HAL_OK) {
130         while(1);
131     }
132     /* Wait until SD card is ready to use for new operation */
133     while (BSP_SD_GetCardState() != SD_TRANSFER_OK) {} //delay for erase finished
134     // if (SD_DMAConfigTx(&hsdl) == HAL_OK) //comment here for repeat customer issue
135     if (HAL_SD_WriteBlocks_DMA(&hsdl, Buffer_Block_WR, WRITE_READ_ADDRESS, 1) != HAL_OK) {
136         while(1);
137     }
138     /* Wait for Tx Transfer completion */
139     while(writestatus == 0) {}
140     writestatus = 0;
141     /* Wait until SD card is ready to use for new operation */
142     while (BSP_SD_GetCardState() != SD_TRANSFER_OK) {}
143     // if (SD_DMAConfigRx(&hsdl) == HAL_OK) //comment here for repeat customer issue
144     if (HAL_SD_ReadBlocks_DMA(&hsdl, Buffer_Block_RD, WRITE_READ_ADDRESS, 1) != HAL_OK) {
145         while(1);
146     }
147     while (readstatus == 0) {}
148     readstatus = 0;
149     /* Wait until SD card is ready to use for new operation */
150     while (BSP_SD_GetCardState() != SD_TRANSFER_OK) {}
151     HAL_Delay(2000);
152     main_count++; //test for main loop
153 }
154
155
156
157
158
159
160
161
162
163
164
            
```

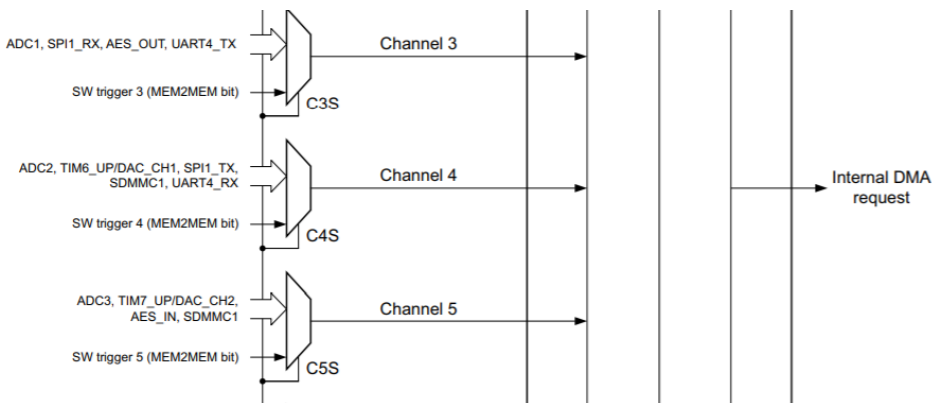
Expression	Value
main_count	0
Buffer_Block_RD	<array>""
[0]	'\0' (0x00)
[1]	'\0' (0x00)
[2]	'\0' (0x00)
[3]	'\0' (0x00)
[4]	'\0' (0x00)
[5]	'\0' (0x00)
[6]	'\0' (0x00)
[7]	'\0' (0x00)
[8]	'\0' (0x00)
[9]	'\0' (0x00)
[10]	'\0' (0x00)
[11]	'\0' (0x00)
[12]	'\0' (0x00)
[13]	'\0' (0x00)
[14]	'\0' (0x00)
[15]	'\0' (0x00)
[16]	'\0' (0x00)
[17]	'\0' (0x00)
[18]	'\0' (0x00)
[19]	'\0' (0x00)
[20]	'\0' (0x00)
[21]	'\0' (0x00)
[22]	'\0' (0x00)
[23]	'\0' (0x00)
[24]	'\0' (0x00)
[25]	'\0' (0x00)

添加好编译测试，会发现代码卡在如上图的 while 循环等待中，main_count=0，也就是一次的读写操作都还没有完成。即复现了客户的现象。但是连续多次的单独写可以顺利执行，连续多次的单独读可以顺利执行(如果不行的话，请注意 SDMMC DMA 中断函数里面的断言是不是判断反了，打断点看看稍微调试即可)。

2.1.3 问题原因分析

通过查阅参考手册中关于 DMA 章节内容，Figure 26. DMA2 request mapping，发现 SDMMC 的 DMA 中断并不像 UART4_TX 和 UART4_RX 请求一样，分别各对应一条 DMA 通道，SDMMC 只有 Channel 4 或 Channel 5 可用且不能同时使用。

图11. DMA 配置参考



2.1.4 问题解决

基于上述的分析后，我们的 SDMMC 的读或写都使用同一个通道，或者两个通道不同时使用，实施代码如下即可。

图12. 实时代码

main.c x	main.c x
