Escuela Universitaria Ingeniería Técnica Industrial ZARAGOZA

ANEXO 1:

Código C de los subsistemas específicos y del prototipo del sistema

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Código C: subsistema adxl

```
// INCLINOMETRO EJE X E Y
#include <m8c.h>        // Constantes y macros núcleo M8C PSoC
#include <stdlib.h>
#include <math.h>
#include "PSoCAPI.h"    // PSoC API definiciones de los user modules

//Definición de variables
int valorX,valorY,inclinacionX,inclinacionY,i;
float valorX_f,valorY_f;      // para formato flotante
char*valorX_char;             // codificicacion del eje X a character
char*valorY_char;
char*gradosX;
char*gradosY;

//FUNCION PARA CALIBRACION DEL INCLINOMETRO Y VISIONADO EN PANTALLA
void refresco_LCD(void)
{
 LCD_1_Control(LCD_1_DISP_CLEAR_HOME);    //Limpieza de la pantalla.
// Calculo de valores

      valorX_f=valorX;                     //paso de entero->float
      valorX_f=(valorX_f*5/4095)+0.65;
      valorX_char = ftoa(valorX_f,0);     //Conversión de float a ASCII
      LCD_1_Position(0,0);
      LCD_1_PrCString("Vx:");
      LCD_1_PrString(valorX_char);         // Valor en V del eje X

      valorY_f=valorY;                     //paso de entero->float
      valorY_f=(valorY_f*5/4095)+0.68;
      valorY_char = ftoa(valorY_f,0);    //Conversion del float a ASCII
      LCD_1_Position(0,7);
      LCD_1_PrCString("  Vy:");
      LCD_1_PrString(valorY_char);         // Valor en V del eje Y

//Comparación de valores y asignación a un valor de inclinación X
 if( 1.56<=valorX_f && valorX_f<=1.639){inclinacionX=1;}
      else if(( 1.51<=valorX_f && valorX_f<=1.55)||( 1.64<=valorX_f &&
valorX_f<=1.67)){inclinacionX=2;}
      else if(( 1.46<=valorX_f && valorX_f<=1.50)||( 1.68<=valorX_f &&
valorX_f<=1.72)){inclinacionX=3;}
      else if(( 1.41<=valorX_f && valorX_f<=1.45)||( 1.73<=valorX_f &&
valorX_f<=1.77)){inclinacionX=4;}
      else if(( 1.36<=valorX_f && valorX_f<=1.40)||( 1.78<=valorX_f &&
valorX_f<=1.82)){inclinacionX=5;}
      else if(( 1.31<=valorX_f && valorX_f<=1.35)||( 1.83<=valorX_f &&
valorX_f<=1.87)){inclinacionX=6;}
      else if(( 1.26<=valorX_f && valorX_f<=1.30)||( 1.88<=valorX_f &&
valorX_f<=1.92)){inclinacionX=7;}
      else if(( 1.21<=valorX_f && valorX_f<=1.25)||( 1.93<=valorX_f &&
valorX_f<=1.97)){inclinacionX=8;}
      else if(( 1.16<=valorX_f && valorX_f<=1.20)||( 1.98<=valorX_f &&
valorX_f<=2.02)){inclinacionX=9;}
      else if(( 1.11<=valorX_f && valorX_f<=1.14)||( 2.03<=valorX_f &&
valorX_f<=2.06)){inclinacionX=10;}

      LCD_1_Position(1,0);
      LCD_1_PrCString("gX:");
```

```
switch(inclinacionX)
{
      case 1: LCD_1_PrCString("0g");
                  break;
      case 2: LCD_1_PrCString("5g");
                  break;
      case 3: LCD_1_PrCString("10g");
                  break;
      case 4: LCD_1_PrCString("15g");
                  break;
      case 5: LCD_1_PrCString("20g");
                  break;
      case 6: LCD_1_PrCString("25g");
                  break;
      case 7: LCD_1_PrCString("30g");
                  break;
      case 8: LCD_1_PrCString("35g");
                  break;
      case 9: LCD_1_PrCString("40g");
                  break;
      case 10: LCD_1_PrCString("45g");
                  break;
      default: LCD_1_PrCString("ERROR");
                  break;
      }
//Comparación de valores y asignación a un valor de inclinación Y

      if( 1.54<=valorY_f && valorY_f<=1.585){inclinacionY=1;}
      else if(( 1.48<=valorY_f && valorY_f<=1.51)||( 1.59<=valorY_f &&
valorY_f<=1.63)){inclinacionY=2;}
      else if(( 1.43<=valorY_f && valorY_f<=1.47)||( 1.64<=valorY_f &&
valorY_f<=1.68)){inclinacionY=3;}
      else if(( 1.38<=valorY_f && valorY_f<=1.41)||( 1.69<=valorY_f &&
valorY_f<=1.73)){inclinacionY=4;}
      else if(( 1.33<=valorY_f && valorY_f<=1.37)||( 1.74<=valorY_f &&
valorY_f<=1.78)){inclinacionY=5;}
      else if(( 1.28<=valorY_f && valorY_f<=1.31)||( 1.79<=valorY_f &&
valorY_f<=1.83)){inclinacionY=6;}
      else if(( 1.23<=valorY_f && valorY_f<=1.27)||( 1.84<=valorY_f &&
valorY_f<=1.88)){inclinacionY=7;}
      else if(( 1.18<=valorY_f && valorY_f<=1.21)||( 1.89<=valorY_f &&
valorY_f<=1.93)){inclinacionY=8;}
      else if(( 1.13<=valorY_f && valorY_f<=1.17)||( 1.94<=valorY_f &&
valorY_f<=1.98)){inclinacionY=9;}
      else if(( 1.08<=valorY_f && valorY_f<=1.11)||( 1.99<=valorY_f &&
valorY_f<=2.03)){inclinacionY=10;}

      LCD_1_Position(1,10);
      LCD_1_PrCString("gY:");

      switch(inclinacionY)
      {
      case 1: LCD_1_PrCString("0g");
                  break;
      case 2: LCD_1_PrCString("5g");
                  break;
      case 3: LCD_1_PrCString("10g");
                  break;
      case 4: LCD_1_PrCString("15g");
                  break;
```

```
        case 5: LCD_1_PrCString("20g");
                break;
        case 6: LCD_1_PrCString("25g");
                break;
        case 7: LCD_1_PrCString("30g");
                break;
        case 8: LCD_1_PrCString("35g");
                break;
        case 9: LCD_1_PrCString("40g");
                break;
        case 10: LCD_1_PrCString("45g");
                break;
        default: LCD_1_PrCString("ERROR");
                break;
        }
        for(i=0;i<25000;i++){;}
        }
        void alarmas (void)
        {

 if(inclinacionX<=8 && inclinacionY<=8)
  {
   PWM8_OK_Start();
   PWM8_ATT_Stop();
   PWM8_PEL_Stop();
  }
 if (inclinacionX==8||inclinacionY==8)
        {
        PWM8_OK_Start();
        PWM8_PEL_Stop();
        PWM8_ATT_Start();
        }
        else if(inclinacionX==9||inclinacionY==9)
              {
              PWM8_PEL_Stop();
              PWM8_OK_Stop();
              PWM8_ATT_Start();
              }
        else if(inclinacionX==10||inclinacionY==10)
              {
              PWM8_ATT_Stop();
              PWM8_PEL_Start();
              }
}

void main(void)
{
//CONFIGURACION MODULOS
        ADCINCVR_X_SetResolution(12); //Establece resolución 12Bits

        ADCINCVR_X_GetSamples(0);     //ADC en modo continuo

        ADCINCVR_Y_SetResolution(12); //Establece resolución 12Bits

        ADCINCVR_Y_GetSamples(0);     //ADC en modo continuo
```

```
//INICIALIZACION DE LOS MODULOS

      PGA_X_Start(PGA_X_HIGHPOWER); //Enciende Amplificador

      ADCINCVR_X_Start(ADCINCVR_X_HIGHPOWER); //Inicializas el ADC

      PGA_Y_Start(PGA_Y_HIGHPOWER); //Enciende Amplificador

      ADCINCVR_Y_Start(ADCINCVR_Y_HIGHPOWER); //Inicializas el ADC

      LCD_1_Start();    //Iniciar el LCD


M8C_EnableGInt;   // Interrupciones globales activada


//BUCLE PRINCIPAL
while(1)
      {

      // REFRESCARA CADA VEZ QUE SE REALICE UNA VCONVERSION
       if (ADCINCVR_X_fIsDataAvailable() != 0) //fin de conversion
{
          valorX = ADCINCVR_X_iGetData(); //obtencion de la conversión

          ADCINCVR_X_ClearFlag();         //limpiamos tras leer

          refresco_LCD();                 //pintado del lcd

          alarmas();
         }
      if (ADCINCVR_Y_fIsDataAvailable() != 0)  //fin de conversion
         {
          valorY = ADCINCVR_Y_iGetData(); //obtencion de la conversion

          ADCINCVR_Y_ClearFlag();         //limpiamos tras leer

          refresco_LCD();                 //pintado del lcd

          alarmas();
         }
}

}
```

Código C: subsistema Hall

```
//-------------------------------------------------------------------
// Sensor Hall para la medición de la altura del plato de corte
//-------------------------------------------------------------------

#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules
#include <stdlib.h>

// definicion de funciones de apoyo
#define Bit(bitNumber)(1<<(bitNumber)) // genera la mascara para el
                                    numero de bit del puerto
#define BTN_UP (PRT0DR&Bit(7))       //PERMITE LEER EL BOTON SUBIR
#define BTN_DOWN (PRT0DR&Bit(5))     //PERMITE LEER EL BOTON BAJAR
#define RESET_HALL (PRT1DR&Bit(7))   //PERMITE LEER EL BOTON RESET
#define SENSOR_HALL (PRT1DR&Bit(2))  //PERMITE LEER EL SENSOR HALL(0/5V)

//Definicion de variables
int valor_mm,contup,contdown;

//Variables para la conversion a ASCII
float mm_f;
char*mm_char;

//RUTINA REFRESCO DEL LCD
void REFRESCO_LCD(void)
{
LCD_1_Start();
LCD_1_Position(0,3);
LCD_1_PrCString("Grillo SpA");
LCD_1_Position(1,0);
LCD_1_PrCString("LAMA:");

//conversion mm a ASCII
mm_f=valor_mm;
mm_char=ftoa(mm_f,0);
LCD_1_PrString(mm_char);
LCD_1_Position(1,10);
LCD_1_PrCString("mm");
}

//RUTINA RETRASO 10ms
void retardo(void)
{
Counter16_1_Start( );
while ((wCounter16_1_ReadCounter( )!=0)){} //RUTINA 10ms
}

//RUTINA DE RESET
void reset(void)//valores iniciales
{
 LCD_1_Control(LCD_1_DISP_CLEAR_HOME);//LIMPIA EL CONTENIDO DE PANTALLA
 valor_mm=80;
 contup=0;
 contdown=0;
 REFRESCO_LCD();
}
```

```
void main(void)
{
  reset();
  REFRESCO_LCD();
  PWM8_1_Start();
//cada contaje global se realizara en 530ms
  while(1){
 Start:        if(BTN_UP){

                  leerUP: if(SENSOR_HALL){contup++;}
                             else{goto leerUP;}

                          if((contup==53)&&(valor_mm<=79))
                            {
                             valor_mm++;
                             REFRESCO_LCD();
                             retardo();
                             contup=0;
                             goto Start;
                      }
                           else if((contup==53)&&(valor_mm==80))
                                   {
                                    contup=0;
                                    LCD_1_Position(1,13);
                             LCD_1_PrCString("MAX");
                                    goto Start;
                                   }

                         }

               if(BTN_DOWN){

                  leerDOWN: if(SENSOR_HALL){contdown++;}
                        else{goto leerDOWN;}

                             if((contdown==53)&&(valor_mm>=21))
                                {
                                 valor_mm--;
                                 REFRESCO_LCD();
                                 retardo();
                                 contdown=0;
                                 goto Start;
                                }
                              else if((contdown==53)&&(valor_mm==20))
                                     {
                                contdown=0;
                                      LCD_1_Position(1,13);
                                LCD_1_PrCString("MIN");
                                      goto Start;
                                     }
                            }

               if(RESET_HALL){
                               reset();
                              goto Start;
                             }
          }
}
```

Código C: subsistema FSR

```
//-----------------------------------------------------------------------
// Sensor de presion basado en FSR
//-----------------------------------------------------------------------

#include <m8c.h>        // Constantes y macros núcleo M8C PSoC
#include <stdlib.h>
#include <math.h>
#include "PSoCAPI.h"    // PSoC API definiciones de los user modules
#define Bit(bitNumber)(1<<(bitNumber))

//Definición de variables
int fuerza,llenado,cuchilla=0;
float fuerza_f;         // para formato flotante
char*fuerza_char;       // codificicacion de la fuerza a character

//FUNCION PARA CALIBRACION DEL INCLINOMETRO Y VISIONADO EN PANTALLA
void refresco_LCD(void)
{
 LCD_1_Control(LCD_1_DISP_CLEAR_HOME);   //Limpieza de la pantalla.

// Calculo de valores
 fuerza_f=fuerza;                //paso de entero->float
 fuerza_f=(fuerza_f*5/4095);
 fuerza_char = ftoa(fuerza_f,0);//Conversion del float a ASCII
 LCD_1_Position(0,0);
 LCD_1_PrCString("FSR:");
 LCD_1_PrString(fuerza_char);  // Valor en V de la fuerza aplicada


if(fuerza_f<=0.25){llenado=1;}
      else if( 0.25<=fuerza_f && fuerza_f<=0.75){llenado=2;}
      else if( 0.75<=fuerza_f && fuerza_f<=1.25){llenado=3;}
      else if( 1.25<=fuerza_f && fuerza_f<=1.75){llenado=4;}
      else if( 1.75<=fuerza_f && fuerza_f<=2.25){llenado=5;}
      else if( 2.25<=fuerza_f && fuerza_f<=2.75){llenado=6;}
      else if( 2.75<=fuerza_f && fuerza_f<=3.25){llenado=7;}
      else if( 3.25<=fuerza_f && fuerza_f<=3.75){llenado=8;}
      else if( 3.75<=fuerza_f && fuerza_f<=4.25){llenado=9;}
      else if( 4.25<=fuerza_f && fuerza_f<=4.75){llenado=10;}
      else if( 4.75<=fuerza_f && fuerza_f<=5){llenado=11;}


LCD_1_Position(1,0);
LCD_1_PrCString("Fuerza:");

switch(llenado)
{
      case 1: LCD_1_PrCString("0Kg");
                  break;
      case 2: LCD_1_PrCString("1Kg");
                  break;
      case 3: LCD_1_PrCString("2Kg");
                  break;
      case 4: LCD_1_PrCString("3Kg");
                  break;
```

```
        case 5: LCD_1_PrCString("4Kg");
                break;
        case 6: LCD_1_PrCString("5Kg");
                break;
        case 7: LCD_1_PrCString("6Kg");
                break;
        case 8: LCD_1_PrCString("7Kg");
                break;
        case 9: LCD_1_PrCString("8Kg");
                break;
        case 10: LCD_1_PrCString("9Kg");
                break;
        case 11: LCD_1_PrCString("10Kg");
                break;
        default: LCD_1_PrCString("ERROR");
                break;
}

}
void alarmas (void)
{

 if(llenado<=2)
  {
   PWM8_OK_Start();
   PWM8_ATT_Stop();
   PWM8_PEL_Stop();
  }
      else if (llenado==3)
      {
      PWM8_OK_Start();
      PWM8_PEL_Stop();
      PWM8_ATT_Start();
      }
      else if(llenado==4)
            {
            PWM8_PEL_Stop();
            PWM8_OK_Stop();
            PWM8_ATT_Start();
            }
      else if(llenado==5)
            {
            PWM8_ATT_Stop();
            PWM8_PEL_Start();
            cuchilla=cuchilla+1;
            }
      else if(cuchilla==3)
            {
            PRT0DR&=~Bit(7);
            } //En el caso de recibir 3 señales de peligro,
       // invertiremos el bit 7 del puerto 0, considerando que el
       // cesto está lleno lo que supondrá la inversión
}             // del bit P0_7(de nivel bajo a nivel alto)
              // y, por tanto,la detención de las cuchillas.
```

```
void main(void)
{
//CONFIGURACION MODULOS
      ADCINCVR_FSR_SetResolution(12);
      //Establece resolución 12Bits
      ADCINCVR_FSR_GetSamples(0);
      //ADC en modo continuo

//INICIALIZACION DE LOS MODULOS

      PGA_FSR_Start(PGA_FSR_HIGHPOWER);
      //Enciende Amplificador
      ADCINCVR_FSR_Start(ADCINCVR_FSR_HIGHPOWER);
      //Inicializa el ADC

      LCD_1_Start();
            //Iniciar el LCD

M8C_EnableGInt;
      // Interrupciones globales activadas

//BUCLE PRINCIPAL
while(1)
      {
      // REFRESCARA CADA VEZ QUE SE REALICE UNA VCONVERSION
      if (ADCINCVR_FSR_fIsDataAvailable() != 0)//fin de conversion
        {
        fuerza = ADCINCVR_FSR_iGetData(); //obtención de la conversion
        ADCINCVR_FSR_ClearFlag();         //limpiamos tras leer
        refresco_LCD();                   //pintado del lcd
        alarmas();                        //Activación alarmas
                            }

      }

}
```

Código C: subsistema UART

```
// UART TEST
#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules
#include <stdlib.h>

//Declaracion de variables
int FSR;
char Enviar_muestra_seg;
char dato_UART;
char sensor;
float FSR_f;
char *FSR_char;
//definimos la interrupción que conducirá a la función del TIMER
#pragma interrupt_handler Timer8_1_ISR

//interrupcion del timer q se ejecuta cada segundo
void Timer8_1_ISR(void)
{
      //Calcular una nueva muestra del conversor
      ADCINC_1_GetSamples(1);
      //Actualizar dato del conversor
      if (ADCINC_1_fIsDataAvailable()!=0)
      {
      // Obtiene el resultado del conversor AD y borra el flag
      FSR=ADCINC_1_iClearFlagGetData();
      //Se escala el dato para saber el voltaje a la entrada del
        conversor (5V/2^8)
      FSR_f=FSR*0.01953125;
      }

      //Si se ha recibido un '2' enviará una muestra del conversor por
        cada segundo
      if (Enviar_muestra_seg==1)
      {
      Visualiza_dato_ADC();
      //se envía en hexadecimal el resultado del conversor cada
segundo.
      UART_1_PutSHexInt(FSR);
      }
}


void main(void)
{
      while(1)
      {
       Inicializacion();

aqui: while(sensor!='f'){
      //Obtiene el dato recibido en la UART en tipo char, si no recibe
        nada devuelve 0
      sensor=UART_1_cReadChar();
```

```
        if (sensor!=0)
              {
              if (sensor=='f'){
              //Con estas instrucciones escribimos en el hiperterminal
                    UART_1_CPutString("\n\r Sensor FSR\n\r");
                    UART_1_CPutString("\n\r1-1muestra 2-1muestra/seg
                                 3-stop n-clean\n\r");
              //Con estas, pintamos el LCD
                    LCD_1_Control(LCD_1_DISP_CLEAR_HOME);
                    LCD_1_Position(0,0);
                    LCD_1_PrCString("SENSOR FSR");
                    goto aqui2;
                              }
              if(sensor!='f'){
              //Si se recibe un caracter distinto de f, escribiremos
          un mensaje en el hypert. y volveremos al principio
        UART_1_CPutString("\n\rIntroduce 'f' para FSR, 'h'
                     para HALL o 'a' para ADXL\n\r");
                    goto aqui;
                             }
                            }
              }

  aqui2: while(dato_UART!='n')
              {
              dato_UART=UART_1_cReadChar();
              //espera hasta que se reciba dato
              if (dato_UART!=0)
                 {
              //si el dato recibido es un '1' envía una sola muestra
                 if (dato_UART=='1')
                    {
                    Enviar_una_muestra_hex();
              //se visualiza el dato de la UART en la 1ª línea del LCD
                    Visualiza_dato_UART();
              //se visualiza el resultado del ADC en la 2ª línea del LCD

                    Visualiza_dato_ADC();
                    goto aqui2;
                    }

              //si el dato recibido es un '2' envía una muestra/segundo
                 if (dato_UART=='2')
                    {
                    Enviar_muestra_seg=1;
                    //se visualiza el dato de la UART en la primera línea
                      del LCD
                    Visualiza_dato_UART();
                    goto aqui2;
                    }
```

```
            //si el dato recibido es un '3' para de enviar muestras por
              segundo
              if (dato_UART=='3')
                 {
                 Enviar_muestra_seg=0;
                 //se visualiza el dato de la UART en la primera línea
                   del LCD
                 Visualiza_dato_UART();
                 //se indica que se ha parado de enviar muestras cada
             segundo
                 LCD_1_Position(1,0);
                 LCD_1_PrCString("Stop");
                 goto aqui2;
                 }

            //si el dato recibido es una 'n' borraremos el
        hiperterminal y comenzaremos de nuevo el proceso

              if (dato_UART=='n')
                 {
                  UART_1_PutChar(12);
                 }
              }
          }
      }
  }

//Inicialización de todos los User modules utilizados y habilitación
de las interrupciones
void Inicializacion (void)
{
      //Inicialización PGA en HIGHPOWER
      PGA_1_Start(PGA_1_HIGHPOWER);

      //Inicialización ADCINC en HIGHPOWER
      ADCINC_1_Start(ADCINC_1_HIGHPOWER);

      //Inicialización UART
      UART_1_CmdReset();
      UART_1_Start(UART_PARITY_NONE);
      sensor=0;
      dato_UART=0;

      //Inicialización de algunos bloques
      Timer8_1_Start();
      LCD_1_Start();
      PWM8_Start();

      //Habilita interrupciones globales
      M8C_EnableGInt;
      Timer8_1_EnableInt();

      //Inicio del LCD
      LCD_1_Position(0,0);
      LCD_1_PrCString("Esperando a user");
      LCD_1_Position(1,0);
      LCD_1_PrCString("dato UART");
      //escribe en el hiperterminal el mensaje de inicio
      smshyper();
}
```

```
void Visualiza_dato_UART (void)
{
 LCD_1_Control(LCD_1_DISP_CLEAR_HOME);
            //Escribe en la primera línea del LCD desde la primera
        columna "Tension medida: "
          LCD_1_Position(0,5);
          LCD_1_PrCString("Dato UART: ");
          LCD_1_WriteData(dato_UART);
}
void Visualiza_dato_ADC (void)
{
//Posiciona el cursor de nuevo al principio de la segunda línea
LCD_1_Position(1,0);
          LCD_1_PrCString("Tension: ");
//Convierte el voltaje de tipo float a ASCII y lo muestra en el LCD
          FSR_char= ftoa (FSR_f,0);
          LCD_1_PrString(FSR_char);
          LCD_1_PrCString("V");
}

void Enviar_una_muestra_hex (void)
{
//envía cuatro caracteres en hexadecimal del resultado del AD
UART_1_PutSHexInt(FSR);
}


void smshyper(void)
{
//Escribe el mensaje de inicio en el hiperterminal
    UART_1_CPutString("\n\r Sensor Stats");
    UART_1_CPutString("\n\r Introduce sensor a comprobar");
    UART_1_CPutString("\n\r Introduce 'f' para FSR, 'H' para HALL o
                      'a' para ADXL\n\r");
    UART_1_CPutString("\n\r");
}
```

