

## DAC, COMP, HRTIM Fault 功能的使用

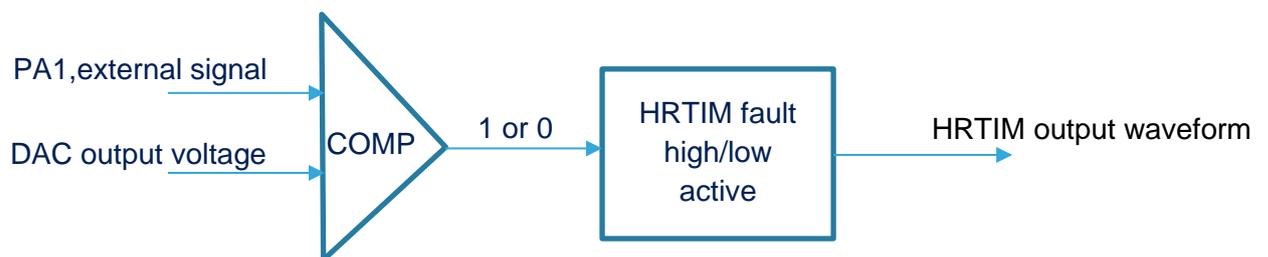
关键字: *HRTIM, Fault, DAC, COMP*

### 1. 引言

这个例程是使用 STM32G474 NUCLEO 进行测试的，集合了 DAC, COMP, HRTIM 的功能模块。

### 2. 信号路径

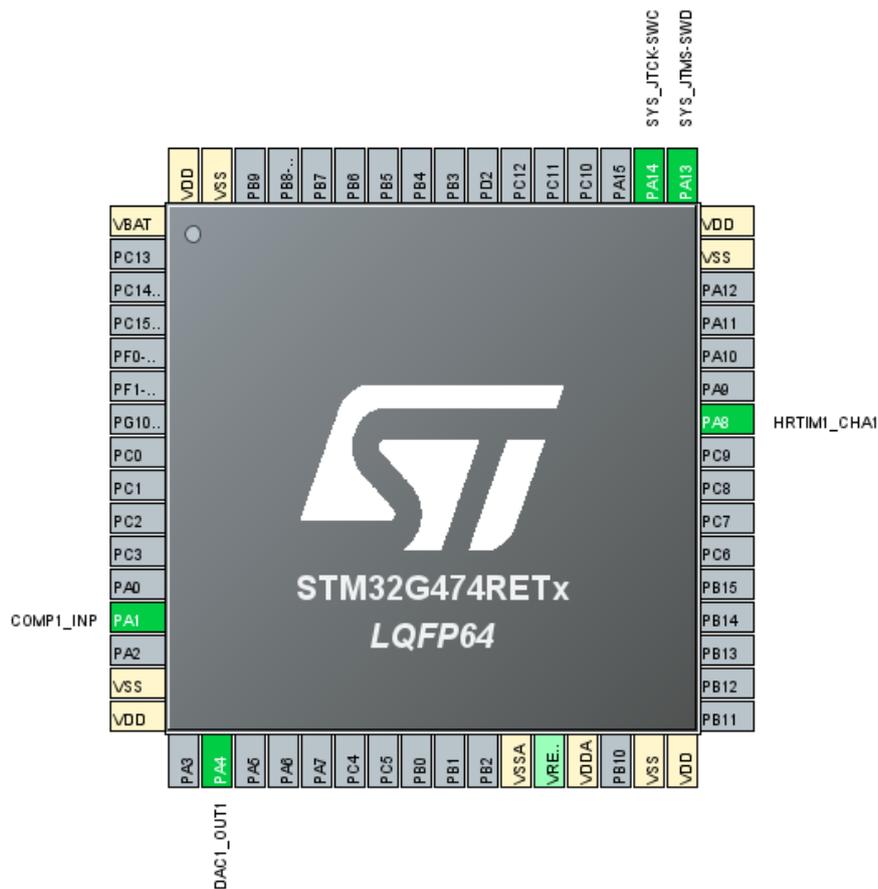
PA1 的输入信号同 DAC 的输出信号进入 COMP 比较器进行比较，经 COMP 比较后的输出信号连接到 HRTIM 的 Fault4 信号，来控制 HRTIM 的输出信号的停止。



