AN10908

Wakeup from Deep Sleep using the CANActivity interrupt

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Document information

Info	Content
Keywords	LPC1700, CAN Controller, CAN Activity, WIC, NVIC, Deep Sleep, Power-down
Abstract	This application note is meant to be accompanied with the CAN Activity wakeup sample project. It briefly discusses on how to utilize the CAN Activity interrupt to wake up the LPC1700 and service CAN bus activity.

Revision history

Rev	Date	Description
01	20100225	Initial version.

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1. Introduction

The LPC1700 contains up to two high performance CAN controllers. These CAN controllers are designed to provide a full implementation of the CAN protocol according to the CAN specification version 2.0B.

CAN networks are commonly used in automotive, industrial, and high speed network applications and can be utilized using low cost twisted-pair media. By design the CAN protocol is a multi-master network architecture. This allows any particular CAN node to send a message to any one or more other CAN nodes on that particular bus.

The full details on how CAN networks function is not discussed in this application note. It is recommended to become familiarized with these networks before continuing this document. Another application note from Keil can be found at http://www.standardics.nxp.com/support/documents/microcontrollers/pdf/lpc17xx.can.arm.pdf. It briefly describes on how to create a CAN network using the LPC1700.

1.1 CAN activity

A CAN network is designed on a shared bus network; meaning that all CAN controllers (or nodes) on a particular bus will send and receive packets on the same physical medium. When no device is currently transmitting, then the bus is known to be in an “Idle” state. Any transition from an “Idle” state to a “non-Idle” state is referred to as “activity” throughout this application note. Activity on the bus can be generated from one or more nodes at once. It is important to note that according to CAN specifications, if two or more nodes are transmitting at the same time, the node with a highest priority will gain control of the bus.

1.2 Reduced power modes

One of the features of the LPC1700 is that it can be put into four different reduced power modes: Sleep, Deep Sleep, Power-down and Deep Power-down. In regards to this application note we will be primarily focusing on the Deep Sleep and Power-down modes.

The CANActivity interrupt will **only** function when the device is either in Deep Sleep or Power-down mode.

In sleep mode, any enabled interrupt will wakeup the LPC1700; however, in this mode the `CAN_IRQHandler` will process the incoming CAN packet.

In Deep Power-down mode the LPC1700 will only wake up when an external reset or RTC interrupt is generated; therefore, this reduced power mode is not applicable to this application note.

Full details on what the reduced power modes do to the LPC1700 can be found in its user manual. For our purposes we will briefly summarize the information that applies to this application note.

Table 1. Reduced power modes
This table is intended just as a quick summary applicable to this application note. Full details on the LPC1700's reduced power modes are found in its user manual.

Power Mode	Short summary
Sleep	A reset or any enabled interrupt will wake up the device. The clock to the ARM core is; whereas the clock to the peripherals continues to run. This power mode does not require any re-initialization of the PLL after being waked up.
Deep Sleep	The IRC remains running while the main oscillator is powered down. Flash is put into standby mode. Reset, NMI, EINT0-3, GPIO Interrupts, Ethernet WOL, Brownout Detect, RTC Alarm Interrupt, WDT timeout, USBActivity, or **CANActivity** interrupt will wake up the device. Afterwards, it requires re-initialization of the PLL and clock dividers.
Power-down	Same as Deep Sleep; however, flash and the IRC are also powered down.
Deep Power-down	Power is shut off to the entire chip. Only reset or the RTC can wake up the device.

2. Requirements

2.1 Hardware

This sample software was developed on Keil's MCB1700 development board which features an LPC1768 microcontroller. This particular microcontroller contains two CAN controllers. In this sample project only CAN1 is used to receive CAN packets.

