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Example 12.1. Design an interface 32 Ω speaker and use it to generate a soft 1 kHz sound.

Solution: To make sound we need to create an oscillating wave. In this example, the wave will be a simple square wave. At 3.3V, a 32 Ω speaker will require a current of about 100 mA. The maximum the TM4C123 can produce on an output pin is 8 mA. If we place a resistor in series with the headphones, then the current will only be $3.3V/(1500+32\Omega) = 2.2mA$. To generate the 1 kHz sound we need a 1 kHz square wave. There are many good methods to generate square waves. In this example we will implement one of the simplest methods. We will activate a periodic interrupt and toggle an output pin in the ISR. To generate a 1 kHz wave we will toggle the PA5 pin every 500 μs . We will assume the PLL is active and the system is running at 80 MHz. We wish to initialize the SysTick to interrupt with a period of 500 μs . The correct value for reload is 39999 $((500\mu s/12.5ns)-1)$. If the bus frequency were to be 16 MHz, we would set the reload value to be 7999 $((500\mu s/62.5ns)-1)$. Since this sound wave output is a real-time signal, we set its priority to highest level, which is 0. See Program 12.6.

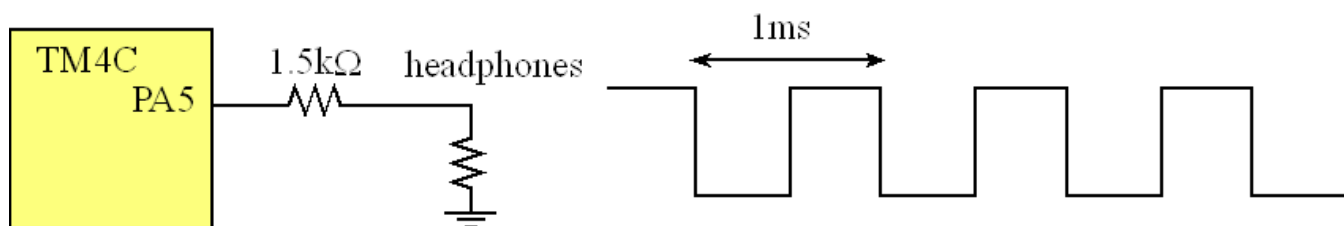


Figure 12.6. A squarewave output connected to a speaker will generate sound.

```
void Sound_Init(void){ unsigned long volatile delay;
    SYSTCL_RCGC2_R |= 0x00000001; // activate port A
    delay = SYSTCL_RCGC2_R;
    GPIO_PORTA_AMSEL_R &= ~0x20;      // no analog
    GPIO_PORTA_PCTL_R &= ~0x00F00000; // regular function
    GPIO_PORTA_DIR_R |= 0x20;         // make PA5 out
    GPIO_PORTA_DR8R_R |= 0x20;        // can drive up to 8mA out
    GPIO_PORTA_AFSEL_R &= ~0x20;      // disable alt funct on PA5
    GPIO_PORTA_DEN_R |= 0x20;         // enable digital I/O on PA5
    NVIC_ST_CTRL_R = 0;               // disable SysTick during setup
    NVIC_ST_RELOAD_R = 39999;         // reload value for 500us (assuming 80MHz)
    NVIC_ST_CURRENT_R = 0;            // any write to current clears it
```

1 kHz sound | 12.5 SysTick Periodic Interrupts...

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```
NVIC_SYS_PRI3_R = NVIC_SYS_PRI3_R&0x00FFFFFF; // priority 0
NVIC_ST_CTRL_R = 0x00000007; // enable with core clock and interrupts
EnableInterrupts();
}

void SysTick_Handler(void){
    GPIO_PORTA_DATA_R ^= 0x20;    // toggle PA5
}
```

Program 12.6. Sound output using a periodic interrupt (C12_SoftSound).

Observation: To make a quieter sound, we could use a larger resistor between the PA5 output and the speaker.



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