当  $PA1 > DAC \text{ value}$ , 比较器输出高“1”，这个信号为 HRTIM 的 fault4 信号，当 HRTIM 配置为 fault4 高有效，则当这个高电平出现时，HRTIM 输出波形停止，具体输出的电平可以通过寄存器进行配置。

### 3. STM32CubeMX 配置

PA1 的输入信号同 DAC 的输出信号进入 COMP 比较器进行比较，经 COMP 比较后的输出信号连接到 HRTIM 的 Fault4 信号，来控制 HRTIM 的输出信号的停止。



首先配置 DAC 模块，DAC out1 选择 connected to on chip-peripherals, 这里为了测试方便，选择了“Connected to external pin and to on chip-peripherals”，DAC 输出信号连接到 IC 内部，同时输出到 PA4 GPIO 口。这样就客户测量 DAC 的具体输出值。

而在 IC 内部，DAC 连接到了 COMP 的负端。

COMP 的配置如下：

PA1: COMP 的正向输入端。

DAC1 OUT1 在 IC 内部连接到了 COMP 的负向输入端。

具体请看下面两种图：

图 1. DAC 配置

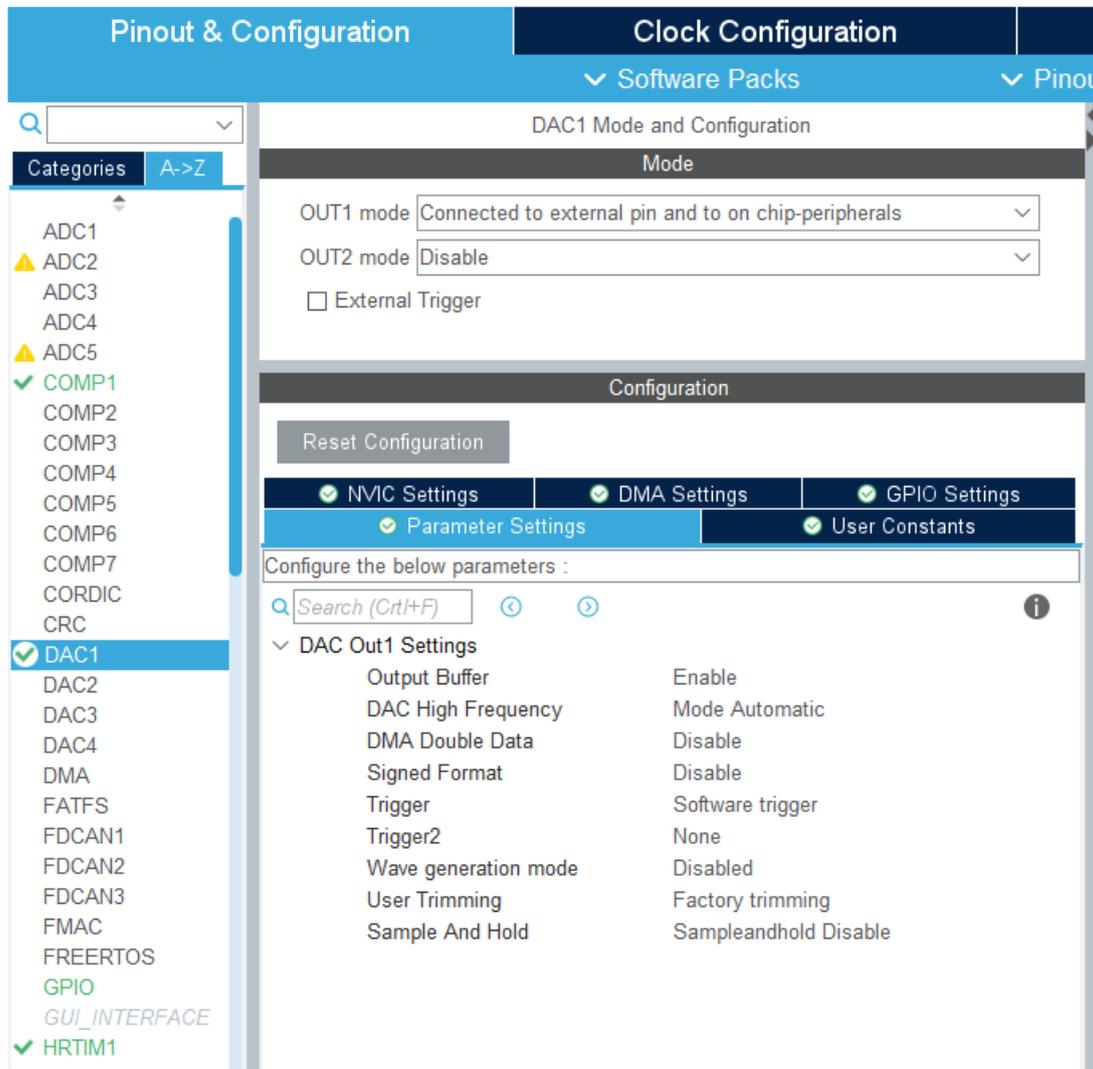
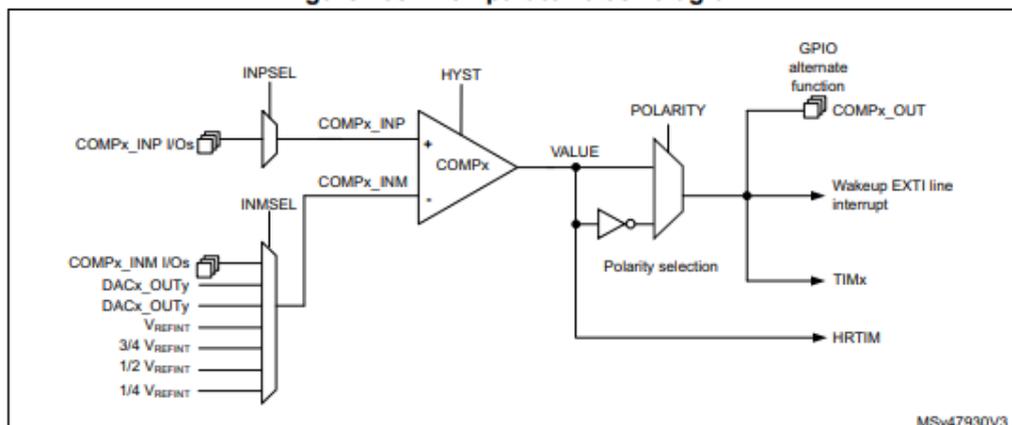
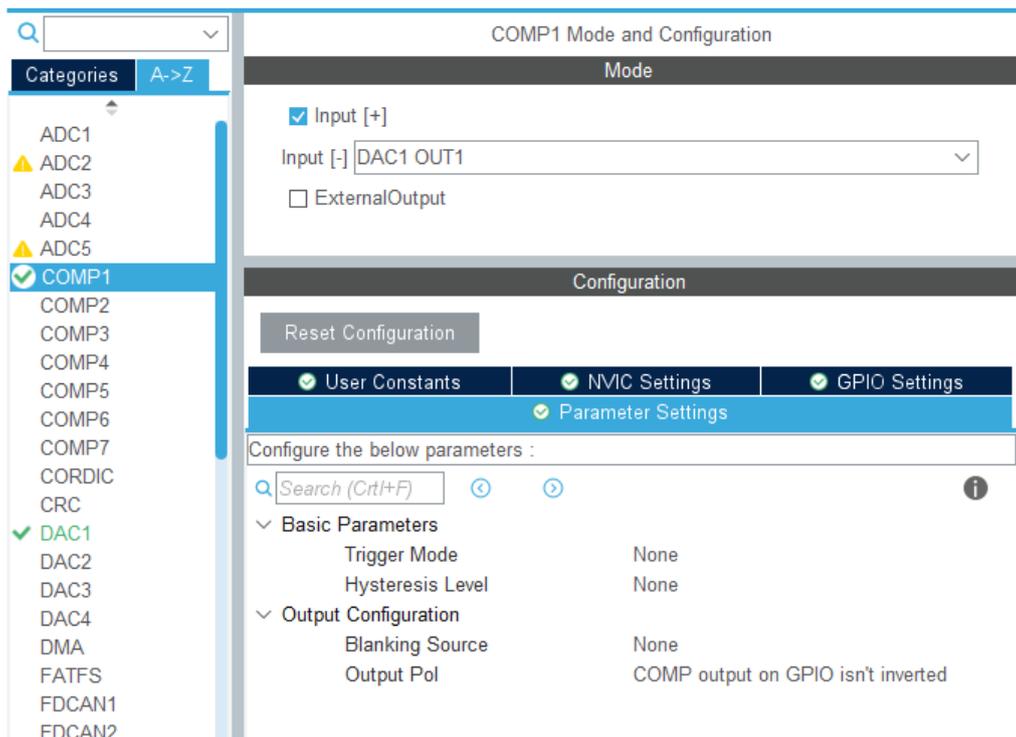