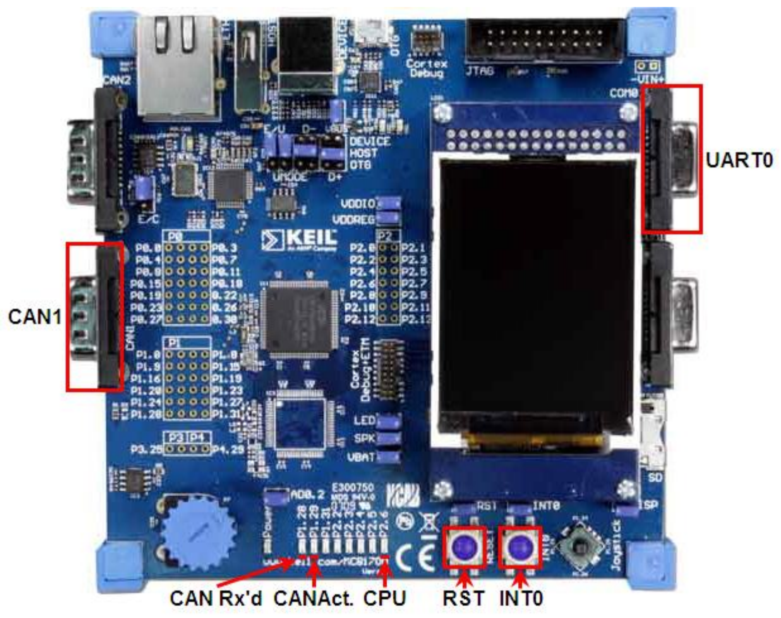


Fig 1. Keil's MCB1700 featuring the LPC1768

Since our objective here is to test the CAN Activity interrupt, we need to place the LPC1700 into Deep Sleep or Power-down mode. This means that we need some additional hardware that will generate CAN packets. This hardware should be the only CAN node connected to the LPC1700 so that we are in control of the CAN bus activity. The hardware required to connect the LPC1700 to the CAN network can be referred to the application note referenced in the Introduction. Although specialized CAN hardware and software products can generate the require CAN packets, it is also possible to use another microcontroller.

For additional debugging information a RS-232 serial cable can be connected to UART0 (COM0).

2.2 Software

Keil uVision version 4.01 was used to create this sample project. There is an issue with the header and startup files included in this version. This sample software uses its own version of corrected files. For more details see the Known issues section.

For programming purposes you can use a ULINK-ME JTAG module or a free optional ISP programming software such as Flash Magic (http://www.nxp.com/redirect/flashmagictool.com/).

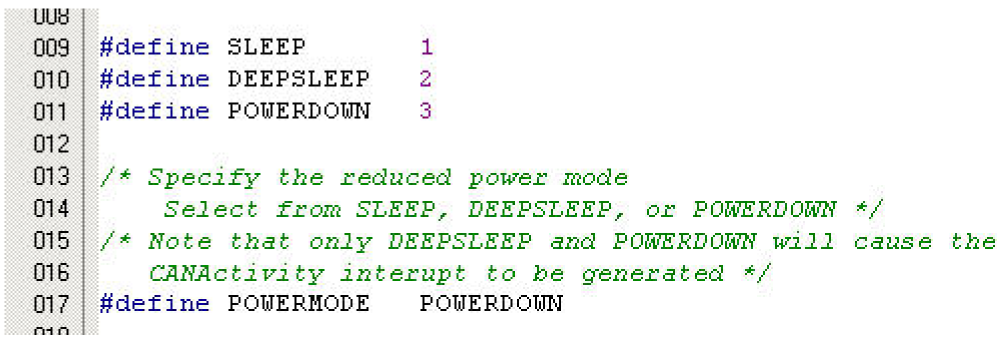
Tera Term Pro can be used to observe the debug information coming from UART0.

3. Implementation

This sample application will demonstrate the wakeup functionality of the LPC1700's CAN Activity interrupt. As a comparison we will put the device into Sleep, Deep Sleep, and Power-down modes to observe the behavior of the CAN Activity interrupt. The behavior of the LPC1700 can be observed using the MCB1700's provided LEDs and serial connection (UART0).

3.1 Button input

Aside from the RESET button, only the INT0 button is used. Pressing INT0 will put the LPC1700 into one of the three applicable reduced power modes. The reduced power mode is specified by the `POWERMODE` definition.



```
#define SLEEP       1
#define DEEPSLEEP   2
#define POWERDOWN   3

/* Specify the reduced power mode
   Select from SLEEP, DEEPSLEEP, or POWERDOWN */
/* Note that only DEEPSLEEP and POWERDOWN will cause the
   CANActivity interupt to be generated */
#define POWERMODE   POWERDOWN
```

Fig 2. Selecting the reduced power mode when pressing INT0

Note that pressing INT0 will also turn off all three LED indicators.