<pre> SD_DMAConfigRx(SD_HandleTypeDef *) 363 HAL_StatusTypeDef SD_DMAConfigRx(SD_HandleTypeDef *hsd) 364 { 365 HAL_StatusTypeDef status = HAL_ERROR; 366 /* Configure DMA Rx parameters */ 367 hdma_sdmmc1_rx.Init.Request = DMA_REQUEST_7; 368 hdma_sdmmc1_rx.Init.Direction = DMA_PERIPH_TO_MEMORY; 369 hdma_sdmmc1_rx.Init.PeriphInc = DMA_PINC_DISABLE; 370 hdma_sdmmc1_rx.Init.MemInc = DMA_MINC_ENABLE; 371 hdma_sdmmc1_rx.Init.PeriphDataAlignment = DMA_PDATAALIGN_WORD; 372 hdma_sdmmc1_rx.Init.MemDataAlignment = DMA_MDATAALIGN_WORD; 373 hdma_sdmmc1_rx.Init.Priority = DMA_PRIORITY_VERY_HIGH; 374 375 hdma_sdmmc1_rx.Instance = DMA2_Channel5; 376 377 /* Associate the DMA handle */ 378 __HAL_LINKDMA(hsd, hdmatrix, hdma_sdmmc1_rx); 379 380 /* Stop any ongoing transfer and reset the state*/ 381 HAL_DMA_Abort(&hdma_sdmmc1_rx); 382 383 /* Deinitialize the Channel for new transfer */ 384 HAL_DMA_DeInit(&hdma_sdmmc1_rx); 385 386 /* Stop any ongoing transfer and reset the state*/ 387 HAL_DMA_Abort(&hdma_sdmmc1_tx); //add here to deint 388 HAL_DMA_DeInit(&hdma_sdmmc1_tx); //add here to deint 389 390 /* Configure the DMA Channel */ 391 status = HAL_DMA_Init(&hdma_sdmmc1_rx); 392 393 /* NVIC configuration for DMA transfer complete interrupt */ 394 HAL_NVIC_SetPriority(DMA2_Channel5_IRQn, 6, 0); 395 HAL_NVIC_EnableIRQ(DMA2_Channel5_IRQn); 396 397 return (status); 398 } </pre>	<pre> SD_DMAConfigTx(SD_HandleTypeDef *) 405 HAL_StatusTypeDef SD_DMAConfigTx(SD_HandleTypeDef *hsd) 406 { 407 HAL_StatusTypeDef status; 408 /* Configure DMA Tx parameters */ 409 hdma_sdmmc1_tx.Init.Request = DMA_REQUEST_7; 410 hdma_sdmmc1_tx.Init.Direction = DMA_MEMORY_TO_PERIPH; 411 hdma_sdmmc1_tx.Init.PeriphInc = DMA_PINC_DISABLE; 412 hdma_sdmmc1_tx.Init.MemInc = DMA_MINC_ENABLE; 413 hdma_sdmmc1_tx.Init.PeriphDataAlignment = DMA_PDATAALIGN_WORD; 414 hdma_sdmmc1_tx.Init.MemDataAlignment = DMA_MDATAALIGN_WORD; 415 hdma_sdmmc1_tx.Init.Priority = DMA_PRIORITY_VERY_HIGH; 416 417 hdma_sdmmc1_tx.Instance = DMA2_Channel4; 418 419 /* Associate the DMA handle */ 420 __HAL_LINKDMA(hsd, hdmatrix, hdma_sdmmc1_tx); 421 422 /* Stop any ongoing transfer and reset the state*/ 423 HAL_DMA_Abort(&hdma_sdmmc1_tx); 424 425 /* Deinitialize the Channel for new transfer */ 426 HAL_DMA_DeInit(&hdma_sdmmc1_tx); //add here to deint 427 HAL_DMA_Abort(&hdma_sdmmc1_rx); //add here to deint 428 429 /* Deinitialize the Channel for new transfer */ 430 HAL_DMA_DeInit(&hdma_sdmmc1_rx); 431 432 /* Configure the DMA Channel */ 433 status = HAL_DMA_Init(&hdma_sdmmc1_tx); 434 435 /* NVIC configuration for DMA transfer complete interrupt */ 436 HAL_NVIC_SetPriority(DMA2_Channel4_IRQn, 6, 0); 437 HAL_NVIC_EnableIRQ(DMA2_Channel4_IRQn); 438 439 return (status); 440 } </pre>