图 2. COMP 框图和配置

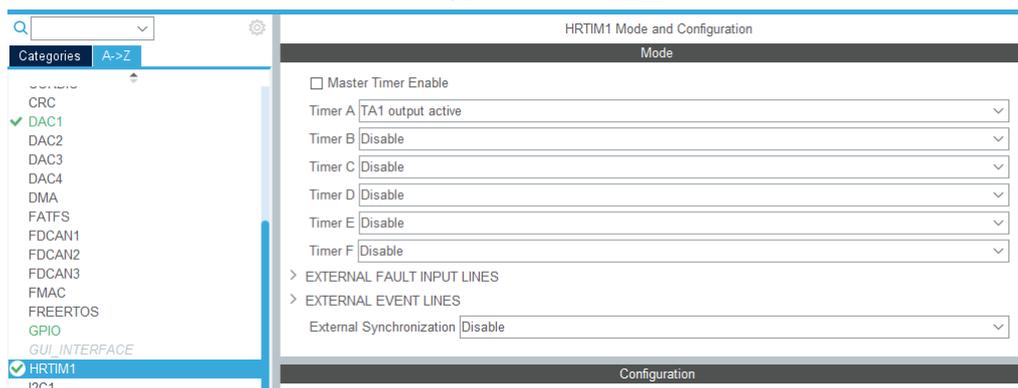
Figure 168. Comparator block diagram





最后配置 HRTIM 模块：  
使能 TimerA 的 TA1 输出。

图 3. HRTIM 配置



配置 TIMA 周期值为 0XCFFF，向上计数模式，持续计数方式, Fault4 作 fault 源。

HRTIM1 Mode and Configuration

Configuration

Reset Configuration

ADC Triggers Configuration  
  Burst Mode Configuration  
  **Timer A**  
  User Constants  
  NVIC Settings  
  DMA Settings  
  GPIO Settings  
 HRTIM Interrupt Configuration  
  Synchro Configuration  
  High Resolution  
  External Event Configuration  
  Fault Lines Configuration

Configure the below parameters :

Search (Ctrl+F)

**General**  
 Timer Idx: Timer A  
 Basic/Advanced Configuration: Advanced (using HAL\_Waveform methods)

**Time Base Setting**  
 Prescaler Ratio: HRTIM Clock (HRTIM Clock is set in Clock Configuration Tab with Max Value = 170MHz)  
 fHRCK Equivalent Frequency: 1.0E8 Hz  
 Period: 0xCFFF  
 Resulting PWM Frequency: 1878 Hz  
 Repetition Counter: 0x00  
 Up Down Mode: Timer counter is operating in up-counting mode  
 Mode: The timer operates in continuous (free-running) mode

**Timing Unit**  
 Interleaved Mode: Disabled  
 Start On Sync: Synchronization input event has no effect on the timer  
 Reset On Sync: Synchronization input event has no effect on the timer  
 Dac Synchro: No DAC synchronization event generated  
 Preload Enable: Preload enabled: the write access is done into the preload register  
 Update Gating: Update done independently from the DMA burst transfer completion  
 Repetition Update: Update on repetition enabled  
 Burst Mode: Timer counter clock is maintained and the timer operates normally  
 Push-Pull: Push-Pull mode disabled  
 Number of Faults to enable: 1  
 1st Fault Source: Fault 4 enabled  
 Fault Lock: Timer fault enabling bits are read/write  
 Dead Time Insertion: Output 1 and output 2 signals are independent  
 Delayed Protection Mode: No action  
 Update Trigger Sources Selection : Please enter the number of Triggers to s...: 0  
 Reset Update: Update by Timer reset / roll-over disabled  
 Resynchronized Update: Update taken into account immediately  
 Reset Trigger Sources Selection : Please enter the number of Triggers to sel...: 0  
 Interrupt Requests Sources Selection : Please enter the number of Active Int...: 0  
 Number of Timer A Internal DMA Request Sources - you first have to enable...: 0