3.2 LED output

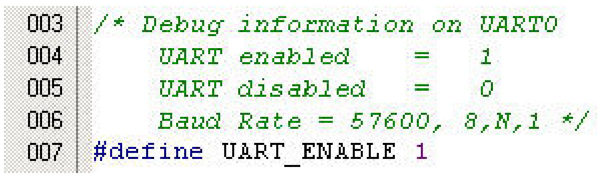
The MCB1700 features several onboard LEDs. Only three of them are used in this sample project. These LEDs will give us an insight on how the CANActivity interrupt works.

Table 2. LED indicator summary
This table will summarize the functions of each LED on the MCB1700

LED Indicator	Descriptive function
P2.6	P2.6 is toggled by the CPU while it is not in a reduced power mode.
P1.28	Receiving a CAN packet on CAN1 will cause P1.28 to be toggled.
P1.29	P1.29 is set only when the CAN Activity interrupt is executed.

3.3 UART output

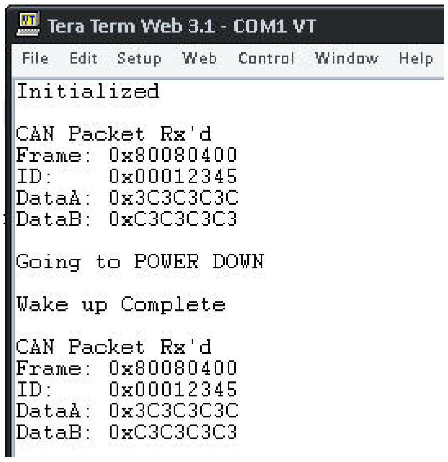
Optionally, debug information can be outputted onto UART0 (COM0). To enable UART0 output, simply specify `UART_ENABLE` to `1`.



```
/* Debug information on UART0
    UART enabled    =   1
    UART disabled   =   0
    Baud Rate = 57600, 8,N,1 */
#define UART_ENABLE 1
```

Fig 3. UART debugging enable

The debug information displays the most recent action performed on the LPC1700. If a CAN packet was received it will output the contents of the packet received.


Tera Term Web 3.1 - COM1 VT
File Edit Setup Web Control Window Help

```
Initialized

CAN Packet Rx'd
Frame:  0x80080400
ID:     0x00012345
DataA:  0x3C3C3C3C
DataB:  0xC3C3C3C3

Going to POWER DOWN

Wake up Complete

CAN Packet Rx'd
Frame:  0x80080400
ID:     0x00012345
DataA:  0x3C3C3C3C
DataB:  0xC3C3C3C3
```

Fig 4. Sample debug information on COM0 (UART0)