Código C: Prototipo del sistema

```c
//----------------------------------------------------------------------
// PROTOTIPO FINAL
//----------------------------------------------------------------------

#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules
#include <stdlib.h>

//Declaracion de los puertos usados
#define Bit(bitNumber)(1<<(bitNumber))
#define SENSOR_HALL (PRT0DR&Bit(0))
#define BTN_DWN (PRT1DR&Bit(1))
#define BTN_UP (PRT1DR&Bit(2))
#define STOP_CORTE (PRT1DR&Bit(4))
#define ON_OFF (PRT1DR&Bit(6))

//Declaracion de variables
int valor_mm,contup,contdown,i,incX,incY;
int FSR,AX,AY,HALL,cesto,cuchilla=0;
char Enviar_muestra_FSR,Enviar_muestra_AX,Enviar_muestra_AY,Enviar_muestra_HALL;
char cadenaF[30],cadenaX[30],cadenaY[30],cadenaH[30];
char sensor,dato_UART;
float FSR_f,AX_f,AY_f,mm_f;
char*mm_char;
char *FSR_char;
char *AX_char;
char *AY_char;

//definimos la interrupcion que conducira a la función del timer
#pragma interrupt_handler Timer8_1_ISR

//interrupcion del timer q se ejecuta cada segundo
void Timer8_1_ISR(void)
{
      //Calcular una nueva muestra del conversor
      ADCINC_1_GetSamples(1);
      //Actualizar dato del conversor
      if (ADCINC_1_fIsDataAvailable()!=0)
            {
            // Obtiene el resultado del conversorAD y borra el flag
            FSR=ADCINC_1_iClearFlagGetData();
            //Se escala el dato para saber el voltaje a la entrada del
            //conversor (5V/2^8)
            FSR_f=FSR*0.01953125;
            }

      DUALADC8_1_GetSamples();
      //Actualizar dato del conversor
      if (DUALADC8_1_fIsDataAvailable()!=0)
        {// Obtiene el resultado del conversorAD y borra el flag
      AX = DUALADC8_1_cGetData1();    // Dato del ADC I1
      AY = DUALADC8_1_cGetData2ClearFlag(); // Dato del ADC I2
        //Se escala el dato nuevamente (5V/2^8)
            AX_f=AX*0.01953125;
            AY_f=AY*0.01953125;
            }
```

```
//Si se ha encendido ON_OFF, el sistema entrará en MODO UART
//Se enviará un indicador del dato, el dato, y el finalizador
//de cadena, que Matlab interpretará para la representación
//gráfica de los datos (finalizador de cadena: \r\n)
      if (Enviar_muestra_FSR==1)
            {
            UART_1_CPutString("\n\rFSR\r\n");
            csprintf(cadenaF,"%i\r\n",FSR);
            UART_1_PutString(cadenaF);

            }
      if (Enviar_muestra_AX==1)
            {
            UART_1_CPutString("\n\rAX\r\n");
            csprintf(cadenaX,"%i\r\n",AX);
            UART_1_PutString(cadenaX);
            }
      if (Enviar_muestra_AY==1)
            {
            UART_1_CPutString("\n\rAY\r\n");
            csprintf(cadenaY,"%i\r\n",AY);
            UART_1_PutString(cadenaY);
            }
      if (Enviar_muestra_HALL==1)
            {
            if(SENSOR_HALL){HALL=5;}
                  else if(!SENSOR_HALL){HALL=0;}
            UART_1_CPutString("\n\rHALL\r\n");
            csprintf(cadenaH,"%i\r\n",HALL);
            UART_1_PutString(cadenaH);
            }
}

void main(void) //RUTINA PRINCIPAL
{
   Inicializacion();
   LCD_1_Control(LCD_1_DISP_CLEAR_HOME);
//BUCLE QUE REPETIRÁ INDEFINIDAMENTE
      while(1)
      {
      Inicio_LCD_Hall();
      do{
         for(i=0;i<500;i++){;}
         rutina_hall();//SUBRUTINA HALL
         rutina_adxl();//SUBRUTINA ADXL
         rutina_fsr();//SUBRUTINA FSR
        }while(!ON_OFF);
       rutina_UART();//SUBRUTINA UART se iniciara si ON_OFF activo
      if(!ON_OFF)
        {
         Enviar_muestra_FSR=0;
         Enviar_muestra_AX=0;
         Enviar_muestra_AY=0;
         Enviar_muestra_HALL=0;
         LCD_1_Control(LCD_1_DISP_CLEAR_HOME);
         UART_1_CPutString("\n\rfin\r\n");
         UART_1_CPutString("\r\n");
        }

       }

  }
```

```
//Inicialización de todos los user modules utilizados y habilitación
de las interrupciones
void Inicializacion (void)
{
	//Inicialización amplificadores en HIGHPOWER
	PGA_FSR_Start(PGA_FSR_HIGHPOWER);
	PGA_X_Start(PGA_X_HIGHPOWER);
	PGA_Y_Start(PGA_Y_HIGHPOWER);
	//Inicializacion ADCINC en HIGHPOWER
	ADCINC_1_Start(ADCINC_1_HIGHPOWER);

	//Inicialización DUALADC8 en HIGHPOWER
	DUALADC8_1_Start(DUALADC8_1_HIGHPOWER);
	DUALADC8_1_SetCalcTime(1);
	//Como está explicado en la memoria, un valor de CalcTime=1
	//determina una frecuencia de muestreo de 9.99 muestras/s

	//Inicialización UART
	UART_1_CmdReset();
	UART_1_Start(UART_PARITY_NONE);
	sensor=0;
	dato_UART=0;

	//Inicialización algunos bloques
	Timer8_1_Start();
	LCD_1_Start();
	PWM8_Start();

	//Habilita interrupciones globales
	M8C_EnableGInt;
	Timer8_1_EnableInt();

	//Inicio del LCD: Mensaje bienvenida
	LCD_1_Position(0,0);
	LCD_1_PrCString("Grillo SpA.");
	LCD_1_Position(1,0);
	LCD_1_PrCString("Control de Datos");
	//escribe en el hiperterminal el mensaje de inicio
	smshyper();
	//Inicialización valores plato de corte y cesto
	valor_mm=80;
	contup=0;
	contdown=0;
	cuchilla=0;
}
void rutina_UART(void)
//Rutina de envio de datos a través del puerto serie
{
while(ON_OFF){
 LCD_1_Position(0,0);
 LCD_1_PrCString("MODO UART        ");
 LCD_1_Position(1,0);
 LCD_1_PrCString("ENVIO DATOS COM2");
 Enviar_muestra_FSR=1;
 Enviar_muestra_AX=1;
 Enviar_muestra_AY=1;
 Enviar_muestra_HALL=1;}
}
```

```
void smshyper(void)
//Mensaje de inicio en el hiperterminal
{
    UART_1_CPutString("\n\rGrillo SpA Sensor Stats");
    UART_1_CPutString("\n\rEnvio de datos desactivado");
    UART_1_CPutString("\n\rEsperando ON_OFF\n\r");
    UART_1_CPutString("\n\r");
}

void Inicio_LCD_Hall(void)
{
   for(i=0;i<5000;i++){;}
   LCD_1_Position(0,0);
   LCD_1_PrCString("PLATO:");
   mm_f=valor_mm; //conversion mm a ASCII
   mm_char=ftoa(mm_f,0);
   LCD_1_PrString(mm_char);
   LCD_1_Position(0,10);
   LCD_1_PrCString("mm");
}
void rutina_hall(void)
{
   if(BTN_UP)
      {
       if(SENSOR_HALL)
         {contup++;}
       if((contup==53)&&(valor_mm<=79))
         {
          valor_mm++;
          LCD_1_Position(0,0);
          LCD_1_PrCString("PLATO:");
          //conversion mm a ASCII
          mm_f=valor_mm;
          mm_char=ftoa(mm_f,0);
          LCD_1_PrString(mm_char);
          LCD_1_Position(0,10);
          LCD_1_PrCString("mm    ");

          Counter8_1_Start( );
          while ((bCounter8_1_ReadCounter( )!=0)){} //RUTINA 10ms
          contup=0;
         }
          else if((contup==53)&&(valor_mm==80))
                 {
                  contup=0;
                  LCD_1_Position(0,13);
                  LCD_1_PrCString("MAX");
                  }
      }

   if(BTN_DWN)
      {
       if(SENSOR_HALL)
         {contdown++;}
       if((contdown==53)&&(valor_mm>=21))
         {
          valor_mm--;
          LCD_1_Position(0,0);
```

```
            LCD_1_PrCString("PLATO:");
            //conversion mm a ASCII
            mm_f=valor_mm;
            mm_char=ftoa(mm_f,0);
            LCD_1_PrString(mm_char);
            LCD_1_Position(0,10);
            LCD_1_PrCString("mm     ");

            Counter8_1_Start( );
            while ((bCounter8_1_ReadCounter( )!=0)){} //RUTINA 10ms
            contdown=0;
            }
            else if((contdown==53)&&(valor_mm==20))
                   {
                    contdown=0;
                    LCD_1_Position(0,13);
                    LCD_1_PrCString("MIN");
                   }
      }
}
void rutina_adxl(void)
{
 DUALADC8_1_GetSamples();
 //Actualizar dato del conversor
 if (DUALADC8_1_fIsDataAvailable()!=0)
   {
    AX = DUALADC8_1_cGetData1();          // Dato del ADC I1
    AY = DUALADC8_1_cGetData2ClearFlag(); // Dato del ADC I1
  //Se escala el dato para saber el voltaje del AD: (5V/2^8)
    AX_f=AX*0.01953125;      //paso de entero->float
    AX_char = ftoa(AX_f,0); //Conversión del float a ASCII
    AY_f=AY*0.01953125;     //paso de entero->float
    AY_char = ftoa(AY_f,0);//Conversion del float a ASCII

    //Sensibilidad a los valores del eje X
    if( 1.26<=AX_f && AX_f<=1.92){incX=1;}

      else if(( 1.21<=AX_f && AX_f<=1.25)||( 1.93<=AX_f &&
AX_f<=1.97)){incX=8;}

      else if(( 1.16<=AX_f && AX_f<=1.20)||( 1.98<=AX_f &&
         AX_f<=2.02)){incX=9;}

      else if(( 1.11<=AX_f && AX_f<=1.14)||( 2.03<=AX_f &&
         AX_f<=2.06)){incX=10;}

    //Sensibilidad a los valores del eje Y
    if( 1.23<=AY_f && AY_f<=1.88){incY=1;}

      else if(( 1.18<=AY_f && AY_f<=1.21)||( 1.89<=AY_f &&
         AY_f<=1.93)){incY=8;}

      else if(( 1.13<=AY_f && AY_f<=1.17)||( 1.94<=AY_f &&
         AY_f<=1.98)){incY=9;}

      else if(( 1.08<=AY_f && AY_f<=1.11)||( 1.99<=AY_f &&
         AY_f<=2.03)){incY=10;}
```

```
 LCD_1_Position(1,0);
 LCD_1_PrCString("INC:");
 //Encendido de alarmas en función de los valores de inclinación
 //Y aparición en el LCD del estado: OK, ATENCIÓN o PELIGRO
 if(incX<=8 && incY<=8)
 {
  PWM8_OK_Start();
  PWM8_ATT_Stop();
  PWM8_PEL_Stop();
  LCD_1_Position(1,4);
  LCD_1_PrCString(" OK");
 }
 if (incX==8||incY==8)
 {
  PWM8_OK_Stop();
  PWM8_PEL_Stop();
  PWM8_ATT_Start();
  LCD_1_Position(1,4);
  LCD_1_PrCString("ATT");
 }
 else if(incX==9||incY==9||incX==10||incY==10)
      {
       PWM8_OK_Stop();
       PWM8_ATT_Stop();
       PWM8_PEL_Start();
       LCD_1_Position(1,4);
       LCD_1_PrCString("PEL");
      }
   }
}
void rutina_fsr(void)
{
 //Calcular una nueva muestra del conversor
 ADCINC_1_GetSamples(1);
 //Actualizar dato del conversor
 if (ADCINC_1_fIsDataAvailable()!=0)
 {
  // Obtiene el resultado del conversorAD y borra el flag
  FSR=ADCINC_1_iClearFlagGetData();
  //Se escala el dato para saber el voltaje del AD
  FSR_f=FSR*0.01953125;
 }
  FSR_char = ftoa(FSR_f,0);//Conversion del float a ASCII
  LCD_1_Position(1,8);
  LCD_1_PrCString("FSR:");

 //Sensibilidad a los valores del sensor FSR
 if(FSR_f<=1.75){cesto=1;}
  else if( 1.75<=FSR_f && FSR_f<=2.25){cesto=5;}
  else if( 2.25<=FSR_f && FSR_f<=2.75){cesto=6;}
  else if( 2.75<=FSR_f && FSR_f<=3.25){cesto=7;}
  //Encendido de alarmas en función de los valores de inclinación
  //Y aparición en el LCD del estado: OK, MEDIO o LLENO
 if(cesto<5) {
   PWMFSR_OK_Start();
   PWMFSR_FULL_Stop();
   LCD_1_Position(1,12);
   LCD_1_PrCString("  OK");
  }
```

```
  else if(cesto==5||cesto==6)
      {
      PWMFSR_OK_Stop();
      PWMFSR_FULL_Start();   //
      for(i=0;i<500;i++){;}  //Hace parpadear el LED
      PWMFSR_FULL_Stop();    //
      LCD_1_Position(1,12);
      LCD_1_PrCString(" MED");
      }
      else if(cesto==7)
            {
        PWMFSR_OK_Stop();
        PWMFSR_FULL_Start();
            LCD_1_Position(1,13);
            LCD_1_PrCString("FULL");
            cuchilla=cuchilla+1;
            }
      else if(cuchilla==10)
            {
            (STOP_CORTE)

}); //En el caso de recibir 3 señales de peligro invertiré el bit 4
//del puerto 1,considerando que el cesto está lleno lo que supondrá la
//inversión del bit P1_4(de nivel bajo a nivel alto)y, por tanto,la
//detención de las cuchillas.
```

ANEXO 2:

Datasheets

Dirigido por:

Antonio Bono Nuez

Realizado por:

Víctor Arnal Herguedas

INDICE

Small, Low Power, 3-Axis ±3 *g* Accelerometer

ADXL335

FEATURES

3-axis sensing
Small, low profile package
4 mm × 4 mm × 1.45 mm LFCSP
Low power : 350 µA (typical)
Single-supply operation: 1.8 V to 3.6 V
10,000 *g* shock survival
Excellent temperature stability
BW adjustment with a single capacitor per axis
RoHS/WEEE lead-free compliant

APPLICATIONS

Cost sensitive, low power, motion- and tilt-sensing applications
Mobile devices
Gaming systems
Disk drive protection
Image stabilization
Sports and health devices

GENERAL DESCRIPTION

The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 *g*. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration.

The user selects the bandwidth of the accelerometer using the C_X, C_Y, and C_Z capacitors at the X_{OUT}, Y_{OUT}, and Z_{OUT} pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the X and Y axes, and a range of 0.5 Hz to 550 Hz for the Z axis.

The ADXL335 is available in a small, low profile, 4 mm × 4 mm × 1.45 mm, 16-lead, plastic lead frame chip scale package (LFCSP_LQ).

FUNCTIONAL BLOCK DIAGRAM

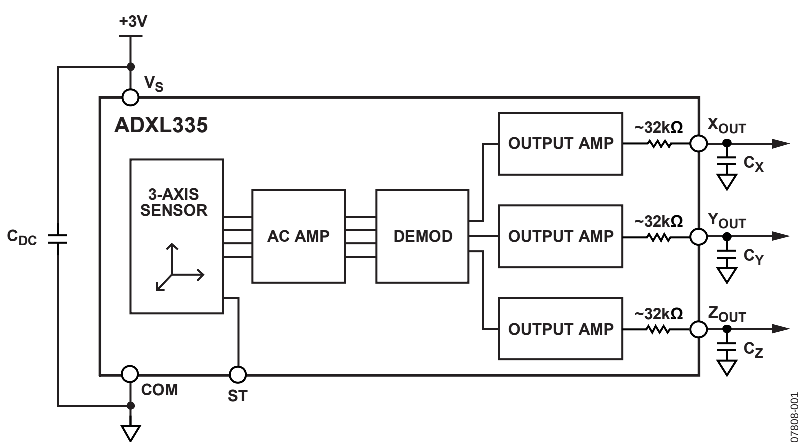

Figure 1.

Rev. 0

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REVISION HISTORY

1/09—Revision 0: Initial Version

SPECIFICATIONS

T_A = 25°C, V_S = 3 V, C_X = C_Y = C_Z = 0.1 μF, acceleration = 0 *g*, unless otherwise noted. All minimum and maximum specifications are guaranteed. Typical specifications are not guaranteed.

Table 1.

Parameter	Conditions	Min	Typ	Max	Unit
SENSOR INPUT	Each axis				
Measurement Range		±3	±3.6		*g*
Nonlinearity	% of full scale		±0.3		%
Package Alignment Error			±1		Degrees
Interaxis Alignment Error			±0.1		Degrees
Cross-Axis Sensitivity[1]			±1		%
SENSITIVITY (RATIOMETRIC)[2]	Each axis				
Sensitivity at X_{OUT}, Y_{OUT}, Z_{OUT}	V_S = 3 V	270	300	330	mV/*g*
Sensitivity Change Due to Temperature[3]	V_S = 3 V		±0.01		%/°C
ZERO *g* BIAS LEVEL (RATIOMETRIC)					
0 *g* Voltage at X_{OUT}, Y_{OUT}	V_S = 3 V	1.35	1.5	1.65	V
0 *g* Voltage at Z_{OUT}	V_S = 3 V	1.2	1.5	1.8	V
0 *g* Offset vs. Temperature			±1		m*g*/°C
NOISE PERFORMANCE					
Noise Density X_{OUT}, Y_{OUT}			150		μ*g*/√Hz rms
Noise Density Z_{OUT}			300		μ*g*/√Hz rms
FREQUENCY RESPONSE[4]					
Bandwidth X_{OUT}, Y_{OUT}[5]	No external filter		1600		Hz
Bandwidth Z_{OUT}[5]	No external filter		550		Hz
R_{FILT} Tolerance			32 ± 15%		kΩ
Sensor Resonant Frequency			5.5		kHz
SELF-TEST[6]					
Logic Input Low			+0.6		V
Logic Input High			+2.4		V
ST Actuation Current			+60		μA
Output Change at X_{OUT}	Self-Test 0 to Self-Test 1	−150	−325	−600	mV
Output Change at Y_{OUT}	Self-Test 0 to Self-Test 1	+150	+325	+600	mV
Output Change at Z_{OUT}	Self-Test 0 to Self-Test 1	+150	+550	+1000	mV
OUTPUT AMPLIFIER					
Output Swing Low	No load		0.1		V
Output Swing High	No load		2.8		V
POWER SUPPLY					
Operating Voltage Range		1.8		3.6	V
Supply Current	V_S = 3 V		350		μA
Turn-On Time[7]	No external filter		1		ms
TEMPERATURE					
Operating Temperature Range		−40		+85	°C

[1] Defined as coupling between any two axes.
[2] Sensitivity is essentially ratiometric to V_S.
[3] Defined as the output change from ambient-to-maximum temperature or ambient-to-minimum temperature.
[4] Actual frequency response controlled by user-supplied external filter capacitors (C_X, C_Y, C_Z).
[5] Bandwidth with external capacitors = 1/(2 × π × 32 kΩ × C). For C_X, C_Y = 0.003 μF, bandwidth = 1.6 kHz. For C_Z = 0.01 μF, bandwidth = 500 Hz. For C_X, C_Y, C_Z = 10 μF, bandwidth = 0.5 Hz.
[6] Self-test response changes cubically with V_S.
[7] Turn-on time is dependent on C_X, C_Y, C_Z and is approximately 160 × C_X or C_Y or C_Z + 1 ms, where C_X, C_Y, C_Z are in microfarads (μF).