再使能两个比较器 compare1 和 compare2，分别配置为 0x2FFF 和 0x8FFF 以生成比较事件：

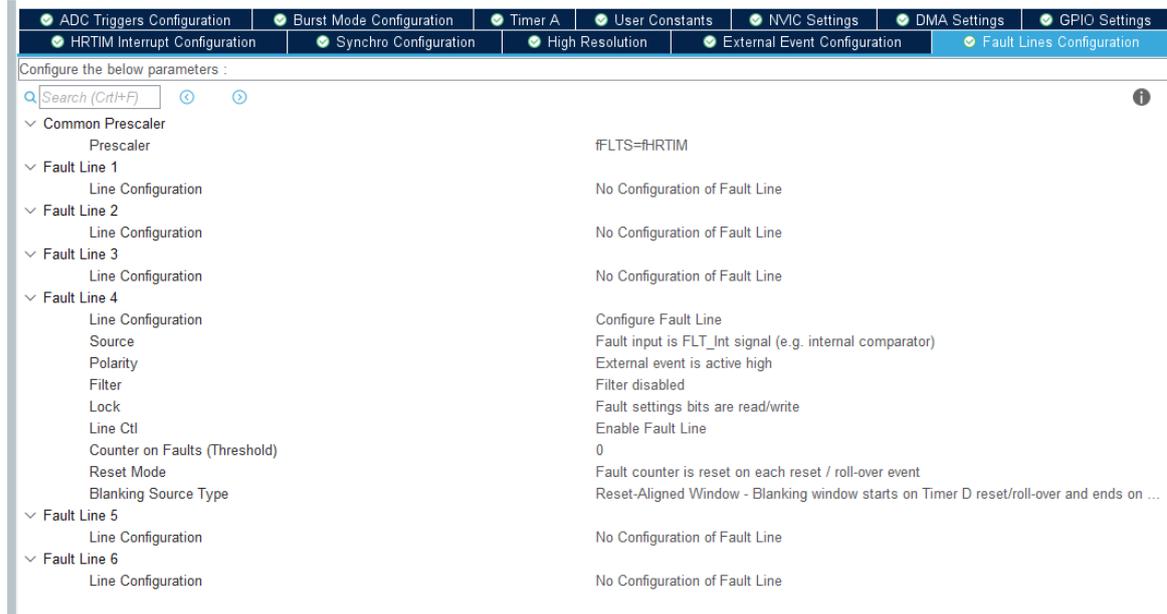
**Compare Unit 1**  
 Compare Unit 1 Configuration: Enable  
 Compare Value: 0x2FFF  
 Greater-than comparison: Timer Compare 1 event is generated when counter is equal

**Compare Unit 2**  
 Compare Unit 2 Configuration: Enable  
 Triggered-Half Mode: Timer Compare 2 register is behaving in standard mode  
 Compare Value: 0x8FFD  
 Auto Delayed Mode: standard compare mode

Compare1 事件之后 HRTIM 输出高电平，compare2 事件之后输出低电平：

**Output 1 Configuration**  
 Output1 Configuration: TA1  
 Polarity: Output is active HIGH  
 Set Source Selection : Please enter the number of Active Set Sources: 1  
 1st Set Source: Timer compare 1 event forces the output to its active state  
 Reset Source Selection : Please enter the number of Active Reset Sources: 1  
 1st Reset Source: Timer compare 2 event forces the output to its inactive state  
 Idle Mode: The output is not affected by the burst mode operation  
 Idle Level: Output at inactive level when in IDLE state  
 Fault Level: Output at inactive level when in FAULT state  
 Chopper Mode Enable: Output signal is not altered  
 Burst Mode Entry Delayed: The programmed Idle state is applied immediately to the Output

