INTERFACE NOTES

Analog Initialization

In labs 6, 7, and 8 we will use analog input and output channels to quantify and create analog signals. Each analog channel must be initialized before it can be read or written. Two functions are provided to initialize the analog input channel 0 and analog output channel 0 on connector C. The prototypes of these functions are

```
void Aio_InitCI0(MyRio_Aio *AIC0); // Input  0
void Aio_InitCO0(MyRio_Aio *AOC0); // Output 0
```

where `AIC0`, and `AOC0`, are structures of type `MyRio_Aio`. These structures are populated by the initialization functions, and will be referenced in the analog channel read and write functions described the following sections.

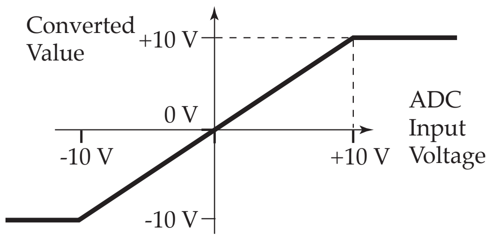
In lab 6, analog input `AIC0` and analog output `AOC0` will be used. The code to initialize these channels would be

```
MyRio_Aio AIC0;  // Connector C analog input 0
MyRio_Aio AOC0;  // Connector C analog output 0
Aio_InitCI0(&AIC0);  // Initialize input 0
Aio_InitCO0(&AOC0);  // Initialize output 0
```

The initialization functions are included in the `T1` library.

Analog-to-Digital Converter

The single-channel 12-bit analog-to-digital converter (ADC) measures the current value of the applied voltage in the range [-10.000, +9.995] V. Voltages outside that range "saturate" the conversion as shown.



The ADC has a resolution of 4.883 mV, with absolute accuracy of ±200 mV. Each channel has input impedance > 500 kΩ. Overload protection: ±16 V.

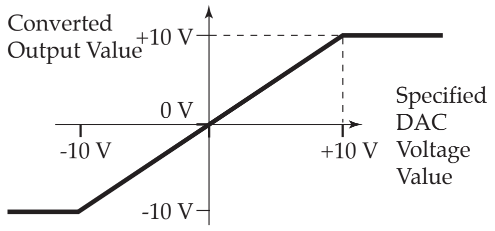
Our library contains a function that reads a specified channel of the ADC, and returns the converted value. Its prototype is:

```
double Aio_Read(MyRio_Aio* channel);
```

where `channel` is the pointer to the channel structure defined above: `&AIC0`.

Digital-to-Analog Converter

The single-channel 12-bit digital-to-analog converter (DAC) produces a voltage at the output terminal in the range [-10.000, +9.995] V. Again, specified voltages outside that range "saturate" the conversion as shown. The



DAC has a resolution of 4.883 mV, with absolute accuracy of ±200 mV. Each channel has a maximum drive current of 3 mA, and a maximum slew rate of $2\mathrm{V}/\mu\mathrm{s}$. Overload protection: ±16 V.

Our library contains a function that accepts a specified channel for the DAC, and returns the converted value. Its prototype is:

```
void Aio_Write(MyRio_Aio* channel, double value);
```

where `channel` is the pointer to the channel structure defined above: `&AOC0`, and value is the specified value of the analog output voltage.

Timer IRQ

Main Thread: Background

Initializing the Timer interrupt is similar to initializing the Digital Input interrupt.

We will use a separate thread to produce interrupts at periodic intervals. Within `main.c` we will configure the Timer interrupt, and create a new thread to respond when the interrupt occurs. The two threads communicate through a *globally defined* thread resource structure:

```
typedef struct {
    NiFpga_IrqContext irqContext; // IRQ context reserved
    NiFpga_Bool irqThreadRdy;     // IRQ thread ready flag
} ThreadResource;
```

National Instruments provides C functions to set up the Timer interrupt request (IRQ).

1) Register the Timer IRQ – The first of these functions reserves the interrupt from FPGA and configures the Timer and IRQ. Its prototype is:

```
int32_t Irq_RegisterTimerIrq( MyRio_IrqTimer* irqChannel,
                              NiFpga_IrqContext* irqContext,
                              uint32_t timeout);
```

where the five input arguments are:

1. `irqChannel`- A pointer to a structure containing the registers and settings for the IRQ I/O to modify; defined in `TimerIRQ.h` as:

```
typedef struct {
 uint32_t timerWrite;      // Timer IRQ interval register
 uint32_t timerSet;        // Timer IRQ setting register
 Irq_Channel timerChannel; // Timer IRQ supported I/O
} MyRio_IrqTimer;
```

2. `irqContext` - a pointer to a context variable identifying the interrupt to be reserved. It is the first component of the thread resources structure.
3. `timeout` - The timeout interval in μs.

The returned value is 0 for success.