ABSOLUTE MAXIMUM RATINGS

Table 2.

Parameter	Rating
Acceleration (Any Axis, Unpowered)	10,000 *g*
Acceleration (Any Axis, Powered)	10,000 *g*
V_S	−0.3 V to +3.6 V
All Other Pins	(COM − 0.3 V) to (V_S + 0.3 V)
Output Short-Circuit Duration (Any Pin to Common)	Indefinite
Temperature Range (Powered)	−55°C to +125°C
Temperature Range (Storage)	−65°C to +150°C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

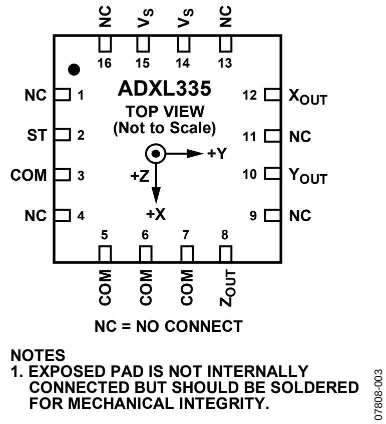


Figure 2. Pin Configuration

Table 3. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	NC	No Connect[1].
2	ST	Self-Test.
3	COM	Common.
4	NC	No Connect[1].
5	COM	Common.
6	COM	Common.
7	COM	Common.
8	Z_{OUT}	Z Channel Output.
9	NC	No Connect[1].
10	Y_{OUT}	Y Channel Output.
11	NC	No Connect[1].
12	X_{OUT}	X Channel Output.
13	NC	No Connect[1].
14	V_S	Supply Voltage (1.8 V to 3.6 V).
15	V_S	Supply Voltage (1.8 V to 3.6 V).
16	NC	No Connect[1].
EP	Exposed Pad	Not internally connected. Solder for mechanical integrity.

[1]NC pins are not internally connected and can be tied to COM pins, unless otherwise noted.

TYPICAL PERFORMANCE CHARACTERISTICS

N > 1000 for all typical performance plots, unless otherwise noted.

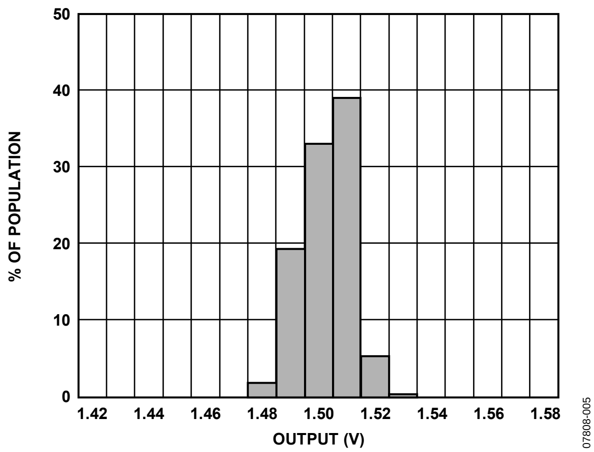


Figure 3. X-Axis Zero g Bias at 25°C, V_S = 3 V

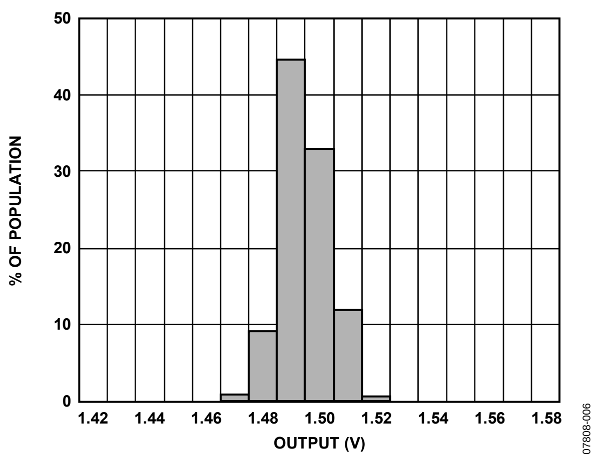


Figure 4. Y-Axis Zero g Bias at 25°C, V_S = 3 V

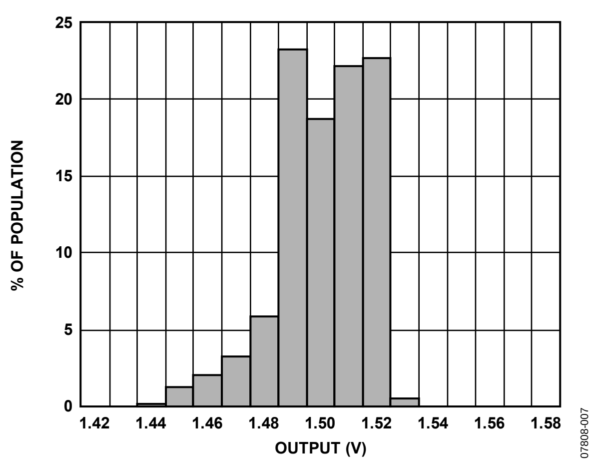


Figure 5. Z-Axis Zero g Bias at 25°C, V_S = 3 V

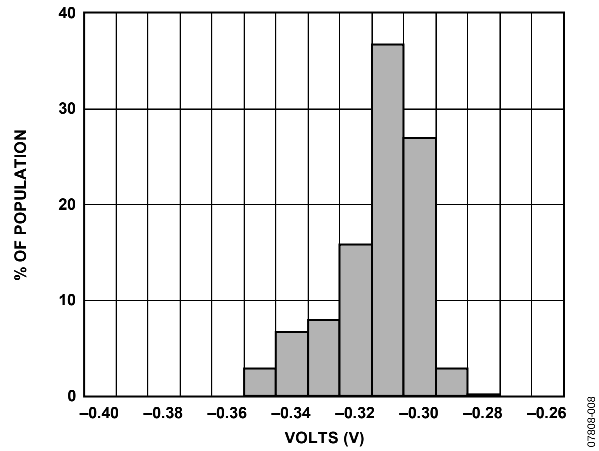


Figure 6. X-Axis Self-Test Response at 25°C, V_S = 3 V

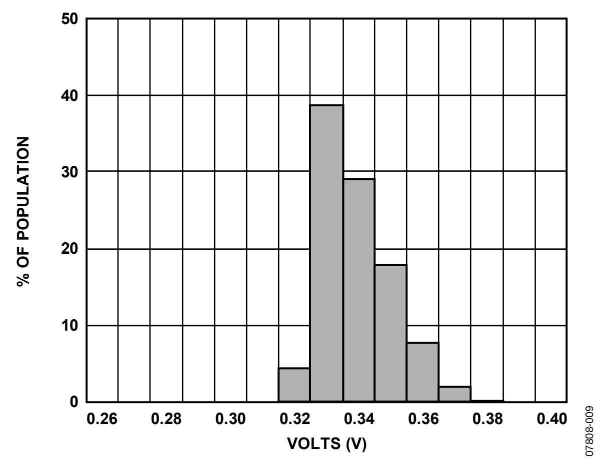


Figure 7. Y-Axis Self-Test Response at 25°C, V_S = 3 V

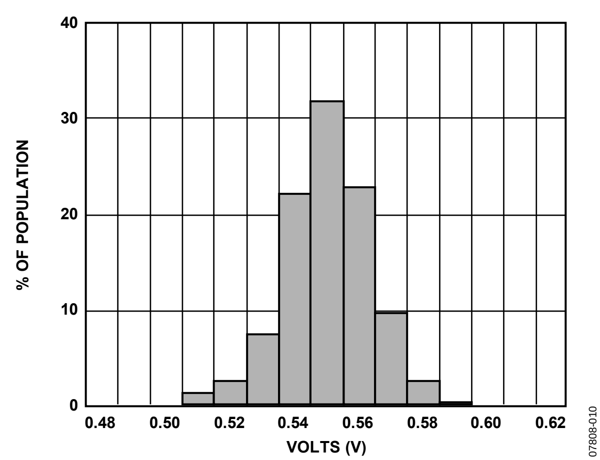


Figure 8. Z-Axis Self-Test Response at 25°C, V_S = 3 V

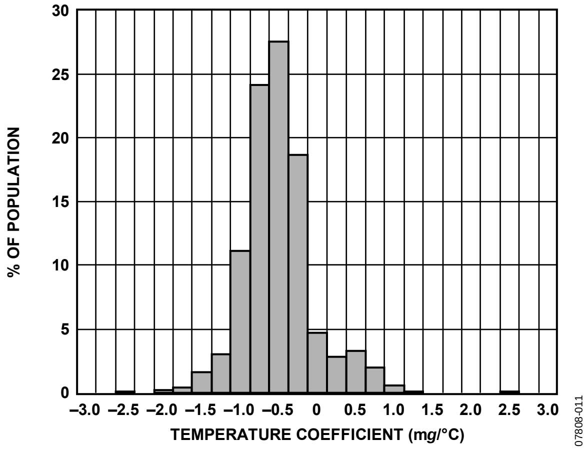


Figure 9. X-Axis Zero g Bias Temperature Coefficient, V_S = 3 V

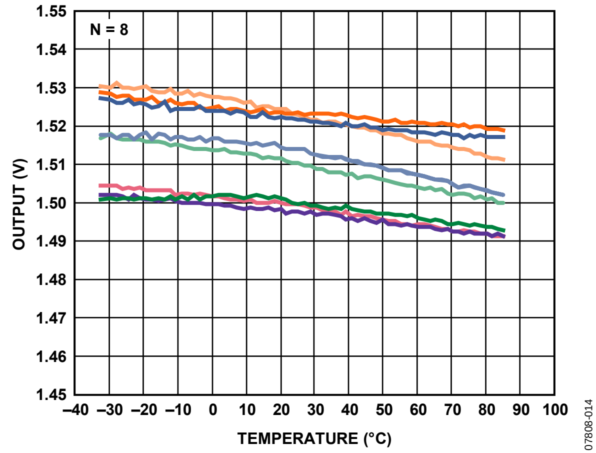


*Figure 12. X-Axis Zero g Bias vs. Temperature—
Eight Parts Soldered to PCB*

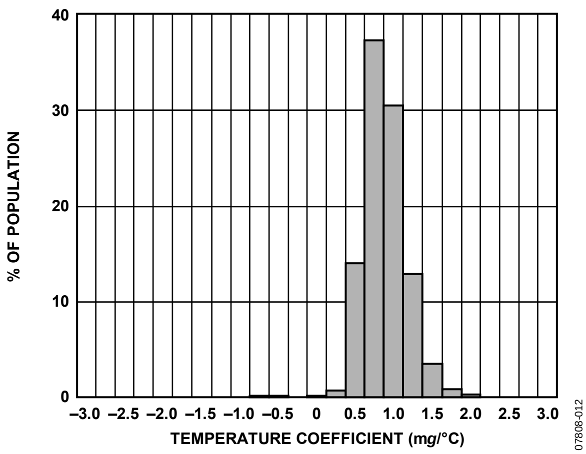


Figure 10. Y-Axis Zero g Bias Temperature Coefficient, V_S = 3 V

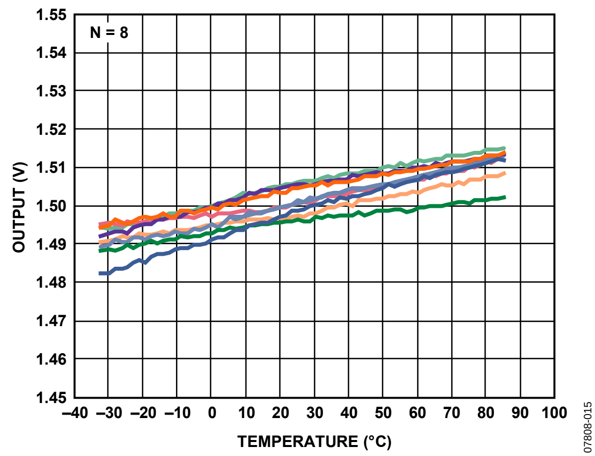


*Figure 13. Y-Axis Zero g Bias vs. Temperature—
Eight Parts Soldered to PCB*

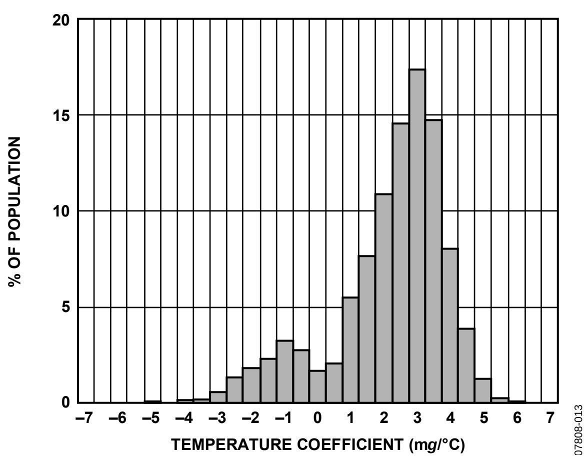


Figure 11. Z-Axis Zero g Bias Temperature Coefficient, V_S = 3 V

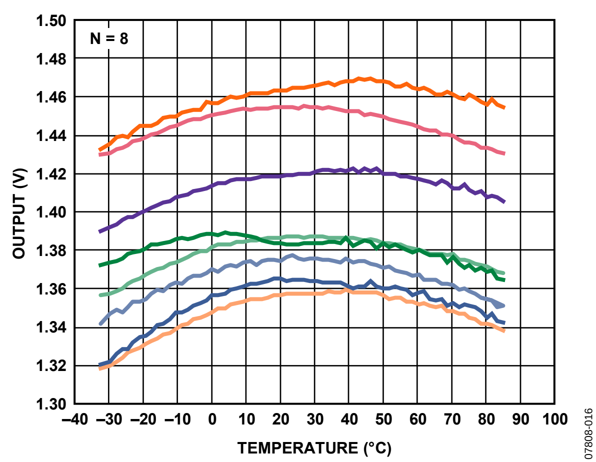


*Figure 14. Z-Axis Zero g Bias vs. Temperature—
Eight Parts Soldered to PCB*

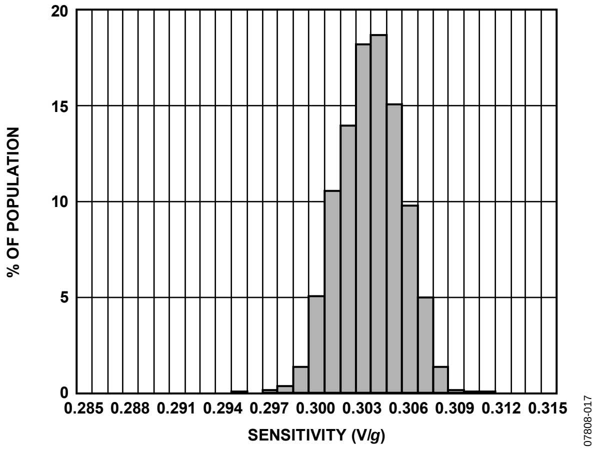


Figure 15. X-Axis Sensitivity at 25°C, V_S = 3 V

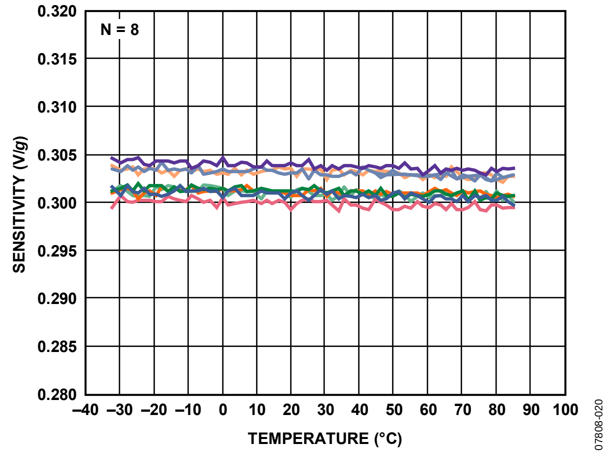


Figure 18. X-Axis Sensitivity vs. Temperature—Eight Parts Soldered to PCB, V_S = 3 V

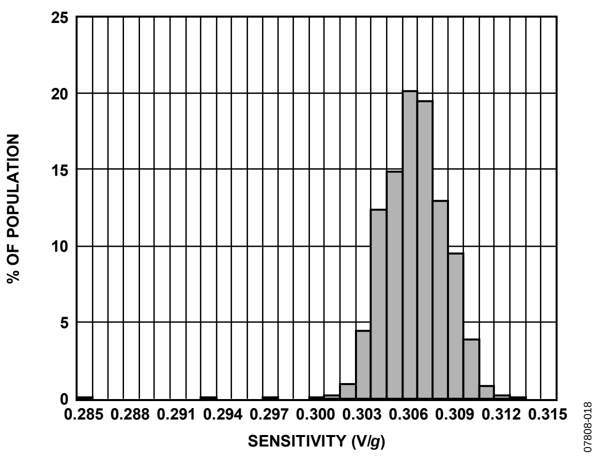


Figure 16. Y-Axis Sensitivity at 25°C, V_S = 3 V

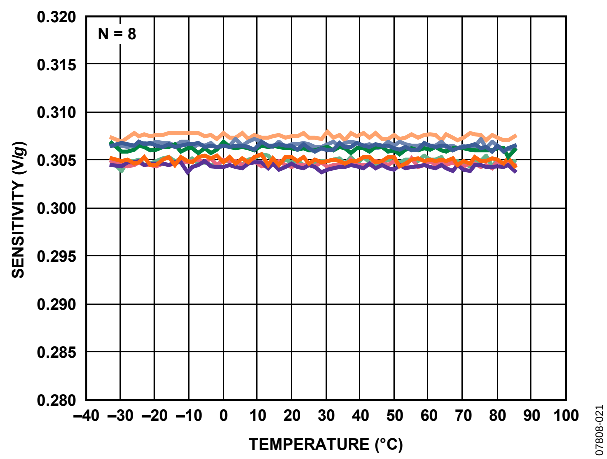


Figure 19. Y-Axis Sensitivity vs. Temperature—Eight Parts Soldered to PCB, V_S = 3 V

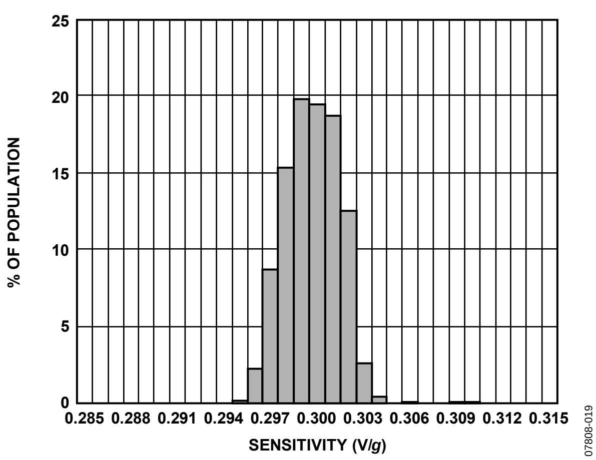


Figure 17. Z-Axis Sensitivity at 25°C, V_S = 3 V

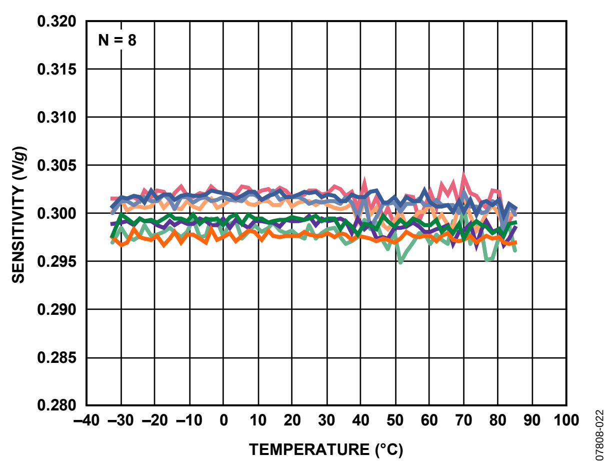


Figure 20. Z-Axis Sensitivity vs. Temperature—Eight Parts Soldered to PCB, V_S = 3 V

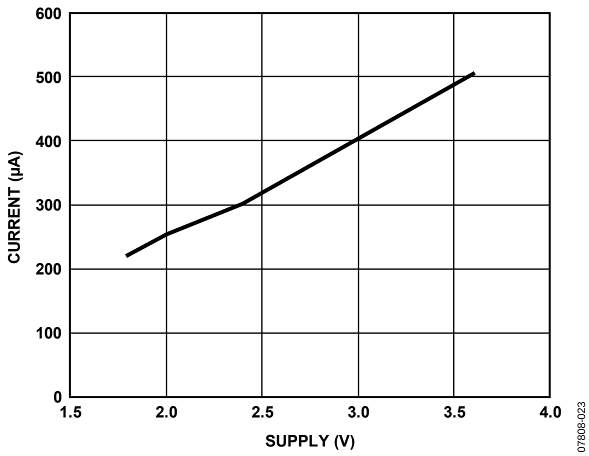


Figure 21. Typical Current Consumption vs. Supply Voltage

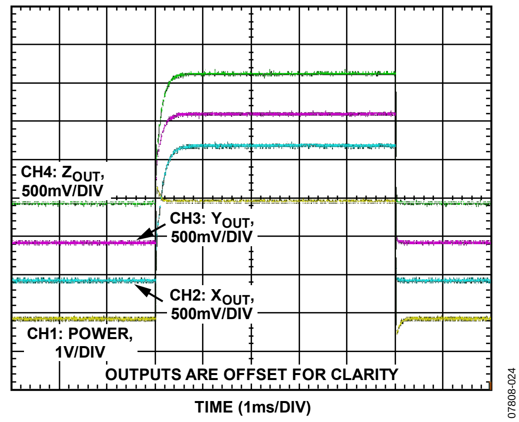


Figure 22. Typical Turn-On Time, $V_S = 3$ V

THEORY OF OPERATION

The ADXL335 is a complete 3-axis acceleration measurement system. The ADXL335 has a measurement range of ±3 *g* minimum. It contains a polysilicon surface-micromachined sensor and signal conditioning circuitry to implement an open-loop acceleration measurement architecture. The output signals are analog voltages that are proportional to acceleration. The accelerometer can measure the static acceleration of gravity in tilt-sensing applications as well as dynamic acceleration resulting from motion, shock, or vibration.