下面是 Fault4 的配置，事件配置成高有效：



HRTIM 输出波形：

下面的方波信号为 HRTIM 的输出波形，由于 compare1 和 compare2 的比较值是固定的，并没有在 Timer、DMA 等模块的控制下进行更改，因此下面的波形周期和占空比是一定的。



## 4. 代码实现

下面是具体实现代码，先初始化 DAC，然后是 COMP，等 COMP 输出信号稳定后再使能 HRTIM 模块。

```
int main(void)
{
    HAL_Init();
    SystemClock_Config();
    MX_GPIO_Init();
    MX_DAC1_Init();
    if (HAL_DAC_SetValue(&hdac1, DAC_CHANNEL_1, DAC_ALIGN_12B_R, 0x500) != HAL_OK)
    { Error_Handler(); }
    if (HAL_DAC_Start(&hdac1, DAC_CHANNEL_1) != HAL_OK)
    { Error_Handler(); }
    MX_COMP1_Init();
    HAL_Delay(1000);
    MX_HRTIM1_Init();
    if (HAL_COMP_Start(&hcomp1) != HAL_OK)
    { Error_Handler(); }
    HAL_HRTIM_WaveformOutputStart(&shrtim1, HRTIM_OUTPUT_TA1 );
    HAL_HRTIM_WaveformCounterStart(&shrtim1, HRTIM_TIMERID_TIMER_A);
    while (1)
    { }
}

static void MX_COMP1_Init(void)
{
    hcomp1.Instance = COMP1;
    hcomp1.Init.InputPlus = COMP_INPUT_PLUS_IO1;
    hcomp1.Init.InputMinus = COMP_INPUT_MINUS_DAC1_CH1;
    hcomp1.Init.OutputPol = COMP_OUTPUTPOL_NONINVERTED;
    hcomp1.Init.Hysteresis = COMP_HYSTERESIS_NONE;
    hcomp1.Init.BlankingSrc = COMP_BLANKINGSRC_NONE;
    hcomp1.Init.TriggerMode = COMP_TRIGGERMODE_NONE;
    if (HAL_COMP_Init(&hcomp1) != HAL_OK)
    {
        Error_Handler();
    }
}

static void MX_DAC1_Init(void)
{
    DAC_ChannelConfTypeDef sConfig = {0};
    hdac1.Instance = DAC1;
    if (HAL_DAC_Init(&hdac1) != HAL_OK)
    {
        Error_Handler();
    }
    sConfig.DAC_HighFrequency = DAC_HIGH_FREQUENCY_INTERFACE_MODE_AUTOMATIC;
    sConfig.DAC_DMADoubleDataMode = DISABLE;
    sConfig.DAC_SignedFormat = DISABLE;
    sConfig.DAC_SampleAndHold = DAC_SAMPLEANDHOLD_DISABLE;
    sConfig.DAC_Trigger = DAC_TRIGGER_SOFTWARE;
    sConfig.DAC_Trigger2 = DAC_TRIGGER_NONE;
    sConfig.DAC_OutputBuffer = DAC_OUTPUTBUFFER_ENABLE;
    sConfig.DAC_ConnectOnChipPeripheral = DAC_CHIPCONNECT_BOTH;
    sConfig.DAC_UserTrimming = DAC_TRIMMING_FACTORY;
    if (HAL_DAC_ConfigChannel(&hdac1, &sConfig, DAC_CHANNEL_1) != HAL_OK)
    {
        Error_Handler();
    }
}
```

```

static void MX_HRTIM1_Init(void)
{
  HRTIM_FaultBlankingCfgTypeDef pFaultBlkCfg = {0};
  HRTIM_FaultCfgTypeDef pFaultCfg = {0};