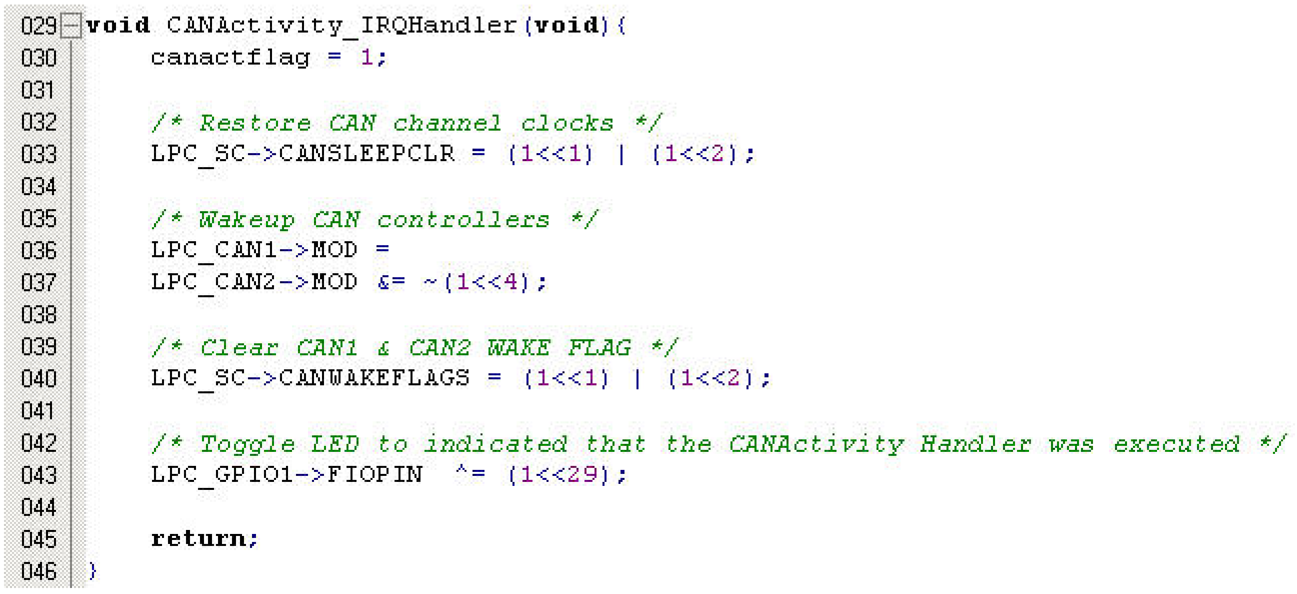
3.4 Sleep mode

By default, if the `WFI` instruction is issued to the device it will go into Sleep mode. If there is any activity on the CAN bus while the LPC1700 is in sleep mode, then the `CAN_IRQHandler` (interrupt) will cause the device to wake up. From that point it will then automatically process the current packet on the bus.

In other words, the CAN Activity interrupt will not be executed while in Sleep mode; therefore, P1.29 will not toggle.

3.5 Deep sleep and Power-down mode

Assuming its interrupt handler is enabled, the CAN Activity interrupt will execute from either Deep Sleep or Power-down mode. To prevent an infinite loop from servicing this interrupt we need to clear the CAN controller's wakeup flags. In this case, we should see P1.29 toggled.



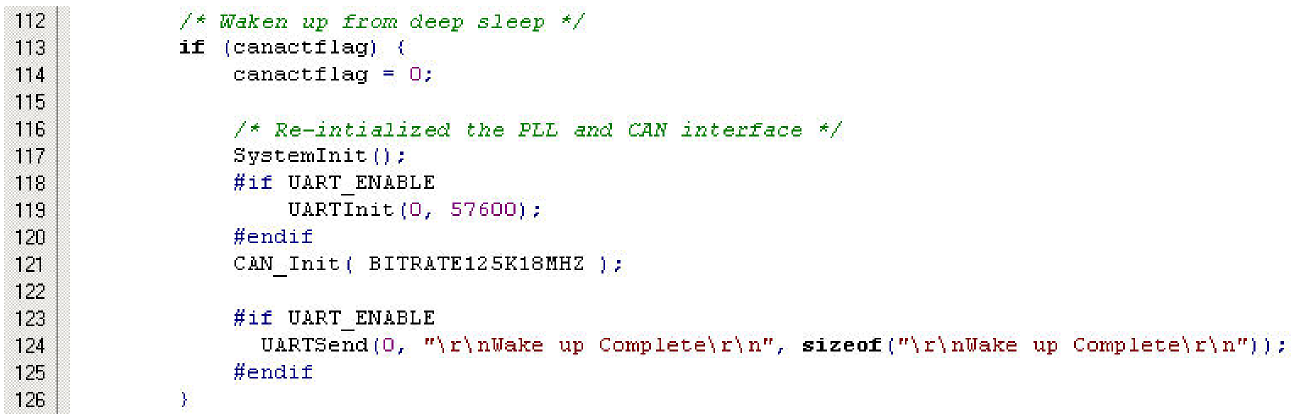
```
void CANActivity_IRQHandler(void){
    canactflag = 1;

    /* Restore CAN channel clocks */
    LPC_SC->CANSLEEPCLR = (1<<1) | (1<<2);

    /* Wakeup CAN controllers */
    LPC_CAN1->MOD =
    LPC_CAN2->MOD &= ~(1<<4);

    /* Clear CAN1 & CAN2 WAKE FLAG */
    LPC_SC->CANWAKEFLAGS = (1<<1) | (1<<2);

    /* Toggle LED to indicated that the CANActivity Handler was executed */
    LPC_GPIO1->FIOPIN  ^= (1<<29);

    return;
}
```

Fig 5. CAN activity service routine

It is also important to note that after the LPC1700 is woken up from Deep sleep or Power-down mode, it needs to have its PLL and clock dividers re-initialized. Moreover, the CAN controller also needs to be reinitialized so that the current activity on the CAN bus can be serviced.