The sensor is a polysilicon surface-micromachined structure built on top of a silicon wafer. Polysilicon springs suspend the structure over the surface of the wafer and provide a resistance against acceleration forces. Deflection of the structure is measured using a differential capacitor that consists of independent fixed plates and plates attached to the moving mass. The fixed plates are driven by 180° out-of-phase square waves. Acceleration deflects the moving mass and unbalances the differential capacitor resulting in a sensor output whose amplitude is proportional to acceleration. Phase-sensitive demodulation techniques are then used to determine the magnitude and direction of the acceleration.

The demodulator output is amplified and brought off-chip through a 32 kΩ resistor. The user then sets the signal bandwidth of the device by adding a capacitor. This filtering improves measurement resolution and helps prevent aliasing.

MECHANICAL SENSOR

The ADXL335 uses a single structure for sensing the X, Y, and Z axes. As a result, the three axes' sense directions are highly orthogonal and have little cross-axis sensitivity. Mechanical misalignment of the sensor die to the package is the chief source of cross-axis sensitivity. Mechanical misalignment can, of course, be calibrated out at the system level.

PERFORMANCE

Rather than using additional temperature compensation circuitry, innovative design techniques ensure that high performance is built in to the ADXL335. As a result, there is no quantization error or nonmonotonic behavior, and temperature hysteresis is very low (typically less than 3 m*g* over the −25°C to +70°C temperature range).

APPLICATIONS INFORMATION

POWER SUPPLY DECOUPLING

For most applications, a single 0.1 µF capacitor, C_{DC}, placed close to the ADXL335 supply pins adequately decouples the accelerometer from noise on the power supply. However, in applications where noise is present at the 50 kHz internal clock frequency (or any harmonic thereof), additional care in power supply bypassing is required because this noise can cause errors in acceleration measurement.

If additional decoupling is needed, a 100 Ω (or smaller) resistor or ferrite bead can be inserted in the supply line. Additionally, a larger bulk bypass capacitor (1 µF or greater) can be added in parallel to C_{DC}. Ensure that the connection from the ADXL335 ground to the power supply ground is low impedance because noise transmitted through ground has a similar effect to noise transmitted through V_S.

SETTING THE BANDWIDTH USING C_X, C_Y, AND C_Z

The ADXL335 has provisions for band limiting the X_{OUT}, Y_{OUT}, and Z_{OUT} pins. Capacitors must be added at these pins to implement low-pass filtering for antialiasing and noise reduction. The equation for the 3 dB bandwidth is

$$F_{-3\ dB} = 1/(2\pi(32\ k\Omega) \times C_{(X,\ Y,\ Z)})$$

or more simply

$$F_{-3\ dB} = 5\ \mu F/C_{(X,\ Y,\ Z)}$$

The tolerance of the internal resistor (R_{FILT}) typically varies as much as ±15% of its nominal value (32 kΩ), and the bandwidth varies accordingly. A minimum capacitance of 0.0047 µF for C_X, C_Y, and C_Z is recommended in all cases.

Table 4. Filter Capacitor Selection, C_X, C_Y, and C_Z

Bandwidth (Hz)	Capacitor (µF)
1	4.7
10	0.47
50	0.10
100	0.05
200	0.027
500	0.01

SELF-TEST

The ST pin controls the self-test feature. When this pin is set to V_S, an electrostatic force is exerted on the accelerometer beam. The resulting movement of the beam allows the user to test if the accelerometer is functional. The typical change in output is −1.08 *g* (corresponding to −325 mV) in the X-axis, +1.08 *g* (or +325 mV) on the Y-axis, and +1.83 *g* (or +550 mV) on the Z-axis. This ST pin can be left open-circuit or connected to common (COM) in normal use.

Never expose the ST pin to voltages greater than V_S + 0.3 V. If this cannot be guaranteed due to the system design (for instance, if there are multiple supply voltages), then a low V_F clamping diode between ST and V_S is recommended.

DESIGN TRADE-OFFS FOR SELECTING FILTER CHARACTERISTICS: THE NOISE/BW TRADE-OFF

The selected accelerometer bandwidth ultimately determines the measurement resolution (smallest detectable acceleration). Filtering can be used to lower the noise floor to improve the resolution of the accelerometer. Resolution is dependent on the analog filter bandwidth at X_{OUT}, Y_{OUT}, and Z_{OUT}.

The output of the ADXL335 has a typical bandwidth of greater than 500 Hz. The user must filter the signal at this point to limit aliasing errors. The analog bandwidth must be no more than half the analog-to-digital sampling frequency to minimize aliasing. The analog bandwidth can be further decreased to reduce noise and improve resolution.

The ADXL335 noise has the characteristics of white Gaussian noise, which contributes equally at all frequencies and is described in terms of µ*g*/√Hz (the noise is proportional to the square root of the accelerometer bandwidth). The user should limit bandwidth to the lowest frequency needed by the application to maximize the resolution and dynamic range of the accelerometer.

With the single-pole, roll-off characteristic, the typical noise of the ADXL335 is determined by

$$rms\ Noise = Noise\ Density \times (\sqrt{BW \times 1.6})$$

It is often useful to know the peak value of the noise. Peak-to-peak noise can only be estimated by statistical methods. Table 5 is useful for estimating the probabilities of exceeding various peak values, given the rms value.

Table 5. Estimation of Peak-to-Peak Noise

Peak-to-Peak Value	% of Time That Noise Exceeds Nominal Peak-to-Peak Value
2 × rms	32
4 × rms	4.6
6 × rms	0.27
8 × rms	0.006

USE WITH OPERATING VOLTAGES OTHER THAN 3 V

The ADXL335 is tested and specified at V_S = 3 V; however, it can be powered with V_S as low as 1.8 V or as high as 3.6 V. Note that some performance parameters change as the supply voltage is varied.

The ADXL335 output is ratiometric, therefore, the output sensitivity (or scale factor) varies proportionally to the supply voltage. At V_S = 3.6 V, the output sensitivity is typically 360 mV/*g*. At V_S = 2 V, the output sensitivity is typically 195 mV/*g*.

The zero *g* bias output is also ratiometric, thus the zero *g* output is nominally equal to $V_S/2$ at all supply voltages.

The output noise is not ratiometric but is absolute in volts; therefore, the noise density decreases as the supply voltage increases. This is because the scale factor (mV/*g*) increases while the noise voltage remains constant. At V_S = 3.6 V, the X-axis and Y-axis noise density is typically 120 μ*g*/√Hz, whereas at V_S = 2 V, the X-axis and Y-axis noise density is typically 270 μ*g*/√Hz.

Self-test response in *g* is roughly proportional to the square of the supply voltage. However, when ratiometricity of sensitivity is factored in with supply voltage, the self-test response in volts is roughly proportional to the cube of the supply voltage. For example, at V_S = 3.6 V, the self-test response for the ADXL335 is approximately −560 mV for the X-axis, +560 mV for the Y-axis, and +950 mV for the Z-axis.

At V_S = 2 V, the self-test response is approximately −96 mV for the X-axis, +96 mV for the Y-axis, and −163 mV for the Z-axis.

The supply current decreases as the supply voltage decreases. Typical current consumption at V_S = 3.6 V is 375 μA, and typical current consumption at V_S = 2 V is 200 μA.

AXES OF ACCELERATION SENSITIVITY

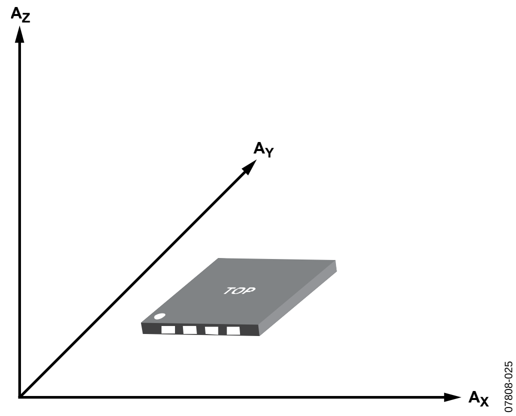


Figure 23. Axes of Acceleration Sensitivity; Corresponding Output Voltage Increases When Accelerated Along the Sensitive Axis.

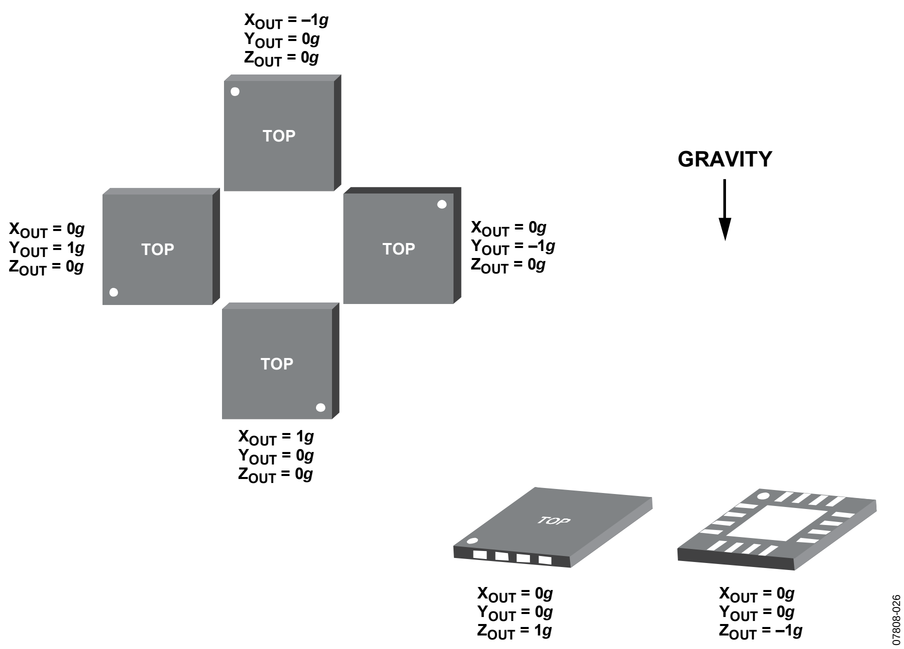


Figure 24. Output Response vs. Orientation to Gravity

LAYOUT AND DESIGN RECOMMENDATIONS

The recommended soldering profile is shown in Figure 25 followed by a description of the profile features in Table 6. The recommended PCB layout or solder land drawing is shown in Figure 26.

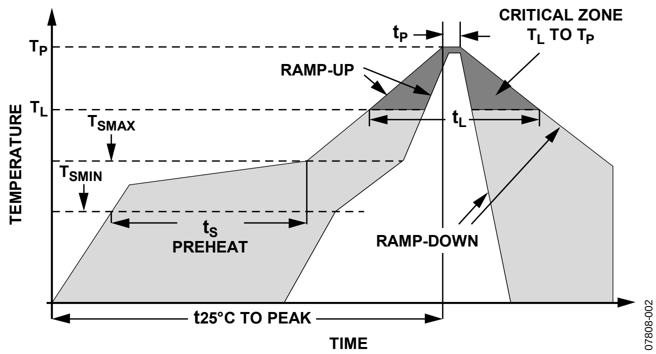


Figure 25. Recommended Soldering Profile

Table 6. Recommended Soldering Profile

Profile Feature	Sn63/Pb37	Pb-Free
Average Ramp Rate (T_L to T_P)	3°C/sec max	3°C/sec max
Preheat		
Minimum Temperature (T_{SMIN})	100°C	150°C
Maximum Temperature (T_{SMAX})	150°C	200°C
Time (T_{SMIN} to T_{SMAX})(t_S)	60 sec to 120 sec	60 sec to 180 sec
T_{SMAX} to T_L		
Ramp-Up Rate	3°C/sec max	3°C/sec max
Time Maintained Above Liquidous (T_L)		
Liquidous Temperature (T_L)	183°C	217°C
Time (t_L)	60 sec to 150 sec	60 sec to 150 sec
Peak Temperature (T_P)	240°C + 0°C/−5°C	260°C + 0°C/−5°C
Time Within 5°C of Actual Peak Temperature (t_P)	10 sec to 30 sec	20 sec to 40 sec
Ramp-Down Rate	6°C/sec max	6°C/sec max
Time 25°C to Peak Temperature	6 minutes max	8 minutes max

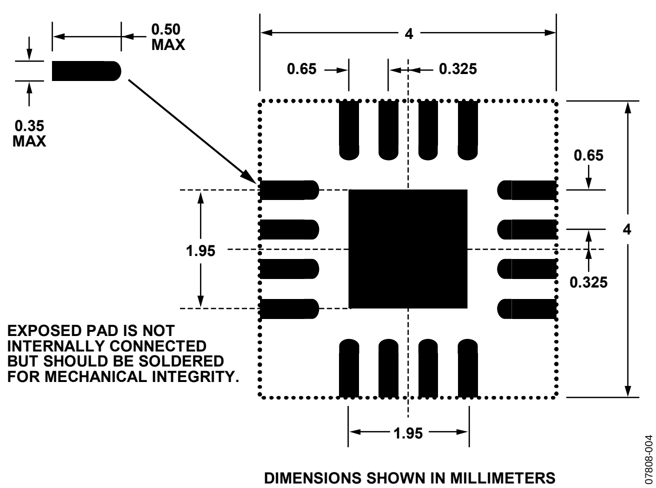


Figure 26. Recommended PCB Layout

OUTLINE DIMENSIONS

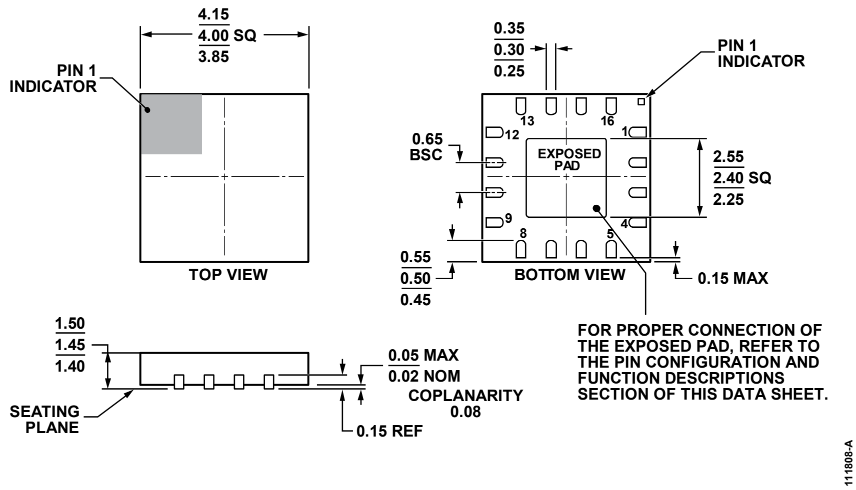


Figure 27. 16-Lead Lead Frame Chip Scale Package [LFCSP_LQ]
4 mm × 4 mm Body, 1.45 mm Thick Quad
(CP-16-14)
Dimensions shown in millimeters

ORDERING GUIDE

Model	Measurement Range	Specified Voltage	Temperature Range	Package Description	Package Option
ADXL335BCPZ[1]	±3 *g*	3 V	−40°C to +85°C	16-Lead LFCSP_LQ	CP-16-14
ADXL335BCPZ–RL[1]	±3 *g*	3 V	−40°C to +85°C	16-Lead LFCSP_LQ	CP-16-14
ADXL335BCPZ–RL7[1]	±3 *g*	3 V	−40°C to +85°C	16-Lead LFCSP_LQ	CP-16-14
EVAL-ADXL335Z[1]				Evaluation Board	

[1] Z = RoHS Compliant Part.

NOTES

NOTES

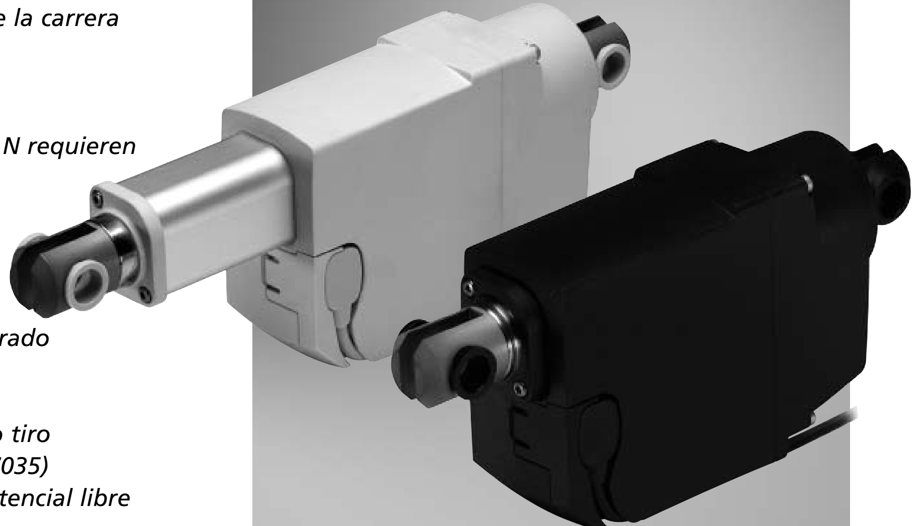
D07808-0-1/09(0)

FICHA TÉCNICA

ACTUADOR LA23

MEDLINE®
IMPROVING EFFICIENCY
CARELINE®
IMPROVING EFFICIENCY
TECHLINE™
IMPROVING FLEXIBILITY

Características:
- *Hasta 2500 N en empuje o tiro*
- *Diseño compacto: ancho 43 mm y dimensiones de instalación 110 mm + longitud de la carrera (versión estándar)*
- *Carcasa Negra*
- *IPX4*
- *Fijación trasera de plástico (2500 N requieren un fijación trasera de acero)*
- *Tuerca guiada*
- *Motor de 24 V*
- *20 a 300 mm de carrera*
- *Cable intercambiable*
- *Final de carrera eléctrico incorporado*



Opciones:
- *Tuerca de seguridad en empuje o tiro*
- *Carcasa de color gris claro (RAL 7035)*
- *Señales de final de carrera de potencial libre*
- *Fijación trasera de acero*
- *Motor de 12V*

Uso:
- *Temperatura de uso: -30°C a +55°C*
- *Ciclo de trabajo: 10%, 2 minutos en funcionamiento seguido de 18 minutos en descanso*
- *Será aprobado según DS/EN60601-1 y UL60601-1 (Aprobaciones no definitivo aún)*
- *Será aprobado y probado para funcionar con: OpenBus™: CB20, CB16, CB6S, JUMBO: CBJ1/2, y CBJC CBJH*
- *Factor de seguridad estático de 2,5*

El LA23 es un actuador pequeño y fuerte en empuje o en tiro (hasta 2500 N). Se puede utilizar el LA23 en varias aplicaciones donde el tamaño es importante.

Algunos de los beneficios que el LA23 le ofrece son:

- Diseño compacto
- Alta fuerza de elevación
- Cables intercambiables

El LA23 estándar está disponible tanto para las gamas de productos CARELINE®, MEDLINE® y TECHLINE™.

LA23

Ejemplo de pedido:

23 6 1 A 0 1 0 00 250 A 4

Grado de protección: **4 = IPX4**

Tipo de motor: **A = 12 V**
B = 24V (funcionando principalmente con la batería (CBJ1, CBJ2, CBJH, CBJC, sillas de ruedas))
G = 24V (para OpenBus (CB20, CB16, CB6s))

Carrera: XXX = mm Min. 020 mm, máx. 300 mm
Versiones estándar:
020 mm
050 mm
100 mm
150 mm
200 mm
250 mm
300 mm

Posicionamiento: **000 = Sin posicionamiento**
01 = Final de carrera de potencial libre
02 = Posicionamiento estándar por Hall Dual.