  HRTIM_TimeBaseCfgTypeDef pTimeBaseCfg = {0};
  HRTIM_TimerCtlTypeDef pTimerCtl = {0};
  HRTIM_TimerCfgTypeDef pTimerCfg = {0};
  HRTIM_CompareCfgTypeDef pCompareCfg = {0};
  HRTIM_OutputCfgTypeDef pOutputCfg = {0};

  hhrtim1.Instance = HRTIM1;
  hhrtim1.Init.HRTIMInterruptResquests = HRTIM_IT_FLT4;
  hhrtim1.Init.SyncOptions = HRTIM_SYNCOPTION_NONE;
  if (HAL_HRTIM_Init(&hhrtim1) != HAL_OK)
  {
    Error_Handler();
  }
  if (HAL_HRTIM_DLLCalibrationStart(&hhrtim1, HRTIM_CALIBRATIONRATE_3) != HAL_OK)
  {
    Error_Handler();
  }
  if (HAL_HRTIM_PollForDLLCalibration(&hhrtim1, 10) != HAL_OK)
  {
    Error_Handler();
  }
  if (HAL_HRTIM_FaultPrescalerConfig(&hhrtim1, HRTIM_FAULTPRESCALER_DIV1) != HAL_OK)
  {
    Error_Handler();
  }
  pFaultBlkCfg.Threshold = 0;
  pFaultBlkCfg.ResetMode = HRTIM_FAULTCOUNTERRST_UNCONDITIONAL;
  pFaultBlkCfg.BlankingSource = HRTIM_FAULTBLANKINGMODE_RSTALIGNED;
  if (HAL_HRTIM_FaultCounterConfig(&hhrtim1, HRTIM_FAULT_4, &pFaultBlkCfg) != HAL_OK)
  {
    Error_Handler();
  }
  if (HAL_HRTIM_FaultBlankingConfigAndEnable(&hhrtim1, HRTIM_FAULT_4, &pFaultBlkCfg) != HAL_OK)
  {
    Error_Handler();
  }
  pFaultCfg.Source = HRTIM_FAULTSOURCE_INTERNAL;
  pFaultCfg.Polarity = HRTIM_FAULTPOLARITY_LOW;
  pFaultCfg.Filter = HRTIM_FAULTFILTER_NONE;
  pFaultCfg.Lock = HRTIM_FAULTLOCK_READWRITE;
  if (HAL_HRTIM_FaultConfig(&hhrtim1, HRTIM_FAULT_4, &pFaultCfg) != HAL_OK)
  {
    Error_Handler();
  }

  HAL_HRTIM_FaultModeCtl(&hhrtim1, HRTIM_FAULT_4, HRTIM_FAULTMODECTL_ENABLED);
  pTimeBaseCfg.Period = 0xCFFF;
  pTimeBaseCfg.RepetitionCounter = 0x00;
  pTimeBaseCfg.PrescalerRatio = HRTIM_PRESCALERRATIO_DIV1;
  pTimeBaseCfg.Mode = HRTIM_MODE_CONTINUOUS;
  if (HAL_HRTIM_TimeBaseConfig(&hhrtim1, HRTIM_TIMERINDEX_TIMER_A, &pTimeBaseCfg) != HAL_OK)
  {
    Error_Handler();
  }
  pTimerCtl.UpDownMode = HRTIM_TIMERUPDOWNMODE_UP;
  pTimerCtl.TrigHalf = HRTIM_TIMERTRIGHALF_DISABLED;
  pTimerCtl.GreaterCMP1 = HRTIM_TIMERGTCMP1_EQUAL;
  pTimerCtl.DualChannelDacEnable = HRTIM_TIMER_DCDE_DISABLED;
  if (HAL_HRTIM_WaveformTimerControl(&hhrtim1, HRTIM_TIMERINDEX_TIMER_A, &pTimerCtl) != HAL_OK)
  {
    Error_Handler();
  }
}