图13. 运行结果

The screenshot shows an IDE workspace for project 'L462_SDMMC_0917'. The main window displays the code for 'main.c' in the 'main()' function. The code includes several loops for waiting for SD card transfer completion and DMA configuration. A 'main_count++' statement is highlighted in green. The Live Watch window on the right shows the current state of variables: 'main_count' is 10, and 'Buffer_Bloc...' is an array of 26 elements, each containing a hexadecimal value from 0x0A to 0x24.

```

138     while(1);
139     }
140 }
141 /* Wait for Tx Transfer completion */
142 while(writestatus == 0){}
143 writestatus = 0;
144
145 /* Wait until SD card is ready to use for new operation */
146 while (BSP_SD_GetCardState() != SD_TRANSFER_OK){}
147
148
149 if(SD_DMAConfigRx(&hsd1) == HAL_OK)
150 {
151     if(HAL_SD_ReadBlocks_DMA(&hsd1,Buffer_Block_RD, WRITE_READ_ADDRESS, 1) != HAL_OK)
152     while(1);
153 }
154 }
155 while (readstatus == 0){}
156 readstatus = 0;
157
158 /* Wait until SD card is ready to use for new operation */
159 while (BSP_SD_GetCardState() != SD_TRANSFER_OK){}
160
161 HAL_Delay(2000);
162 main_count++; //test for main loop
163 /* USER CODE END WHILE */
164
165 /* USER CODE BEGIN 3 */
166 }
167 /* USER CODE END 3 */
168 }
169
170 /**
    
```

Expression	Value
main_count	10
Buffer_Bloc...	<array>...
[0]	'\n' (0x0A)
[1]	'\v' (0x0B)
[2]	'\f' (0x0C)
[3]	'\r' (0x0D)
[4]	'.' (0x0E)
[5]	'.' (0x0F)
[6]	'.' (0x10)
[7]	'.' (0x11)
[8]	'.' (0x12)
[9]	'.' (0x13)
[10]	'.' (0x14)
[11]	'.' (0x15)
[12]	'.' (0x16)
[13]	'.' (0x17)
[14]	'.' (0x18)
[15]	'.' (0x19)
[16]	'.' (0x1A)
[17]	'.' (0x1B)
[18]	'.' (0x1C)
[19]	'.' (0x1D)
[20]	'.' (0x1E)
[21]	'.' (0x1F)
[22]	'.' (0x20)
[23]	'!' (0x21)
[24]	'"' (0x22)
[25]	'#' (0x23)
[26]	'\$' (0x24)

成功！另外，感兴趣的同学，也可以参考如下路径的例程。

.....\STM32Cube_FW_L4_V1.17.0\Projects\32L496GDISCOVERY\Applications\FatFs\FatFs_uSD_D
MA_RTOS\

版本历史

日期	版本	变更
2021 年 12 月 14 日	1.0	首版发布

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