Opción de seguridad: **0 = No hay opciones de seguridad (paso del eje 3, 6 o 9)**
1 = Tuerca de seguridad en empuje (paso del eje 3, 6 o 9)
2 = Tuerca de seguridad en tiro (paso del eje 6 o 9)

Color de Carcasa: **1 = Negro (RAL 9005)**
2 = Gris claro (RAL7035)

Fijación del vástago: **0 = Estándar (acero) con ranura (6,1 mm), pasador de Ø10.1 mm, incluyendo casquillos de plástico.**
1 = estándar (acero) con ranura (6,1 mm), pasador de Ø10.1 mm, excluyendo casquillos de plástico

Rotación de fijación Trasera:

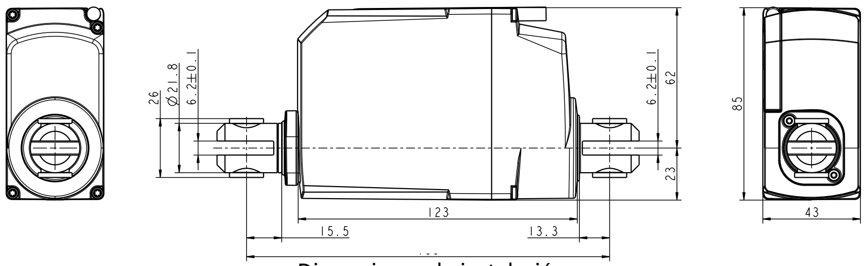
0 = 0° en sentido horario	**1 = 90° en sentido horario**
A = 7,5° en sentido horario	M = 97.5° en sentido horario
B = 15° en sentido horario	N = 105° en sentido horario
C = 22,5° en sentido horario	P = 112,5° en sentido horario
D = 30° en sentido horario	Q = 120° en sentido horario
E = 37,5° en sentido horario	R = 127,5° en sentido horario
F = 45° en sentido horario	S = 135° en sentido horario
G = 52,5° en sentido horario	T = 142,5° en sentido horario
H = 60° en sentido horario	U = 150° en sentido horario
J = 67,5° en sentido horario	V = 157,5° en sentido horario
K = 75° en sentido horario	W = 165° en sentido horario
L = 82,5° en sentido horario	Z = 172,5° en sentido horario

Fijación trasera: **1 = plástico con ranura (6,1 mm), pasador de Ø10.1 (Sólo para paso del eje 6 ó 9 y la opción de seguridad 0 ó 1 (tiro))**
2 = acero con ranura (6,1 mm), pasador de Ø10.1 mm, incl. casquillos de plástico (paso del eje de 3, 6 ó 9)
3 = acero con ranura (6,1 mm), pasador de Ø10.1 mm, excl. casquillos de plástico (brea o pez de 3, 6 o 9)

Tipo de eje roscado: **3 = 3 mm de paso (2500 N)**
6 = 6 mm de paso (1500 N)
9 = 9 mm de paso (1200 N)

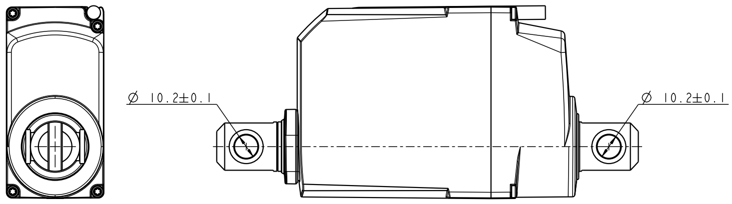
Tipo de actuador: **23 = LA23**

Dimensiones:



Dimensiones de instalación

Orientación de fijación trasera opción 1



Orientación de fijación trasera opción 0

Las dimensiones de instalación dependen de la opción elegida de seguridad y la longitud de la carrera.
Por favor, consulte la siguiente información:

	Dimensiones de instalación paso del eje 3 mm	**Dimensiones de instalación paso del eje 6 y 9 mm**
Longitud de carrera 20 mm:	168 mm	160 mm
Longitud de carrera 50-200 mm:	Carrera + 118 mm	Carrera + 110 mm
Longitud de carrera 200-300 mm:	Carrera + 138 mm	Carrera + 130 mm
Tuerca de seguridad en empuje: sin cambiar las dimensiones de instalación		
Tuerca de seguridad en tiro: añade 12 mm a las dimensiones de instalación		

Especificaciones técnicas:

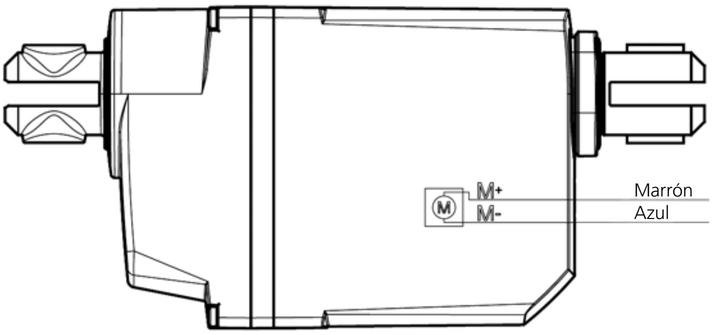
Fuente de alimentación	Paso del eje (mm)	Carga max. Tiro o Empuje (N)	Tipo de motor	Velocidad en vacío/plena carga (mm/sec.)	Corriente en vacío/plena carga (Amp.)
12VDC	3	2500 / 2500	A : 12V	3.1 / 2.3	0.6 / 3.3
CBJ1/2, CBJH y CBJC	3	2500 / 2500	B : 24V	3.2 / 2.5	0.3 / 1.8
OpenBus	3	2500 / 2500	G : 24V	3.2 / 2.7	0.2 / 1.2
12VDC	6	1500 / 1500	A : 12V	6.2 / 4.6	0.8 / 3.6
CBJ1/2, CBJH y CBJC	6	1500 / 1500	B : 24V	6.4 / 5.5	0.3 / 1.5
OpenBus	6	1500 / 1500	G : 24V	6.3 / 5.5	0.2 / 1.1
12VDC	9	1200 / 1200	A : 12V	9.3 / 6.8	0.7 / 3.8
CBJ1/2, CBJH y CBJC	9	1200 / 1200	B : 24V	9.4 / 8.2	0.4 / 1.9
OpenBus	9	1200 / 1200	G : 24V	9.2 / 8.2	0.2 / 1.1

Cables para el LA23:

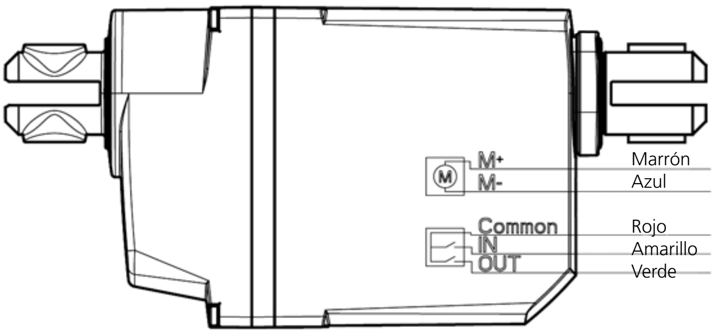
Nº de artículo	Polos	Tipo de conector	Color	Usar con (CB)
0237002-1500	6 polos	Microfit - abierto	Negro	No con cajas de control de LINAK
0237002-2500	6 polos	Microfit - abierto	Negro	No con cajas de control de LINAK
0237002-5000	6 polos	Microfit - abierto	Negro	No con cajas de control de LINAK
0237003-0750	6 polos	Microfit - minifit	Gris claro	CB20, CB6S, CB16, CBJH
0237003-1500	6 polos	Microfit - minifit	Gris claro	CB20, CB6S, CB16, CBJH
0237003-2250	6 polos	Microfit - minifit	Gris claro	CB20, CB6S, CB16, CBJH
0237004-0750	6 polos	Microfit - Jack	Gris claro	CBJ1, CBJ2, CBJC
0237004-1250	6 polos	Microfit - Jack	Gris claro	CBJ1, CBJ2, CBJC

Diagramas de conexión:

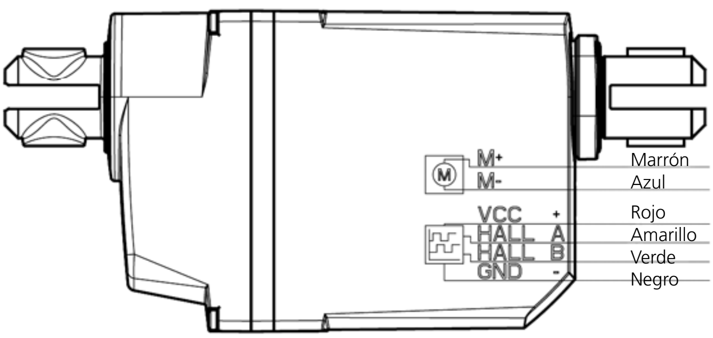
Básico LA23
LA23XXXXXX00XXXXX



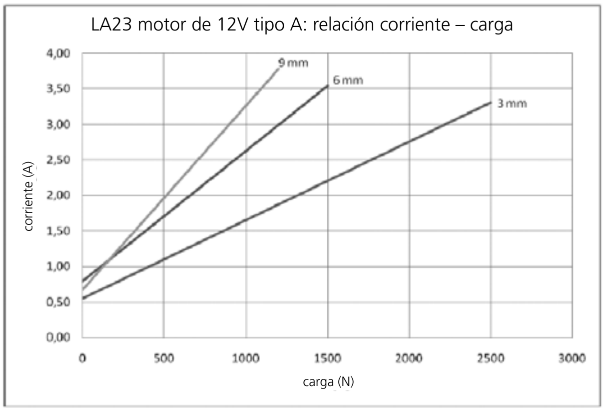
LA23 con finales de carrera de potencial libre
LA23XXXXXX01XXXXX

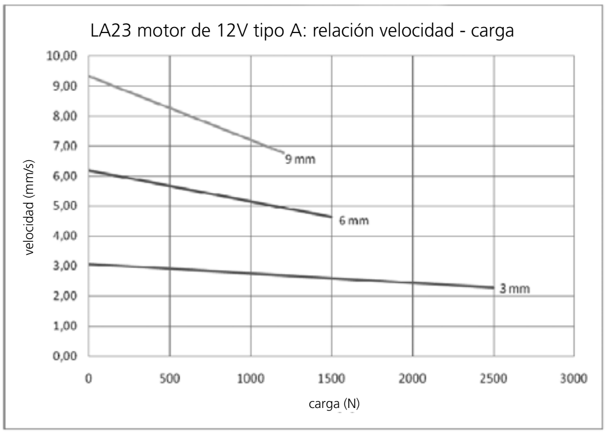


LA23 con dual Hall estándar
LA23XXXXXX02XXXXX

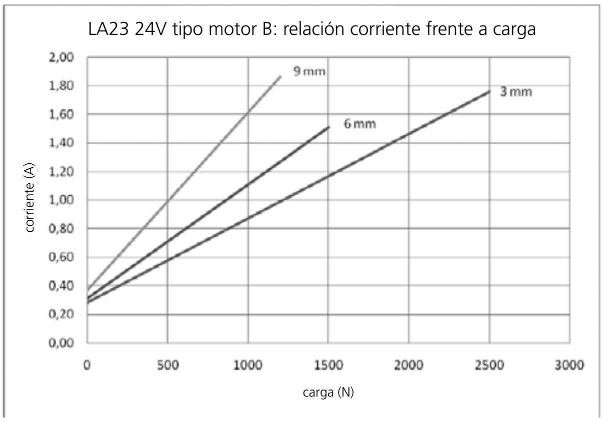


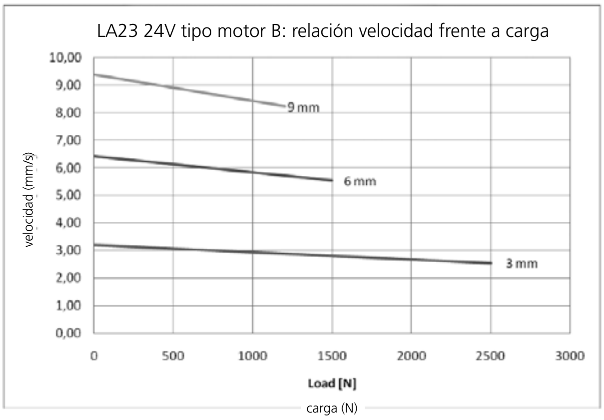
Curvas de velocidad, carga y corriente: motor de 12V – tipo A



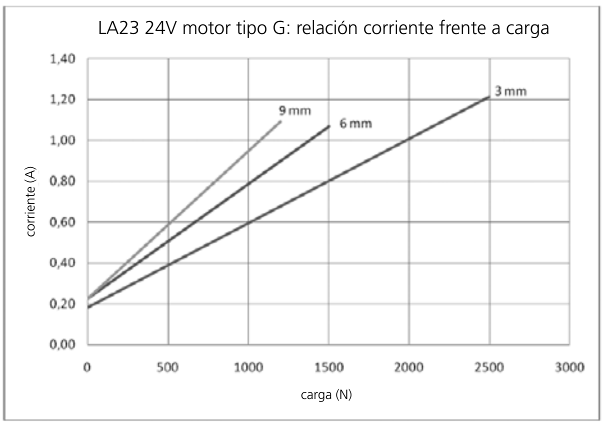


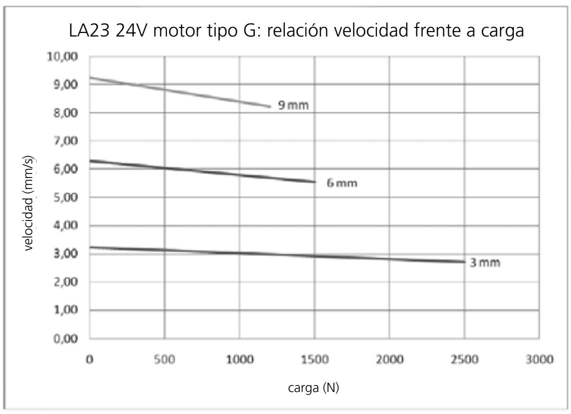
Motor de 24V tipo B – unidad de batería (CBJC, CBJH, CBJ1/2 o sillas de ruedas)





Motor de 24V tipo G – Fuentes de alimentación OpenBus (CB6S, CB16, CB20)





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FSR® Integration Guide & Evaluation Parts Catalog With Suggested Electrical Interfaces

Interlink Electronics manufactures custom FSR devices to meet the needs of specific customer applications. FSR devices can be produced in almost any shape, size, and geometry. To discuss custom design or to obtain a quote, contact Interlink Electronics at (805) 484-8855.

Force Sensing Resistors
An Overview of the Technology

Force Sensing Resistors (FSR) are a polymer thick film (PTF) device which exhibits a decrease in resistance with an increase in the force applied to the active surface. Its force sensitivity is optimized for use in human touch control of electronic devices. FSRs are not a load cell or strain gauge, though they have similar properties. FSRs are not suitable for precision measurements.

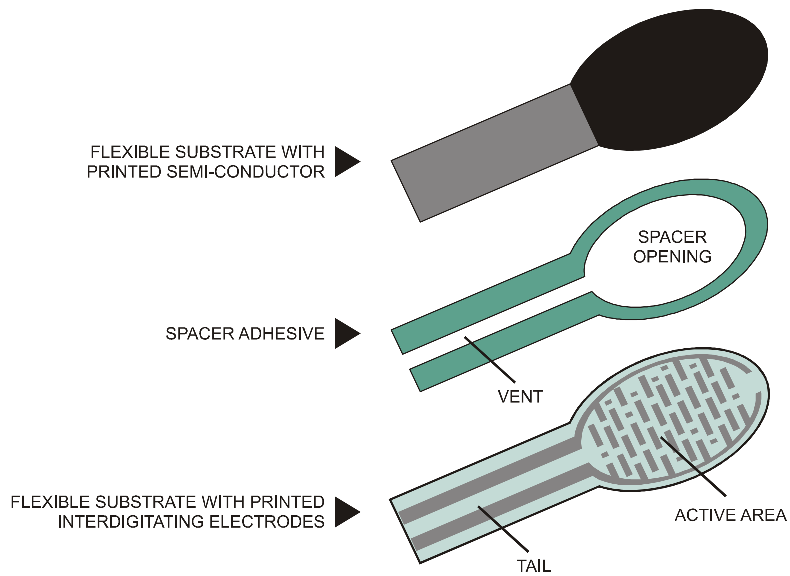


Figure 1: FSR Construction

Force vs. Resistance

The force vs. resistance characteristic shown in Figure 2 provides an overview of FSR typical response behavior. For interpretational convenience, the force vs. resistance data is plotted on a log/log format. These data are representative of our typical devices, with this particular force-resistance characteristic being the response of evaluation part # 402 (0.5” [12.7 mm] diameter circular active area). A stainless steel actuator with a 0.4” [10.0 mm] diameter hemispherical tip of 60 durometer polyurethane rubber was used to actuate the FSR device. In general, FSR response approximately follows an inverse power-law characteristic (roughly 1/R).

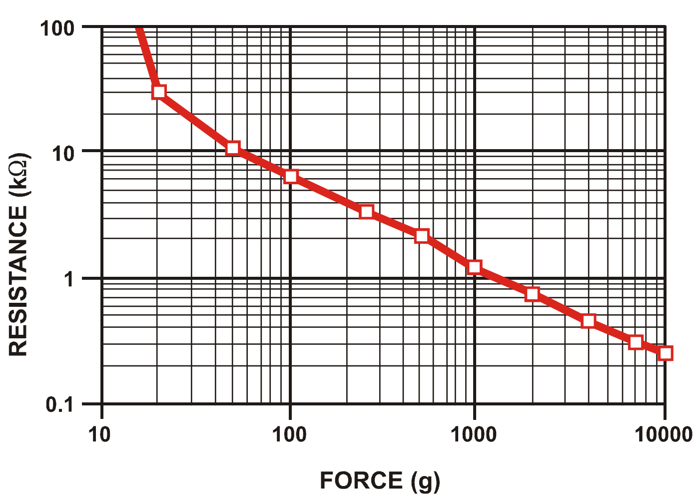


Figure 2: Resistance vs. Force

Referring to Figure 2, at the low force end of the force-resistance characteristic, a switch-like response is evident. This turn-on threshold, or ‘break force”, that swings the resistance from greater than 100 kΩ to about 10 kΩ (the beginning of the dynamic range that follows a power-law) is determined by the substrate and overlay thickness and flexibility, size and shape of the actuator, and spacer-adhesive thickness (the gap between the facing conductive elements). Break force increases with increasing substrate and overlay rigidity, actuator size, and spacer-adhesive thickness. Eliminating the adhesive, or keeping it well away from the area where the force is being applied, such as the center of a large FSR device, will give it a lower rest resistance (e.g. stand-off resistance).

At the high force end of the dynamic range, the response deviates from the power-law behavior, and eventually saturates to a point where increases in force yield little or no decrease in resist-ance. Under these conditions of Figure 2, this saturation force is beyond 10 kg. The saturation point is more a function of pressure than force. The saturation pressure of a typical FSR is on the order of 100 to 200 psi. For the data shown in Figures 2, 3 and 4, the actual measured pressure range is 0 to 175 psi (0 to 22 lbs applied over 0.125 in^2). Forces higher than the saturation force can be measured by spreading the force over a greater area; the overall pressure is then kept below the saturation point, and dynamic response is maintained. However, the converse of this effect is also true, smaller actuators will saturate FSRs earlier in the dynamic range, since the saturation point is reached at a lower force.

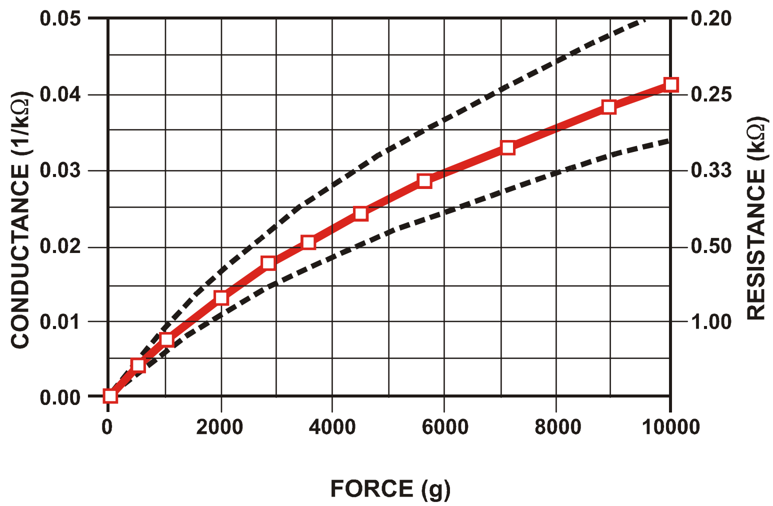


Figure 3:
Conductance vs. Force (0-10Kg)

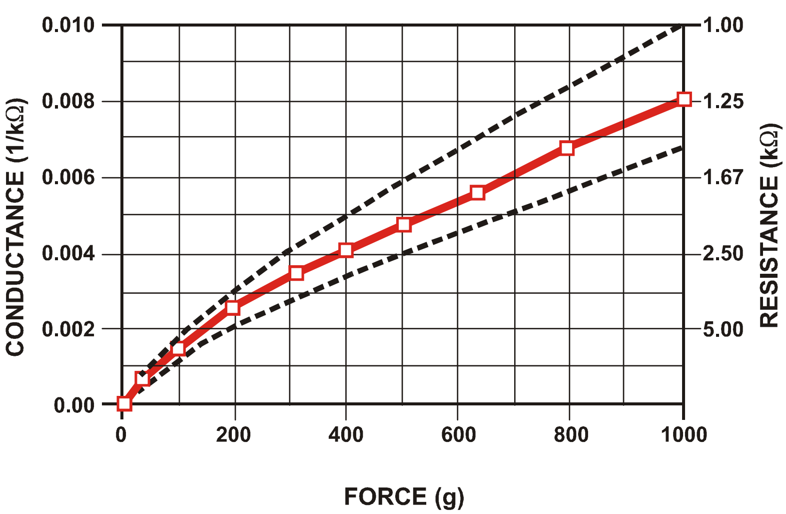


Figure 4:
Conductance vs. Force (0-1Kg) Low Force Range

Force vs. Conductance

In Figure 3, the conductance is plotted vs. force (the inverse of resistance: 1/r). This format allows interpretation on a linear scale. For reference, the corresponding resistance values are also included on the right vertical axis. A simple circuit called a current-to-voltage converter (see page 21) gives a voltage output directly proportional to FSR conductance and can be useful where response linearity is desired. Figure 3 also includes a typical part-to-part repeatability envelope. This error band determines the maximum accuracy of any general force measurement. The spread or width of the band is strongly dependent on the repeatability of any actuating and measuring system, as well as the repeatability tolerance held by Interlink Electronics during FSR production. Typically, the part-to-part repeatability tolerance held during manufacturing ranges from ± 15% to ± 25% of an established nominal resistance.