However, due to the nature of the CAN protocol, if the CAN node transmits a CAN packet onto the bus it will continuously transmit the same packet until another node sends an acknowledge bit. This may inadvertently cause an issue when there is another CAN node on the CAN network. By protocol design, any CAN node on the network can send this acknowledgment bit.

When the LPC1700 is put into Deep Sleep or Power-down mode, it will require some amount of time to wake up again and re-initialize the PLL, clock dividers, and CAN controller. If any other CAN node sends the Acknowledgement bit bus during the wakeup period, then the LPC1700's CAN controller will not read in the initial packet that generated the activity on the bus in the first place. This wakeup delay will most likely cause several CAN packets to be lost before a re-initialized CAN controller can read the current (or perhaps the new) CAN packet on the bus. One solution to avoid this situation would be to put the other CAN nodes into a listen-only mode.



```
        /* Waken up from deep sleep */
        if (canactflag) {
            canactflag = 0;

            /* Re-intialized the PLL and CAN interface */
            SystemInit();
            #if UART_ENABLE
                UARTInit(0, 57600);
            #endif
            CAN_Init( BITRATE125K18MHZ );

            #if UART_ENABLE
              UARTSend(0, "\r\nWake up Complete\r\n", sizeof("\r\nWake up Complete\r\n"));
            #endif
        }
```

Fig 6. Re-initializing the LPC1700 after the CAN Activity ISR

Fortunately, this scenario will not take place when only two devices are on the CAN bus. The transmitting CAN node will continuously transmit the same packet until the receiver acknowledges it. Once the LPC1700 has been woken up from the reduced power mode, it will perform the re-initialization and service the CAN Activity.

4. Conclusion

Assuming that the CAN Activity interrupt service routine is enabled; it can only be executed if the LPC1700 is in either Deep Sleep or Power-down mode. To prevent this service routine to execute indefinitely the CAN controllers' wakeup flags need to be cleared. After the device has been restored from Deep Sleep or Power-down mode it needs to be re-initialized. This includes the PLL, clock dividers, and CAN controllers. Until the CAN controller has been re-initialized, the LPC1700 may miss several CAN packet transmissions; therefore, special care should be taken when including other CAN nodes onto the network.

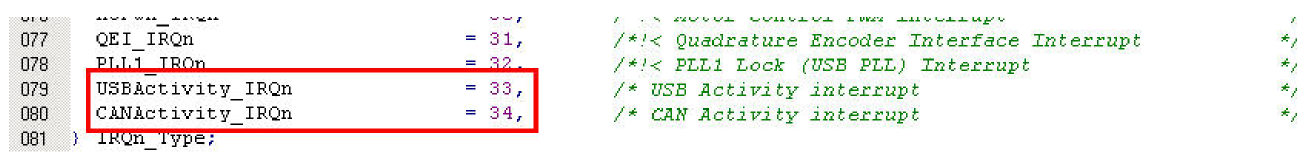
5. Known issues

Depending on the version of uVision that is being used, you may have to make some file modifications. If you are planning to use the `LPC17xx.h` or `startup_LPC17xx.s` supplied with the uVision development tools, please take a moment to verify or make the necessary changes shown below. The portions of code within the red boxes are the updated definitions.

The `LPC17xx.h` and `startups_LPC17xx.s` supplied with the sample software are already updated and therefore do not need any changes.

5.1 LPC17xx.h

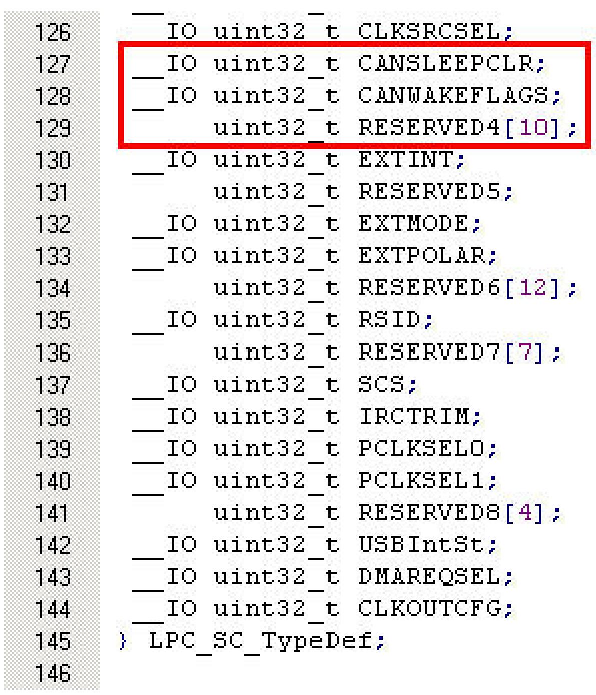
Add the interrupt vector number definitions in the `IRQn_Type` structure.



```
  QEI_IRQn                        = 31,      /*!< Quadrature Encoder Interface Interrupt         */
  PLL1_IRQn                       = 32,      /*!< PLL1 Lock (USB PLL) Interrupt                  */
  USBActivity_IRQn                = 33,      /* USB Activity interrupt                           */
  CANActivity_IRQn                = 34,      /* CAN Activity interrupt                           */
} IRQn_Type;
```