```

```

pTimerCfg.InterruptRequests = HRTIM_TIM_IT_NONE;
pTimerCfg.DMAREquests = HRTIM_TIM_DMA_NONE;
pTimerCfg.DMASrcAddress = 0x0000;
pTimerCfg.DMADstAddress = 0x0000;
pTimerCfg.DMASize = 0x1;
pTimerCfg.HalfModeEnable = HRTIM_HALFMODE_DISABLED;
pTimerCfg.InterleavedMode = HRTIM_INTERLEAVED_MODE_DISABLED;
pTimerCfg.StartOnSync = HRTIM_SYNCSTART_DISABLED;
pTimerCfg.ResetOnSync = HRTIM_SYNCRESET_DISABLED;
pTimerCfg.DACSynchro = HRTIM_DACSYNC_NONE;
pTimerCfg.PreloadEnable = HRTIM_PRELOAD_ENABLED;
pTimerCfg.UpdateGating = HRTIM_UPDATEGATING_INDEPENDENT;
pTimerCfg.BurstMode = HRTIM_TIMERBURSTMODE_MAINTAINCLOCK;
pTimerCfg.RepetitionUpdate = HRTIM_UPDATEONREPETITION_ENABLED;
pTimerCfg.PushPull = HRTIM_TIMPUSHPULLMODE_DISABLED;
pTimerCfg.FaultEnable = HRTIM_TIMFAULTENABLE_FAULT4;
pTimerCfg.FaultLock = HRTIM_TIMFAULTLOCK_READWRITE;
pTimerCfg.DeadTimeInsertion = HRTIM_TIMDEADTIMEINSERTION_DISABLED;
pTimerCfg.DelayedProtectionMode = HRTIM_TIMER_A_B_C_DELAYEDPROTECTION_DISABLED;
pTimerCfg.UpdateTrigger = HRTIM_TIMUPDATETRIGGER_NONE;
pTimerCfg.ResetTrigger = HRTIM_TIMERSETTRIGGER_NONE;
pTimerCfg.ResetUpdate = HRTIM_TIMERUPDATEONRESET_ENABLED;
pTimerCfg.ReSyncUpdate = HRTIM_TIMERESYNC_UPDATE_UNCONDITIONAL;
if (HAL_HRTIM_WaveformTimerConfig(&shrtiml, HRTIM_TIMERINDEX_TIMER_A, &pTimerCfg) != HAL_OK)
{
    Error_Handler();
}
pCompareCfg.CompareValue = 0x2FFF;
if (HAL_HRTIM_WaveformCompareConfig(&shrtiml, HRTIM_TIMERINDEX_TIMER_A, HRTIM_COMPAREUNIT_1, &pCompareCfg) != HAL_OK)
{
    Error_Handler();
}
pCompareCfg.CompareValue = 0x8FFD;
pCompareCfg.AutoDelayedMode = HRTIM_AUTODELAYEDMODE_REGULAR;
pCompareCfg.AutoDelayedTimeout = 0x0000;

if (HAL_HRTIM_WaveformCompareConfig(&shrtiml, HRTIM_TIMERINDEX_TIMER_A, HRTIM_COMPAREUNIT_2, &pCompareCfg) != HAL_OK)
{
    Error_Handler();
}
pOutputCfg.Polarity = HRTIM_OUTPUTPOLARITY_HIGH;
pOutputCfg.SetSource = HRTIM_OUTPUTSET_TIMCMP1;
pOutputCfg.ResetSource = HRTIM_OUTPUTRESET_TIMCMP2;
pOutputCfg.IdleMode = HRTIM_OUTPUTIDLEMODE_NONE;
pOutputCfg.IdleLevel = HRTIM_OUTPUTIDLELEVEL_INACTIVE;
pOutputCfg.FaultLevel = HRTIM_OUTPUTFAULTLEVEL_INACTIVE;
pOutputCfg.ChopperModeEnable = HRTIM_OUTPUTCHOPPERMODE_DISABLED;
pOutputCfg.BurstModeEntryDelayed = HRTIM_OUTPUTBURSTMODEENTRY_REGULAR;
if (HAL_HRTIM_WaveformOutputConfig(&shrtiml, HRTIM_TIMERINDEX_TIMER_A, HRTIM_OUTPUT_TA1, &pOutputCfg) != HAL_OK)
{
    Error_Handler();
}
HAL_HRTIM_MspPostInit(&shrtiml);
}
    
```

## 5. 小结

STM32G474 在 IC 内部有很多内部连接通路，可以根据具体应用灵活进行配置。在上面的应用中 DAC 的输出信号连接到 COMP 比较器的 INM 输入口，COMP 的输出信号连接到 HRTIM 的 Fault4 信号，来控制 HRTIM 的输出停止。

## 版本历史

日期	版本	变更
2022年10月17日	1.0	首版发布

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