Figure 4 highlights the 0-1 kg (0-2.2 lbs) range of the conductance-force characteristic. As in Figure 3, the corresponding resistance values are included for reference. This range is common to human interface applications. Since the conductance response in this range is fairly linear, the force resolution will be uniform and data interpretation simplified. The typical part-to-part error band is also shown for this touch range. In most human touch control applications this error is insignificant, since human touch is fairly inaccurate. Human factors studies have shown that in this force range repeatability errors of less than ± 50% are difficult to discern by touch alone.

FSR Integration Notes
A Step-by-Step Guide to Optimal Use

For best results, follow these seven steps when beginning any new product design, proof-of-concept, technology evaluation, or first prototype implementation:

1. Start with Reasonable Expectations (Know Your Sensor)

The FSR sensor is not a strain gauge, load cell or pressure transducer. While it can be used for dynamic measurement, only qualitative results are generally obtainable. Force accuracy ranges from approximately ± 5% to ± 25% depending on the consistency of the measurement and actuation system, the repeatability tolerance held in manufacturing, and the use of part calibration.

Accuracy should not be confused with resolution. The force resolution of FSR devices is better than ± 0.5% of full use force.

2. Choose the Sensor that Best Fits the Geometry of Your Application

Usually sensor size and shape are the limiting parameters in FSR integration, so any evaluation part should be chosen to fit the desired mechanical actuation system. In general, standard FSR products have a common semiconductor make-up and only by varying actuation methods (e.g. overlays and actuator areas) or electrical interfaces can different response characteristics be achieved.

3. Set-up a Repeatable and Reproducible Mechanical Actuation System

When designing the actuation mechanics, follow these guidelines to achieve the best force repeatability:

- Provide a consistent force distribution. FSR response is very sensitive to the distribution of the applied force. In general, this precludes the use of dead weights for characterization since exact duplication of the weight distribution is rarely repeatable cycle-to-cycle. A consistent weight (force) distribution is more difficult to achieve than merely obtaining a consistent total applied weight (force). As long as the distribution is the same cycle-to-cycle, then repeatability will be maintained. The use of a thin elastomer between the applied force and the FSR can help absorb error from inconsistent force distributions.

- Keep the actuator area, shape, and compliance constant. Charges in these parameters significantly alter the response characteristic of a given sensor. Any test, mock-up, or evaluation conditions should be closely matched to the final use conditions. The greater the cycle-to-cycle consistency of these parameters, the greater the device repeatability. In human interface applications where a finger is the mode of actuation, perfect control of these parameters is not generally possible. However, human force sensing is somewhat inaccurate; it is rarely sensitive enough to detect differences of less than ± 50%.

- Control actuator placement. In cases where the actuator is to be smaller than the FSR active area, cycle-to-cycle consistency of actuator placement is necessary. (Caution: FSR layers are held together by an adhesive that surrounds the electrically active areas. If force is applied over an area which includes the adhesive, the resulting response characteristic will be drastically altered.) In an extreme case (e.g., a large, flat, hard actuator that bridges the bordering adhesive), the adhesive can present FSR actuation

- Keep actuation cycle time consistent. Because of the time dependence of the FSR resistance to an applied force, it is important when characterizing the sensor system to assure that increasing loads (e.g. force ramps) are applied at consistent rates (cycle-to-cycle). Likewise, static force measurements must take into account FSR mechanical setting time. This time is dependent on the mechanics of actuation and the amount of force applied and is usually on the order of seconds.

4. Use the Optimal Electronic Interface

In most product designs, the critical characteristic is Force vs. Output Voltage, which is controlled by the choice of interface electronics. A variety of interface solutions are detailed in the TechNote section of this guide. Summarized here are some suggested circuits for common FSR applications.

- For FSR Pressure or Force Switches, use the simple interfaces detailed on pages 16 and 17.

- For dynamic FSR measurements or Variable Controls, a current-to-voltage converter (see pages 18 and 19) is recommended. This circuit produces an output voltage that is inversely proportional to FSR resistance. Since the FSR resistance is roughly inversely proportional to applied force, the end result is a direct proportionality between force and voltage; in other words, this circuit gives roughly linear increases in output voltage for increases in applied force. This linearization of the response optimizes the resolution and simplifies data interpretation.

5. Develop a Nominal Voltage Curve and Error Spread

When a repeatable and reproducible system has been established, data from a group of FSR parts can be collected. Test several FSR parts in the system. Record the output voltage at various pre-selected force points throughout the range of interest. Once a family of curves is obtained, a nominal force vs. output voltage curve and the total force accuracy of the system can be determined.

6. Use Part Calibration if Greater Accuracy is Required

For applications requiring the highest obtainable force accuracy, part calibration will be necessary. Two methods can be utilized: gain and offset trimming, and curve fitting.

- Gain and offset trimming can be used as a simple method of calibration. The reference voltage and feedback resistor of the current-to-voltage converter are adjusted for each FSR to pull their responses closer to the nominal curve.

- Curve fitting is the most complete calibration method. A parametric curve fit is done for the nominal curve of a set of FSR devices, and the resultant equation is stored for future use. Fit parameters are then established for each individual FSR (or sending element in an array) in the set. These parameters, along with the measured sensor resistance (or voltage), are inserted into the equation to obtain the force reading. If needed, temperature compensation can also be included in the equation.

7. Refine the System

Spurious results can normally be traced to sensor error or system error. If you have any questions, contact Interlink Electronics' Sales Engineers to discuss your system and final data.

FSR Usage Tips
The Do's and Don'ts

- **Do** follow the seven steps of the FSR Integration Guide.
- **Do**, if possible, use a firm, flat and smooth mounting surface.
- **Do** be careful if applying FSR devices to curved surfaces. Pre-loading of the device can occur as the two opposed layers are forced into contact by the bending tension. The device will still function, but the dynamic range may be reduced and resistance drift could occur. The degree of curvature over which an FSR can be bent is a function of the size of the active area. The smaller the active area, the less effect a given curvature will have on the FSR's response.
- **Do** avoid air bubbles and contamination when laminating the FSR to any surface. Use only thin, uniform adhesives, such as Scotch® brand double-sided laminating adhesives. Cover the entire surface of the sensor.
- **Do** be careful of kinks or dents in active areas. They can cause false triggering of the sensors.
- **Do** protect the device from sharp objects. Use an overlay, such as a polycarbonate film or an elastomer, to prevent gouging of the FSR device.
- **Do** use soft rubber or a spring as part of the actuator in designs requiring some travel.

- **Do not** kink or crease the tail of the FSR device if you are bending it; this can cause breaks in the printed silver traces. The smallest suggested bend radius for the tails of evaluation parts is about 0.1" [2.5 mm]. In custom sensor designs, tails have been made that bend over radii of 0.03" (0.8 mm]. Also, be careful if bending the tail near the active area. This can cause stress on the active area and may result in pre-loading and false readings.
- **Do not** block the vent. FSR devices typically have an air vent that runs from the open active area down the length of the tail and out to the atmosphere. This vent assures pressure equilibrium with the environment, as well as allowing even loading and unloading of the device. Blocking this vent could cause FSRs to respond to any actuation in a non-repeatable manner. Also note, that if the device is to be used in a pressure chamber, the vented end will need to be kept vented to the outside of the chamber. This allows for the measurement of the differential pressure.
- **Do not** solder directly to the exposed silver traces. With flexible substrates, the solder joint will not hold and the substrate can easily melt and distort during the soldering. Use Interlink Electronics' standard connection techniques, such as solderable tabs, housed female contacts, Z-axis conductive tapes, or ZIF (zero insertion force) style connectors.
- **Do not** use cyanoacrylate adhesives (e.g. Krazy Glue®) and solder flux removing agents. These degrade the substrate and can lead to cracking.
- **Do not** apply excessive shear force. This can cause delamination of the layers.
- **Do not** exceed 1mA of current per square centimeter of applied force (actuator area). This can irreversibly damage the device.

Descriptions and Dimensions

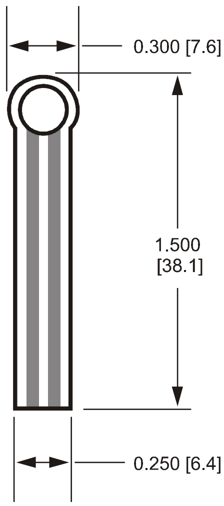


Figure 5:
Part No. 400 (0.2" Circle)

Active Area: 0.2" [5.0] diameter

Nominal Thickness: 0.012" [0.30 mm]

Material Build:

Semiconductive layer
0.004" [0.10] PES
Spacer adhesive
0.002" [0.05] Acrylic
Conductive layer
0.004" [0.10] PES
Rear adhesive
0.002" [0.05] Acrylic
Connector options

a. No connector
b. Solder Tabs (not shown)
c. AMP Female connector

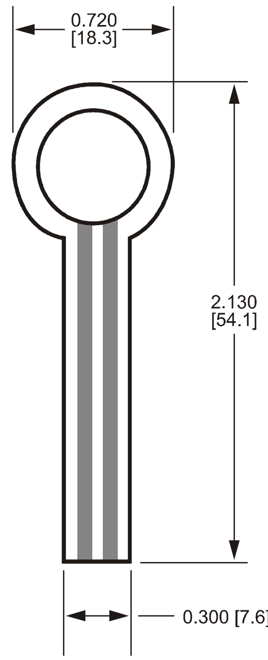


Figure 6:
Part No. 402 (0.5" Circle)

Active Area: 0.5" [12.7] diameter

Nominal thickness: 0.018" [0.46 mm]

Material Build:

Semiconductive Layer
0.005" [0.13] Ultem
Spacer Adhesive
0.006" [0.15] Acrylic
Conductive Layer
0.005" [0.13] Ultem
Rear Adhesive
0.002" [0.05] Acrylic
Connector

a. No connector
b. Solder Tabs (not shown)
c. AMP Female connector

Dimensions in brackets: millimeters • Dimensional Tolerance: ± 0.015" [0.4] • Thickness Tolerance: ± 10%

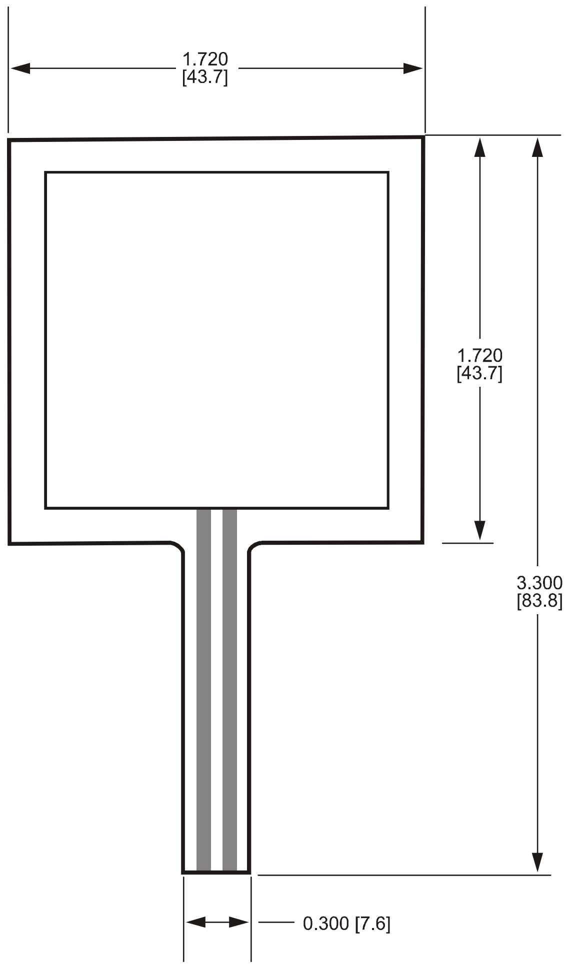


Figure 7:
Part No. 406 (1.5" Square)

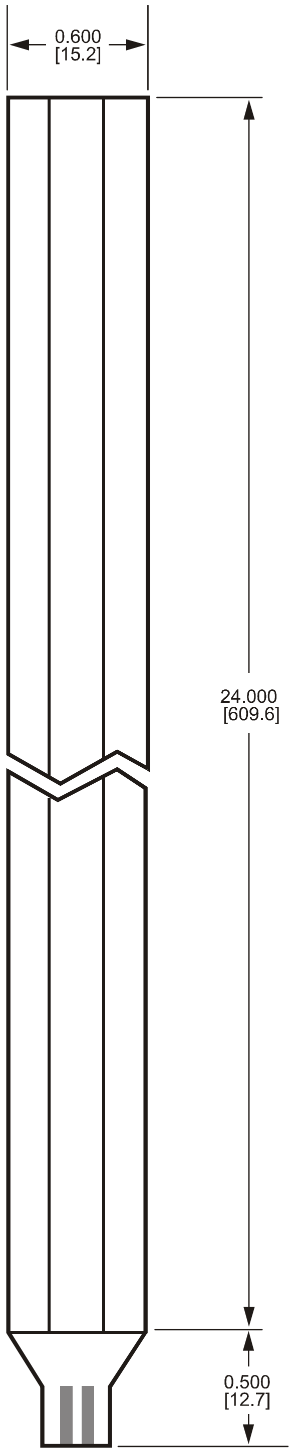
Active Area: 1.5" [38.1] x 1.5" [38.1]

Nominal thickness: 0.018" [0.46 mm]

Material Build:

Semiconductive Layer
0.005" [0.13] Ultem
Spacer Adhesive
0.006" [0.15] Acrylic
Conductive Layer
0.005" [0.13] Ultem
Rear Adhesive
0.002" [0.05] Acrylic
Connectors
a. No connector
b. Solder Tabs (not shown)
c. AMP Female connector

Dimensions in brackets: millimeters • Dimensional Tolerance: ± 0.015" [0.4] • Thickness Tolerance: ± 10%



Active Area: 24" [609.6] x 0.25" [6.3]

Nominal thickness: 0.135" [0.34 mm]

Material Build:

Semiconductive Layer
0.004" [0.10] PES
Spacer Adhesive
0.0035" [0.089] Acrylic
Conductive Layer
0.004" [0.10] PES
Rear Adhesive
0.002" [0.05] Acrylic
Connectors

a. No connector
b. Solder Tabs (not shown)
c. AMP Female connector

Figure 8
Part No. 408 (24" Trimmable Strip)

Dimensions in brackets: millimeters
Dimensional Tolerance: ± 0.015" [0.4]
Thickness Tolerance: ± 10%

General FSR Characteristics

These are typical parameters. The FSR is a custom device and can be made for use outside these characteristics. Consult Sales Engineering with your specific requirements.

Simple FSR Devices and Arrays

PARAMETER	VALUE	NOTES
Size Range	Max = 20" x 24" (51 x 61 cm) Min = 0.2" x 0.2" (0.5 x 0.5 cm)	Any shape
Device thickness	0.008" to 0.050" (0.20 to 1.25 mm)	Dependent on materials
Force Sensitivity Range	< 100 g to > 10 kg	Dependent on mechanics
Pressure Sensitivity Range	< 1.5 psi to > 150 psi (< 0.1 kg/cm^2 to > 10 kg/cm^2)	Dependent on mechanics
Part-to-Part Force Repeatability	± 15% to ± 25% of established nominal resistance	With a repeatable actuation system
Single Part Force Repeatability	± 2% to ± 5% of established nominal resistance	With a repeatable actuation system
Force Resolution	Better than 0.5% full scale	
Break Force (Turn-on Force)	20 g to 100 g (0.7 oz to 3.5 oz)	Dependent on mechanics and FSR build
Stand-Off Resistance	> 1MΩ	Unloaded, unbent
Switch Characteristic	Essentially zero travel	
Device Rise Time	1-2 msec (mechanical)	
Lifetime	> 10 million actuations	
Temperature Range	-30ºC to +70°C	Dependent on materials
Maximum Current	I mA/cm^2 of applied force	
Sensitivity to Noise/Vibration	Not significantly affected	
EMI / ESD	Passive device	
Lead Attachment	Standard flex circuit techniques	

INTERLINK ELECTRONICS

For Linear pots

PARAMETER	VALUE	NOTES
Positional Resolution	0.003” to 0.02” (0.075 to 0.5 mm)	Dependent on actuator size
Positional Accuracy	Better than ± 1% of full length	

FSR terminology is defined on pages 14 and 15 of this guide.

The product information contained in this document is designed to provide general information and guidelines only and must not be used as an implied contract with Interlink Electronics. Acknowledging our policy of continual product development, we reserve the right to change without notice any detail in this publication. Since Interlink Electronics has no control over the conditions and method of use of our products, we suggest that any potential user confirm their suitability before adopting them for commercial use.

Glossary of Terms

Active Area The area of an FSR device that responds to normal force with a decrease in resistance.

Actuator The object which contacts the sensor surface and applies force to FSRs.

Applied Force The force applied by the actuator on the active area of the sensor.

Array Any grouping or matrix of FSR sensors which can be individually actuated and measured.

Break Force The minimum force required, with a specific actuator size, to cause the onset of the FSR response.

Cross-talk Measurement noise or inaccuracies of a sensor as a result of the actuation of another sensor on the same substrate. See also false triggering.

Driff The change in resistance with time under a constant (static) load. Also called resistance drift.

Durometer The measure of the hardness of rubber.

EMI Electromagnetic interference.

ESD Electrostatic discharge.

False triggering The unwanted actuation of a FSR device from unexpected stimuli; e.g., bending or cross-talk.

Fixed Resistor The printed resistor on linear potentiometers that is used to measure position.

Footprint Surface area and force distribution of the actuator in contact with the sensor surface.

Force Resolution The smallest measurable difference in force.

FSR™ Force Sensing Resistors®. A polymer thick film device with exhibits a decrease in resistance with an increase in force applied normal to the device surface.

Graphic Overlay A printed substrate that covers the FSR. Usually used for esthetics and protection.

Housed Female A stitched on AMP connector with a receptacle (female) ending. A black plastic housing protects the contacts. Suitable for removable ribbon cable connector and header pin attachment.

Hysteresis In a dynamic measurement, the difference between instantaneous force measurements at a given force for an increasing load versus a decreasing load.

Interdigitating Electrodes The conductor grid. An interweaving pattern of linearly offset conductor traces used to achieve electrical contact. This grid is shunted by the semiconductor layer to give the FSR response.

Lead Out or Busing System The method of electrically accessing each individual sensor.

Lexan® Polycarbonate. A substrate used for graphic overlays and labels. Available in a variety of surface textures.

Melinex® A brand of polyester(PET). A substrate with lower temperature resistance than Ulterm® or PES, but with excellent flexibility and low cost. Similar to Mylar™.

Part or Device The FSR. Consists of the FSR semiconductive material, conductor, adhesives, graphics or overlays, and connectors.

PES Polyethersulfone. A transparent substrate with excellent temperature resistance, moderate chemical resistance, and good flexibility.

Pin Out The descriptions of a FSR's electrical access at the connector pad (tail).

Repeatability The ability to repeat, within a tolerance, a previous response characteristic.

Response Characteristic The relationship of force or pressure vs. resistance.

Saturation Pressure The pressure level beyond with the FSR response characteristic deviates from its inverse power law characteristic. Past the saturation pressure, increases in force yield little or no decrease in resistance.

Sensor Each area of the FSR device that is independently force sensitive (as in an array).

Solder-tabs Stitched on AMP connectors with tab endings. Suitable for direct PC board connection or for soldering to wires.

Space and Trace The widths of the gaps and fingers of the conductive grid; also called pitch.

Spacer Adhesive The adhesive used to laminate FSR devices tighter. Dictates stand-off.

Stand-off The gap or distance between the opposed polymer film layers when the sensor in unloaded and unbent.

Stand-off Resistance The FSR resistance when the device is unloaded and unbent.

Substrate Any base material on which the FSR semi-conductive or metallic polymers are printed. (For example, polyetherimide, polyethersulforne and polyester films).

Tail The region where the lead out or busing system terminates. Generally, the tail ends in a connector.

Ulterm® Polyetherimide (PEI). A yellow, semi-transparent substrate with excellent temperature and chemical resistance and limited flexibility.