Fig 7. Additional interrupt vectors for the LPC17xx.h

The `LPC_SC_TypeDef` structure may have a larger `RESERVED4[]` placeholder. This placeholder should be modified with the contents shown in Fig 8.

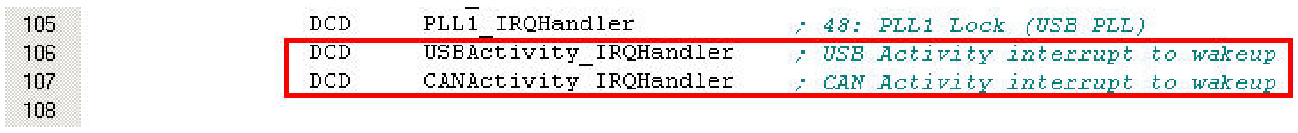


```
  __IO uint32_t CLKSRCSEL;
  __IO uint32_t CANSLEEPCLR;
  __IO uint32_t CANWAKEFLAGS;
       uint32_t RESERVED4[10];
  __IO uint32_t EXTINT;
       uint32_t RESERVED5;
  __IO uint32_t EXTMODE;
  __IO uint32_t EXTPOLAR;
       uint32_t RESERVED6[12];
  __IO uint32_t RSID;
       uint32_t RESERVED7[7];
  __IO uint32_t SCS;
  __IO uint32_t IRCTRIM;
  __IO uint32_t PCLKSEL0;
  __IO uint32_t PCLKSEL1;
       uint32_t RESERVED8[4];
  __IO uint32_t USBIntSt;
  __IO uint32_t DMAREQSEL;
  __IO uint32_t CLKOUTCFG;
} LPC_SC_TypeDef;
```

Fig 8. Additional register definitions

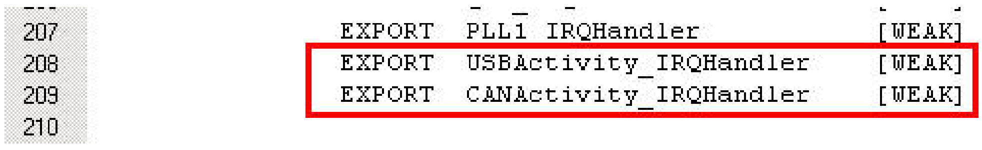
5.2 startup_LPC17xx.s

Add all of the following statements into the startup file if not present already.



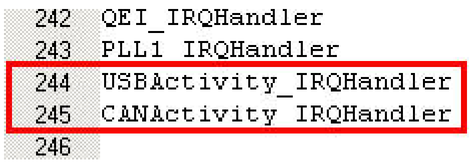
```
                DCD     PLL1_IRQHandler           ; 48: PLL1 Lock (USB PLL)
                DCD     USBActivity_IRQHandler    ; USB Activity interrupt to wakeup
                DCD     CANActivity_IRQHandler    ; CAN Activity interrupt to wakeup
```

Fig 9. Interrupt vector table handler definitions



```
                EXPORT  PLL1_IRQHandler           [WEAK]
                EXPORT  USBActivity_IRQHandler    [WEAK]
                EXPORT  CANActivity_IRQHandler    [WEAK]
```

Fig 10. Interrupt vector table EXPORT definitions



```
QEI_IRQHandler
PLL1_IRQHandler
USBActivity_IRQHandler
CANActivity_IRQHandler
```

Fig 11. Interrupt vector table handlers

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