2) Create the interrupt thread – A new thread must be configured to service the Timer interrupt. In `main.c` we will use `pthread_create()` to set up that thread. Its prototype is:

```
int pthread_create( pthread_t *thread,
                    const pthread_attr_t *attr,
                    void *(*start_routine) (void *),
                    void *arg);
```

where the four input arguments are:

1. `thread` - A pointer to a thread identifier.
2. `attr` - A pointer to thread attributes. In our case, use NULL to apply the default attributes.
3. `start_routine` - Name of starting function in the new thread.
4. `arg` - The sole argument to be passed to the new thread. In our case, it will be a *pointer* to the thread resource structure defined above and used in the second argument of `Irq_RegisterTimerIrq()`.

This function also returns 0 for success.

Main Thread: Our Case

We can combine these ideas into *a portion* of the `main.c` code needed to initialize the timer IRQ.[1] For interrupts triggered by the timer in the FPGA, we have:

```
int32_t status;
MyRio_IrqTimer irqTimer0;
ThreadResource  irqThread0;
pthread_t thread;

//  Registers corresponding to the IRQ channel
irqTimer0.timerWrite = IRQTIMERWRITE;
irqTimer0.timerSet = IRQTIMERSETTIME;
timeoutValue = 5;

status = Irq_RegisterTimerIrq( &irqTimer0,
                               &irqThread0.irqContext,
                               timeoutValue);

// Set the indicator to allow the new thread.
 irqThread0.irqThreadRdy = NiFpga_True;

// Create new thread to catch the IRQ.
status = pthread_create( &thread,
                         NULL,
                         Timer_Irq_Thread,
                         &irqThread0);
```

Other `main()` tasks go here.

After the tasks of `main.c` are completed, it should signal the new thread to terminate by setting the `irqThreadRdy` flag in the `ThreadResource` structure. Then wait for the thread to terminate. For example,

```
irqThread0.irqThreadRdy = NiFpga_False;
status = pthread_join(thread, NULL);
```

Finally, the timer interrupt must be unregistered:

```
status = Irq_UnregisterTimerIrq( &irqTimer0,
                                 irqThread0.irqContext);
```

using the same above arguments.

[1]The IRQ settings symbols associated with the timer interrupt, are defined in the header file: TimerIRQ.h.

3) The interrupt thread – This is the separate thread that was named and started by the `pthread_create()` function. Its overall task is to perform any necessary function in response to the interrupt. This thread will run until signaled to stop by `main.c`.

The new thread is the starting routine specified in the `pthread_create()` function called in `main.c`. In our case: `void *Timer_Irq_Thread(void* resource)`.

The first step in `Timer_Irq_Thread()` is to cast its input argument (passed as `void *`) into appropriate form. In our case, we cast the `resource` argument back to a `ThreadResource` structure. For example, declare

```
ThreadResource* threadResource = (ThreadResource*) resource;
```

The second step is to enter a while loop. Two functions are performed each time through the loop:

```
- while the main thread does not signal this thread to stop {
    1. Wait for the occurrence (or timeout) of the IRQ.
        - if it has, "schedule" the next interrupt.
    2. if the Timer IRQ has been asserted {
        - Perform operations to service the interrupt.
        - Acknowledge the interrupt.
}
```

The while loop should continue until the `irqThreadRdy` flag (set in `main.c`) indicates that the thread should end. For example,

1. Use the `Irq_Wait()` function to pause the loop while waiting for the interrupt. For our case the call might be:

   ```
   uint32_t irqAssert = 0;
   Irq_Wait( threadResource->irqContext,
             TIMERIRQNO,
             &irqAssert,
             (NiFpga_Bool*) &(threadResource->irqThreadRdy));
   ```

   Notice that it receives the `ThreadResource` context and Timer IRQ number information, and returns the `irqThreadRdy` flag set in the `main.c` thread.

   Schedule the next interrupt by writing the time interval into the `IRQTIMERWRITE` register, and setting the `IRQTIMERSETTIME` flag. That is,

   ```
   NiFpga_WriteU32( myrio_session,
                    IRQTIMERWRITE,
                    timeoutValue );

   NiFpga_WriteBool( myrio_session,
                     IRQTIMERSETTIME,
                     NiFpga_True);
   ```

   The `timeoutValue` is the number of microseconds (`uint32_t`) until the next interrupt. The `myrio_session` used in these functions should be declared within this timer thread. That is,

   ```
   extern NiFpga_Session myrio_session;
   ```

   This variable was defined when you called `MyRio_Open()` in the main thread.

2. Because the `Irq_Wait()` times out after 100 ms, we must check the `irqAssert` flag to see if the Timer IRQ has been asserted.

   In addition, after the interrupt is serviced, it must be acknowledged to the scheduler. For example,

   ```
   if(irqAssert) {

       % Your interrupt service code here

       Irq_Acknowledge(irqAssert);
   }
   ```

In the third step (after the end of the loop) we terminate the new thread, and return from the function:

```
pthread_exit(NULL);
return NULL;
```