Suggested Electrical Interfaces
Basic FSRs

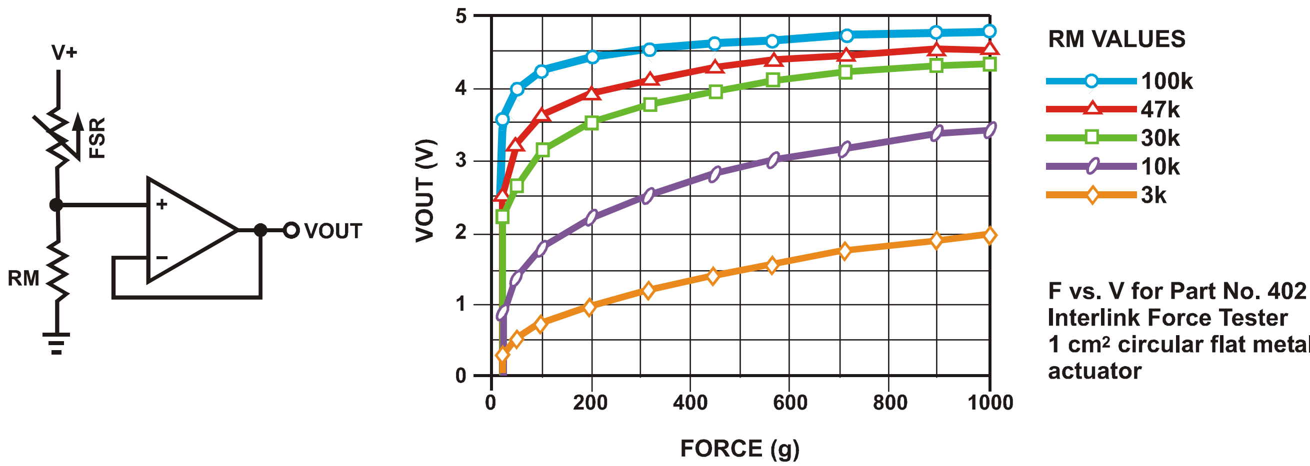


Figure 9
FSR Voltage Divider

FSR Voltage Divider

For a simple force-to-voltage conversion, the FSR device is tied to a measuring resistor in a voltage divider configuration. The output is described by the equation:

$$VOUT = (V+) / [1 + RFSR/RM].$$

In the shown configuration, the output voltage increases with increasing force. If RFSR and RM are swapped, the output swing will decrease with increasing force. These two output forms are mirror images about the line VOUT = (V+) / 2.

The measuring resistor, RM, is chosen to maximize the desired force sensitivity range and to limit current. The current through the FSR should be limited to less than 1 mA/square cm of applied force. Suggested op-amps for single sided supply designs are LM358 and LM324. FET input devices such as LF355 and TL082 are also good. The low bias currents of these op-amps reduce the error due to the source impedance of the voltage divider.

A family of FORCE vs. VOUT curves is shown on the graph above for a standard FSR in a voltage divider configuration with various RM resistors. A (V+) of +5V was used for these examples.

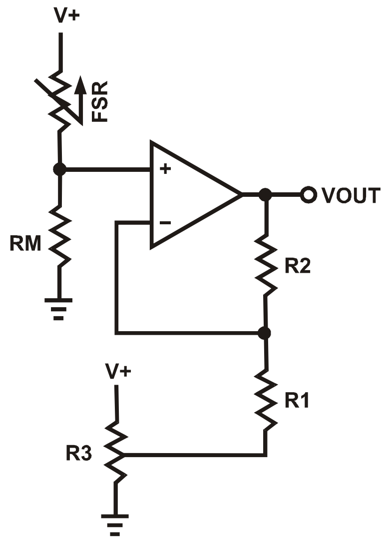


Figure 10
Adjustable Buffer

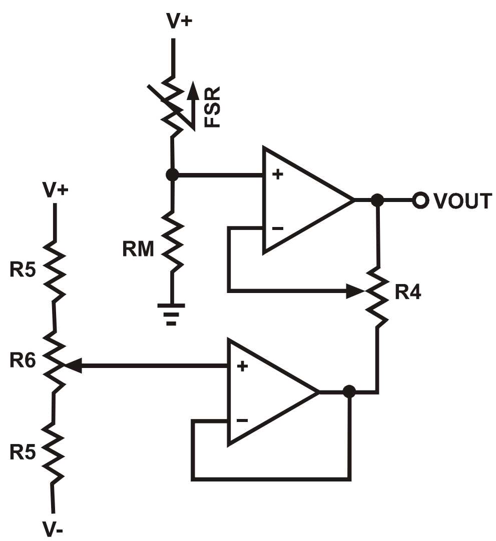


Figure 11
Adjustable Buffer

Adjustable Buffers

Similar to the FSR Voltage Divider, these interfaces isolate the output from the high source impedance of the Force Sensing Resistor. However, these alternatives allow adjustment of the output offset and gain.

In Figure 10, the ratio of resistors R2 and R1 sets the gain of the output. Offsets resulting from the non-infinite FSR resistance at zero force (or bias currents) can be trimmed out with the potentiometer, R3. For best results, R3 should be about one-twentieth of R1 or R2. Adding an additional pot at R2 makes the gain easily adjustable. Broad range gain adjustment can be made by replacing R2 and R1 with a single pot.

The circuit in Figure 11 yields similar results to the previous one, but the offset trim is isolated from the adjustable gain. With this separation, there is no constraint on values for the pot. Typical cal for R5 and the pot are around 10kΩ.

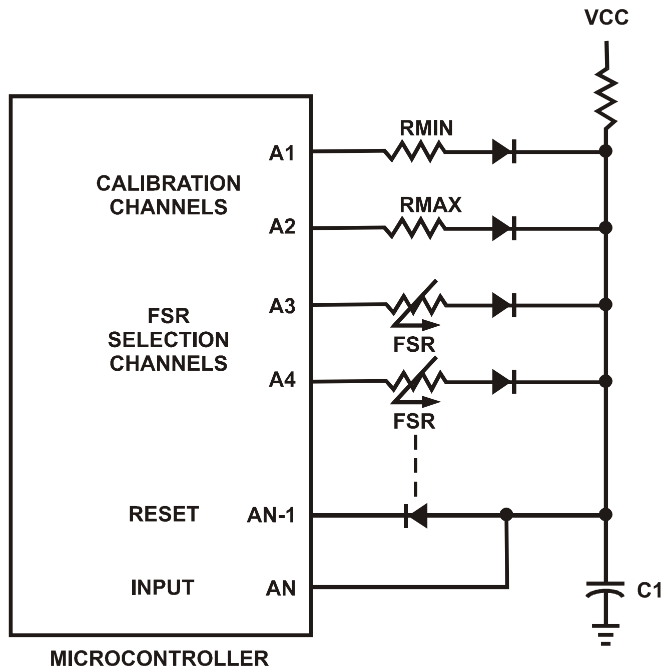


Figure 12
Multi-Channel FSR-to-Digital Interface

Multi-Channel to FSR-to-Digital Interface

Sampling Cycle (any FSR channel):
The microcontroller switches to a specific FSR channel, toggling it high, while all other FSR channels are toggled low. The RESET channel is toggled high, a counter starts and the capacitor C1 charges, with its charging rate controlled by the resistance of the FSR (t ~ RC). When the capacitor reaches the high digital threshold of the INPUT channel, the counter shuts off, the RESET is toggled low, and the capacitor discharges.

The number of "counts" it takes from the toggling of the RESET high to the toggling of the INPUT high is proportional to the resistance of the FSR. The resistors RMIN and RMAX are used to set a minimum and maximum "counts" and therefore the range of the "counts". They are also used periodically to re-calibrate the reference. A sampling cycle for RMIN is run, the number of "counts" is stored and used as a new zero. Similarly, a sampling cycle for RMAX is run and the value is stored as the maximum range (after subtracting the RMIN value). Successive FSR samplings are normalized to the new zero. The full range is "zoned" by dividing the normalized maximum "counts" by the number of desired zones. This will delineate the window size or width of each zone.

Continual sampling is done to record changes in FSR resistance due to change sin force. Each FSR is selected sequentially.

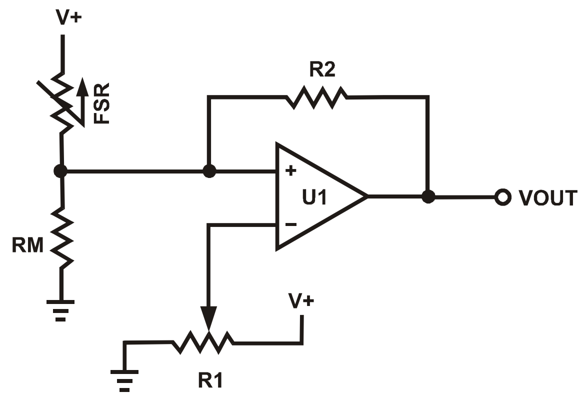


Figure 13
FSR Variable Force Threshold Switch

FSR Variable Force Threshold Switch

This simple circuit is ideal for applications that require on-off switching at a specified force, such as touch-sensitive membrane, cut-off, and limit switches. For a variation of this circuit that is designed to control relay switching, see the following page.

The FSR device is arranged in a voltage divider with RM. An op-amp, U1, is used as a comparator. The output of U1 is either high or low. The non-inverting input of the op-amp is driven by the output of the divider, which is a voltage that increases with force. At zero force, the output of the op-amp will be low. When the voltage at the non-inverting input of the op-amp exceeds the voltage of the inverting input, the output of the op-amp will toggle high. The triggering voltage, and therefore the force threshold, is set at the inverting input by the pot R1. The hysteresis, R2, acts as a "debouncer", eliminating any multiple triggerings of the output that might occur.

Suggested op-amps are LM358 and LM324. Comparators like LM393 also work quite well. The parallel combination of R2 with RM is chosen to limit current and to maximize the desired force sensitivity range. A typical value for this combination is about 47kΩ.

The threshold adjustment pot, R1, can be replaced by two fixed value resistors in a voltage divider configuration.

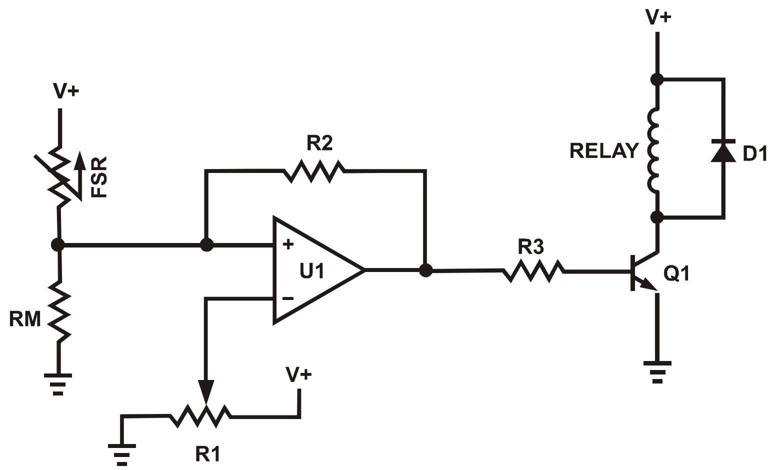


Figure 14
FSR Variable Force Threshold Relay Switch

FSR Variable Force Threshold Relay Switch

This circuit is a derivative of the simple FSR Variable Force Threshold Switch on the previous page. It has use where the element to be switched requires higher current, like automotive and industrial control relays.

The FSR device is arranged in a voltage divider with RM. An op-amp, U1, is used as a comparator. The output of U1 is either high or low. The non-inverting input of the op-amp sees the output of the divider, which is a voltage that increases with force. At zero force, the output of the op-amp will be low. When the voltage at the non-inverting input of the op-amp exceeds the voltage of the inverting input, the output of the op-amp will toggle high. The triggering voltage, and therefore the force threshold, is set at the inverting input by the pot R1. The transistor Q1 is chosen to match the required current specification for the relay. Any medium power NPN transistor should suffice. For example, an NTE272 can sink 2 amps, and an NTE291 can sink 4 amps. The resistor R3 limits the base current (a suggested value is 4.7kΩ). The hysteresis resistor, R2, acts as a "debouncer', eliminating any multiple triggerings of the output that might occur.

Suggested op-amps are LM358 and LM324. Comparators like LM393 and LM339 also work quite well, but must be used in conjunction with a pull-up resistor. The parallel combination of R2 with RM is chosen to limit current and to maximize the desired force sensitivity range. A typical value for this combination is about 47kΩ.

The threshold adjustment pot, R1, can be replaced by two fixed value resistors in a voltage divider configuration. The diode D1 is included to prevent flyback, which could harm the relay and the circuitry.

FSR Current-to-Voltage Converter

In this circuit, the FSR device is the input of a current-to-voltage converter. The output of this amplifier is described by the equation:

$$VOUT = VREF \bullet [-RG/RFSR].$$

With a positive reference voltage, the output of the op-amp must be able to swing below ground, from 0V to –VREF, therefore dual sided supplies are necessary. A negative reference voltage will yield a positive output swing, from 0V to +VREF.

$$VOUT = (-RG \bullet VREF) /RFSR.$$

VOUT is inversely proportional to RFSR. Changing RG and/or VREF changes the response slope. The following is an example of the sequence used for choosing the component values and output swing:

For a human-to-machine variable control device, like a joystick, the maximum force applied to the FSR is about 1kg. Testing of a typical FSR shows that the corresponding RFSR at 1kg is about 4.6kΩ. If VREF is –5V, and an output swing of 0V to +5V is desired, then RG should be approximately equal to this minimum RFSR. RG is set at 4.7kΩ. A full swing of 0V to +5V is thus achieved. A set of FORCE vs. VOUT curves is shown in Figure 15 for a standard FSR using this interface with a variety of RG values.

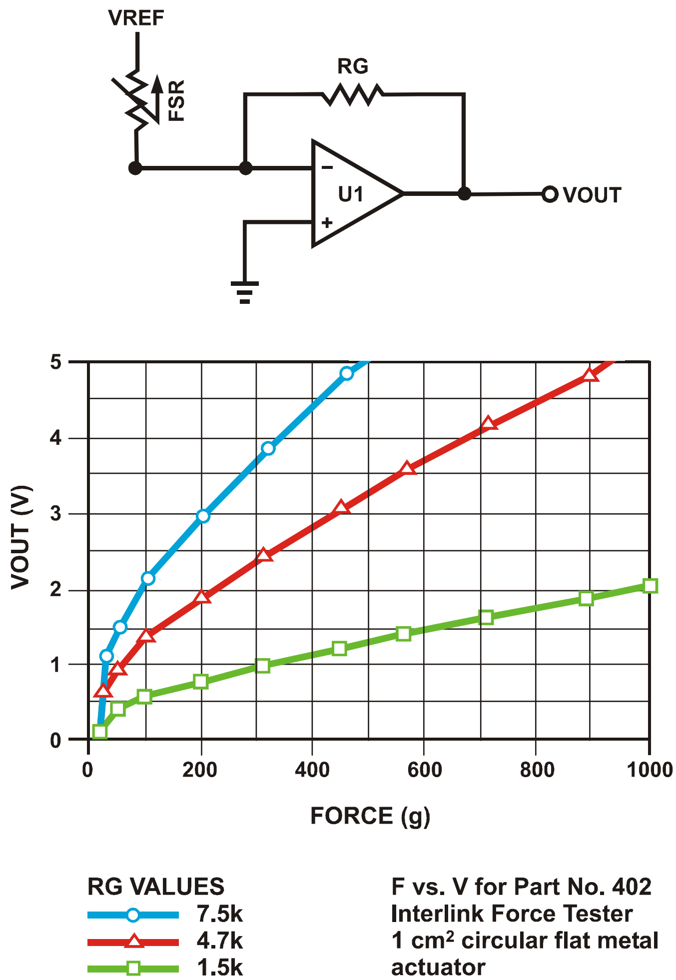


Figure 15
FSR Current-to-Voltage Converter

The current through the FSR device should be limited to less than 1 mA/square cm of applied force. As with the voltage divider circuit, adding a resistor in parallel with RFSR will give a definite rest voltage, which is essentially a zero-force intercept value. This can be useful when resolution at low forces is desired.

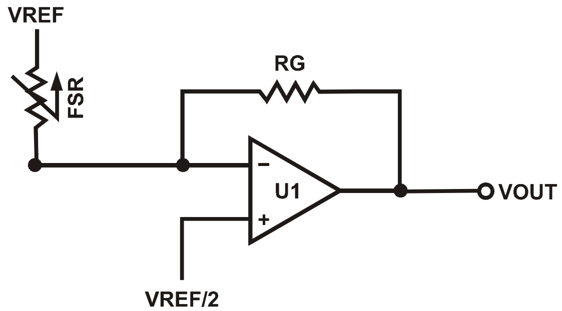


Figure 16
Add'l FSR Current-to-Voltage Converter

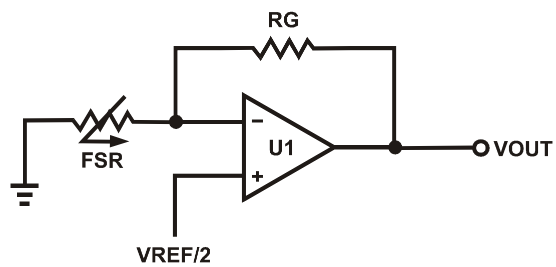


Figure 17
Add'l FSR Current-to-Voltage Converter

Additional FSR Current-to-Voltage Converters

These circuits are a slightly modified version of the current-to-voltage converter detailed on the previous page. Please refer to it for more detail.

The output of Figure 16 is described by the equation:

$$VOUT = [VREF/2] * [1-RG/RFSR]$$

The output swing of this circuit is from (VREF/2) to 0V. In the case where RG is greater than RFSR, the output will go into negative saturation.

The output of Figure 17 is described by the equation:

$$VOUT = VREF/2 \bullet [1 + RG/RFSR].$$

The output swing of this circuit is from (VREF/2) to VREF. In the case where RG is greater than RFSR, the output will go into positive saturation.

For either of these configurations, a zener diode placed in parallel with RG will limit the voltage built up across RG. These designs yield one-half the output swing of the previous circuit, but only require single sided supplies and positive reference voltages. Like the preceding circuit, the current through the FSR should be limited to less than 1 mA/square cm of applied force.

Suggested op-amps are LM358 and LM324.

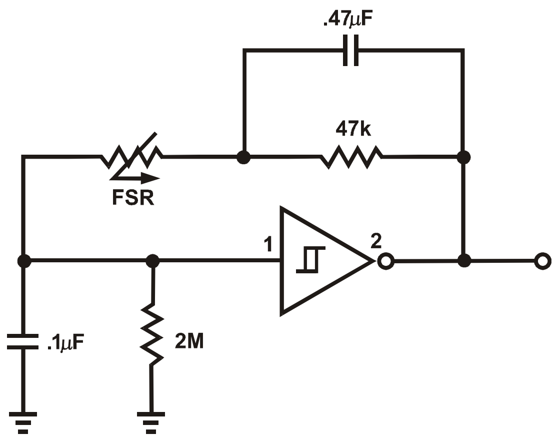


Figure 18
FSR Schmitt Trigger Oscillator

FSR Schmitt Trigger Oscillator

In this circuit, an oscillator is made using the FSR device as the feedback element around a Schmitt Trigger. In this manner, a simple force-to-frequency converter is made. At zero force, the FSR is an open circuit. Depending on the last stage of the trigger, the output remains constant, either high or low. When the FSR is pressed, the oscillator starts, its frequency increasing with increasing force. The 2MΩ resistor at the input of the trigger insures that the oscillator is off when FSRs with non-infinite resistance at zero force are used. The 47kΩ resistor and the 0.47 µF capacitor control the force-to-frequency characteristic. Changes in the "feel" of this circuit can be made by adjusting these values. The 0.1µF capacitor controls the frequency range of the oscillator. By implementing this circuit with CMOS or TTL, a digital process can be controlled by counting leading and/or trailing edges of the oscillator output. Suggested Schmitt Triggers are CD40106, CD4584 or 74C14.

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National Semiconductor

March 1, 2010

LM117/LM317A/LM317

3-Terminal Adjustable Regulator

General Description

The LM117 series of adjustable 3-terminal positive voltage regulators is capable of supplying in excess of 1.5A over a 1.2V to 37V output range. They are exceptionally easy to use and require only two external resistors to set the output voltage. Further, both line and load regulation are better than standard fixed regulators. Also, the LM117 is packaged in standard transistor packages which are easily mounted and handled.

In addition to higher performance than fixed regulators, the LM117 series offers full overload protection available only in IC's. Included on the chip are current limit, thermal overload protection and safe area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected.

Normally, no capacitors are needed unless the device is situated more than 6 inches from the input filter capacitors in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejection ratios which are difficult to achieve with standard 3-terminal regulators.

Besides replacing fixed regulators, the LM117 is useful in a wide variety of other applications. Since the regulator is “floating” and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input to output differential is not exceeded, i.e., avoid short-circuiting the output.

Also, it makes an especially simple adjustable switching regulator, a programmable output regulator, or by connecting a fixed resistor between the adjustment pin and output, the LM117 can be used as a precision current regulator. Supplies with electronic shutdown can be achieved by clamping the adjustment terminal to ground which programs the output to 1.2V where most loads draw little current.

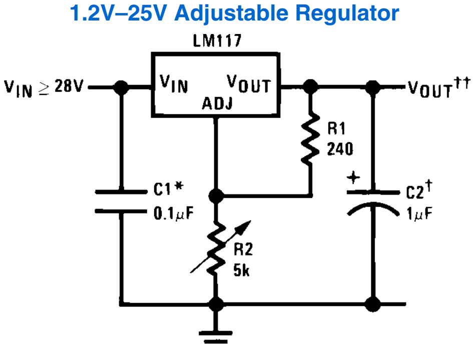
For applications requiring greater output current, see LM150 series (3A) and LM138 series (5A) data sheets. For the negative complement, see LM137 series data sheet.

Features

- Guaranteed 1% output voltage tolerance (LM317A)
- Guaranteed max. 0.01%/V line regulation (LM317A)
- Guaranteed max. 0.3% load regulation (LM117)
- Guaranteed 1.5A output current
- Adjustable output down to 1.2V
- Current limit constant with temperature
- P+ Product Enhancement tested
- 80 dB ripple rejection
- Output is short-circuit protected

Typical Applications

1.2V–25V Adjustable Regulator



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Full output current not available at high input-output voltages

*Needed if device is more than 6 inches from filter capacitors.

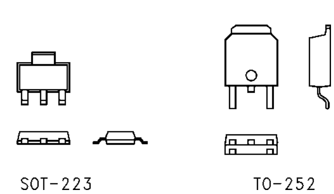
†Optional—improves transient response. Output capacitors in the range of 1μF to 1000μF of aluminum or tantalum electrolytic are commonly used to provide improved output impedance and rejection of transients.

$$††V_{OUT} = 1.25V \left(1 + \frac{R2}{R1}\right) + I_{ADJ}(R_2)$$

LM117/LM317A/LM317 Package Options

Part Number	Suffix	Package	Output Current
LM117, LM317	K	TO-3	1.5A
LM317A, LM317	T	TO-220	1.5A
LM317	S	TO-263	1.5A
LM317A, LM317	EMP	SOT-223	1.0A
LM117, LM317A, LM317	H	TO-39	0.5A
LM117	E	LCC	0.5A
LM317A, LM317	MDT	TO-252	0.5A

SOT-223 vs. TO-252 (D-Pak) Packages



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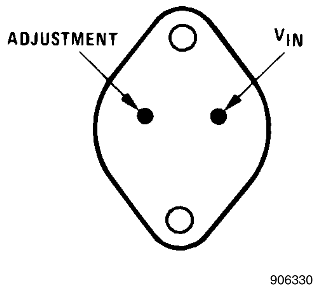
Scale 1:1

Connection Diagrams

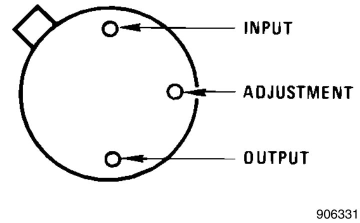
TO-3 (K)
Metal Can Package



CASE IS OUTPUT

Bottom View
Steel Package
NS Package Number K02A or K02C

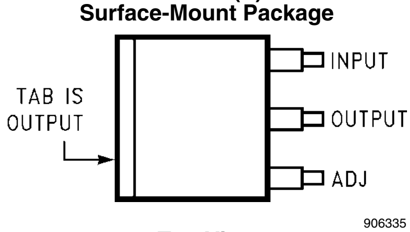
TO-39 (H)
Metal Can Package



CASE IS OUTPUT

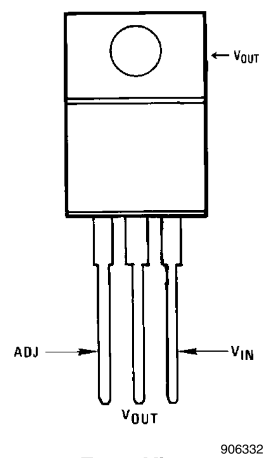
Bottom View
NS Package Number H03A

TO-263 (S)
Surface-Mount Package



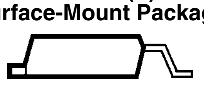
Top View

TO-220 (T)
Plastic Package



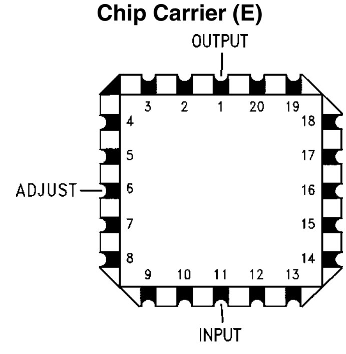
Front View
NS Package Number T03B

TO-263 (S)
Surface-Mount Package



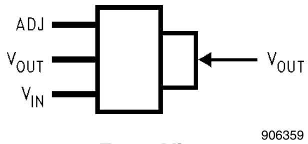
Side View
NS Package Number TS3B

Ceramic Leadless
Chip Carrier (E)



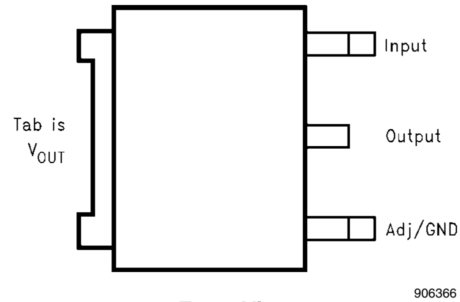
Top View
NS Package Number E20A

4-Lead SOT-223 (EMP)



Front View
NS Package Number MP04A

TO-252 (MDT)



Front View
NS Package Number TD03B

Ordering Information

Package	Temperature Range	Output Current	Order Number	Package Marking	Transport Media	NSC Drawing
TO-3 Metal Can (K)	$-55°C \le T_J \le +150°C$	1.5A	LM117K STEEL	LM117K STEEL P+	50 Per Bag	K02A
	$0°C \le T_J \le +125°C$	1.5A	LM317K STEEL	LM317K STEEL P+	50 Per Bag	
	$-55°C \le T_J \le +150°C$	1.5A	LM117K/883	LM117K/883	50 Per Bag	K02C
TO-220 3- Lead	$-40°C \le T_J \le +125°C$	1.5A	LM317AT	LM317AT P+	45 Units/Rail	T03B
	$0°C \le T_J \le +125°C$	1.5A	LM317T	LM317T P+	45 Units/Rail	
TO-263 3- Lead	$0°C \le T_J \le +125°C$	1.5A	LM317S	LM317S P+	45 Units/Rail	TS3B
			LM317SX		500 Units Tape and Reel	
SOT-223 4- Lead	$0°C \le T_J \le +125°C$	1.0A	LM317EMP	N01A	1k Units Tape and Reel	MP04A
			LM317EMPX		2k Units Tape and Reel	
	$-40°C \le T_J \le +125°C$	1.0A	LM317AEMP	N07A	1k Units Tape and Reel	
			LM317AEMPX		2k Units Tape and Reel	
TO-39 Metal Can (H)	$-55°C \le T_J \le +150°C$	0.5A	LM117H	LM117H P+	500 Per Box	H03A
	$-55°C \le T_J \le +150°C$	0.5A	LM117H/883	LM117H/883	20 Per Tray	
	$-40°C \le T_J \le +125°C$	0.5A	LM317AH	LM317AH P+	500 Per Box	
	$0°C \le T_J \le +125°C$	0.5A	LM317H	LM317H P+	500 Per Box	
LCC	$-55°C \le T_J \le +150°C$	0.5A	LM117E/883	LM117E/883	50 Units/Rail	E20A
TO-252 3- Lead D-Pack	$0°C \le T_J \le +125°C$	0.5A	LM317MDT	LM317MDT	75 Units/Rail	TD03B
			LM317MDTX		2.5k Units Tape and Reel	
	$-40°C \le T_J \le +125°C$	0.5A	LM317AMDT	LM317AMDT	75 Units/Rail	
			LM317AMDTX		2.5k Units Tape and Reel	

Absolute Maximum Ratings (*Note 1*)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Power Dissipation	Internally Limited
Input-Output Voltage Differential	+40V, −0.3V
Storage Temperature	−65°C to +150°C
Lead Temperature	
Metal Package (Soldering, 10 seconds)	300°C
Plastic Package (Soldering, 4 seconds)	260°C
ESD Tolerance (*Note 5*)	3 kV

Operating Temperature Range

LM117	$-55°C \le T_J \le +150°C$
LM317A	$-40°C \le T_J \le +125°C$
LM317	$0°C \le T_J \le +125°C$

Preconditioning

Thermal Limit Burn-In	All Devices 100%

LM117 Electrical Characteristics (*Note 3*)

Specifications with standard type face are for $T_J = 25°C$, and those with **boldface type** apply over **full Operating Temperature Range**. Unless otherwise specified, $V_{IN} - V_{OUT} = 5V$, and $I_{OUT} = 10$ mA.

Parameter	Conditions	LM117 (*Note 2*)			Units
		Min	Typ	Max	
Reference Voltage	$3V \le (V_{IN} - V_{OUT}) \le 40V$, $10\text{ mA} \le I_{OUT} \le I_{MAX}$	**1.20**	**1.25**	**1.30**	V
Line Regulation	$3V \le (V_{IN} - V_{OUT}) \le 40V$ (*Note 4*)		0.01 **0.02**	0.02 **0.05**	%/V
Load Regulation	$10\text{ mA} \le I_{OUT} \le I_{MAX}$ (*Note 4*)		0.1 **0.3**	0.3 **1**	%
Thermal Regulation	20 ms Pulse		0.03	0.07	%/W
Adjustment Pin Current			**50**	**100**	μA
Adjustment Pin Current Change	$10\text{ mA} \le I_{OUT} \le I_{MAX}$ $3V \le (V_{IN} - V_{OUT}) \le 40V$		**0.2**	**5**	μA
Temperature Stability	$T_{MIN} \le T_J \le T_{MAX}$		**1**		%
Minimum Load Current	$(V_{IN} - V_{OUT}) = 40V$		**3.5**	**5**	mA
Current Limit	$(V_{IN} - V_{OUT}) \le 15V$ K Package H, E Package	 **1.5** **0.5**	 **2.2** **0.8**	 **3.4** **1.8**	A
	$(V_{IN} - V_{OUT}) = 40V$ K Package H, E Package	 0.3 0.15	 0.4 0.20		A
RMS Output Noise, % of V_{OUT}	$10\text{ Hz} \le f \le 10\text{ kHz}$		0.003		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 0$ μF		**65**		dB
	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 10$ μF	**66**	**80**		dB
Long-Term Stability	$T_J = 125°C$, 1000 hrs		0.3	1	%
Thermal Resistance, θ_{JC} Junction-to-Case	K (TO-3) Package H (TO-39) Package E (LCC) Package		2 21 12		°C/W
Thermal Resistance, θ_{JA} Junction-to-Ambient (No Heat Sink)	K (TO-3) Package H (TO-39) Package E (LCC) Package		39 186 88		°C/W

LM317A and LM317 Electrical Characteristics (Note 3)

Specifications with standard type face are for $T_J = 25°C$, and those with **boldface type** apply over **full Operating Temperature Range**. Unless otherwise specified, $V_{IN} - V_{OUT} = 5V$, and $I_{OUT} = 10$ mA.

Parameter	Conditions	LM317A Min	LM317A Typ	LM317A Max	LM317 Min	LM317 Typ	LM317 Max	Units
Reference Voltage		1.238	1.250	1.262	-	1.25	-	V
	$3V \le (V_{IN} - V_{OUT}) \le 40V$, $10 mA \le I_{OUT} \le I_{MAX}$	**1.225**	**1.250**	**1.270**	**1.20**	**1.25**	**1.30**	V
Line Regulation	$3V \le (V_{IN} - V_{OUT}) \le 40V$ (Note 4)		0.005 **0.01**	0.01 **0.02**		0.01 **0.02**	0.04 **0.07**	%/V
Load Regulation	$10 mA \le I_{OUT} \le I_{MAX}$ (Note 4)		0.1 **0.3**	0.5 **1**		0.1 **0.3**	0.5 **1.5**	%
Thermal Regulation	20 ms Pulse		0.04	0.07		0.04	0.07	%/W
Adjustment Pin Current			**50**	**100**		**50**	**100**	μA
Adjustment Pin Current Change	$10 mA \le I_{OUT} \le I_{MAX}$ $3V \le (V_{IN} - V_{OUT}) \le 40V$		**0.2**	**5**		**0.2**	**5**	μA
Temperature Stability	$T_{MIN} \le T_J \le T_{MAX}$		**1**			**1**		%
Minimum Load Current	$(V_{IN} - V_{OUT}) = 40V$		**3.5**	**10**		**3.5**	**10**	mA
Current Limit	$(V_{IN} - V_{OUT}) \le 15V$ K, T, S Packages EMP Package H, MDT Packages	 - **1.5** **0.5**	 - **2.2** **0.8**	 - **3.4** **1.8**	 **1.5** **1.5** **0.5**	 **2.2** **2.2** **0.8**	 **3.4** **3.4** **1.8**	A
	$(V_{IN} - V_{OUT}) = 40V$ K, T, S Packages EMP Package H, MDT Packages	 - 0.112 0.075	 - 0.30 0.20		 0.15 0.112 0.075	 0.40 0.30 0.20		A
RMS Output Noise, % of V_{OUT}	$10 Hz \le f \le 10 kHz$		0.003			0.003		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 0$ μF		65			65		dB
	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 10$ μF	**66**	**80**		**66**	**80**		dB
Long-Term Stability	$T_J = 125°C$, 1000 hrs		0.3	1		0.3	1	%
Thermal Resistance, θ_{JC} Junction-to-Case	K (TO-3) Package T (TO-220) Package S (TO-263) Package EMP (SOT-223) Package H (TO-39) Package MDT (TO-252) Package		- - - 23.5 21 12			2 4 4 23.5 21 12		°C/W
Thermal Resistance, θ_{JA} Junction-to-Ambient (No Heat Sink)	K (TO-3) Package T (TO-220) Package S (TO-263) Package (Note 6) EMP (SOT-223) Package (Note 6) H (TO-39) Package MDT (TO-252) Package (Note 6)		- - - 140 186 103			39 50 50 140 186 103		°C/W

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed.

Note 2: Refer to RETS117H drawing for the LM117H, or the RETS117K for the LM117K military specifications.

Note 3: $I_{MAX} = 1.5A$ for the K (TO-3), T (TO-220), and S (TO-263) packages. $I_{MAX} = 1.0A$ for the EMP (SOT-223) package. $I_{MAX} = 0.5A$ for the H (TO-39), MDT (TO-252), and E (LCC) packages. Device power dissipation (P_D) is limited by ambient temperature (T_A), device maximum junction temperature (T_J), and package thermal resistance (θ_{JA}). The maximum allowable power dissipation at any temperature is : $P_{D(MAX)} = ((T_{J(MAX)} - T_A)/\theta_{JA})$. All Min. and Max. limits are guaranteed to National's Average Outgoing Quality Level (AOQL).

Note 4: Regulation is measured at a constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specifications for thermal regulation.

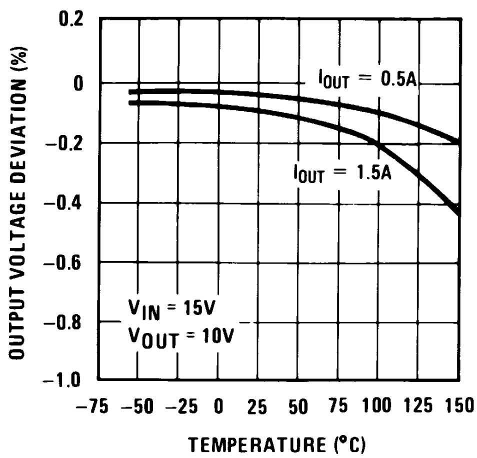
Note 5: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 6: When surface mount packages are used (TO-263, SOT-223, TO-252), the junction to ambient thermal resistance can be reduced by increasing the PC board copper area that is thermally connected to the package. See the Applications Hints section for heatsink techniques.

Typical Performance Characteristics

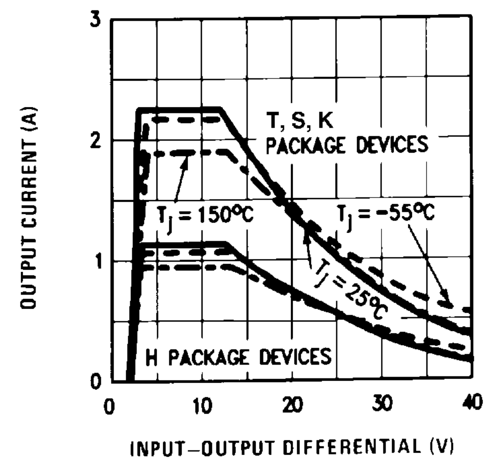
Output Capacitor = 0 µF unless otherwise noted

Load Regulation



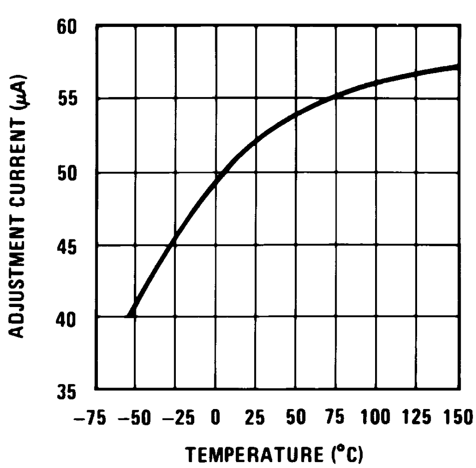
906337

Current Limit



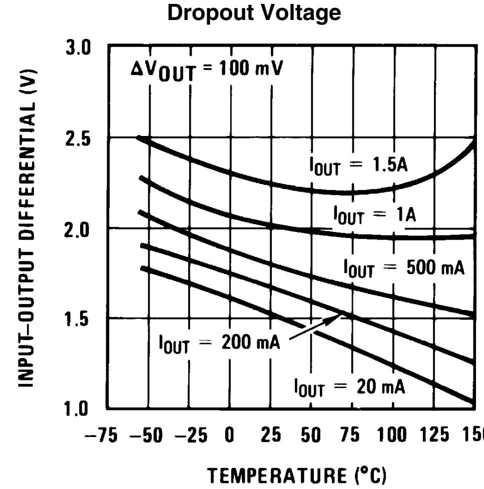
906338

Adjustment Current



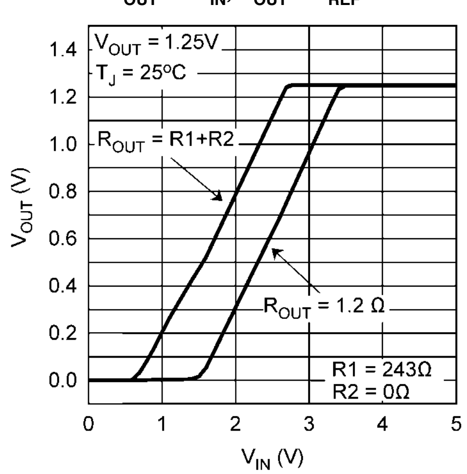
906339

Dropout Voltage



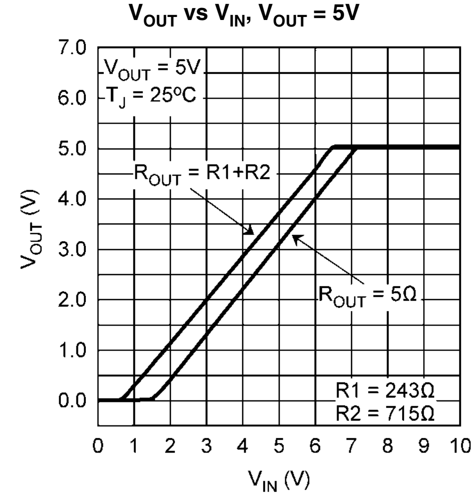
906340

V_{OUT} vs V_{IN}, V_{OUT} = V_{REF}



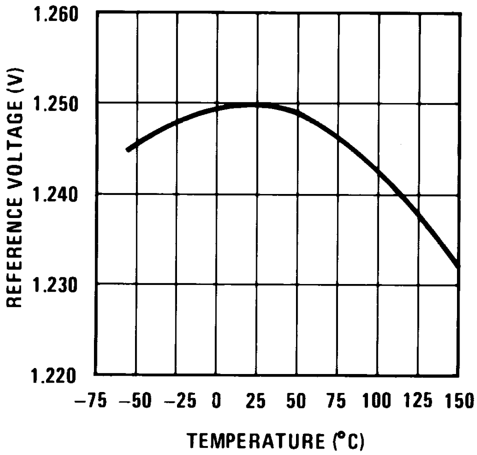
906367

V_{OUT} vs V_{IN}, V_{OUT} = 5V



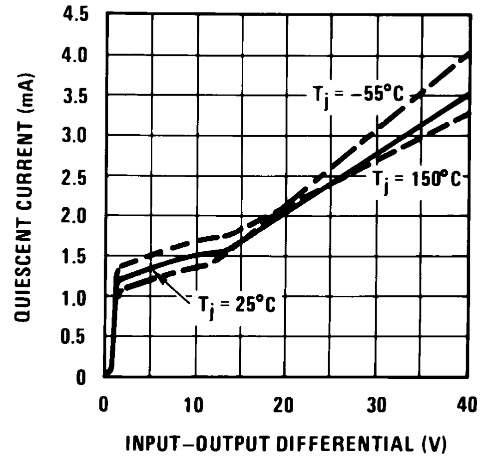
906368

Temperature Stability



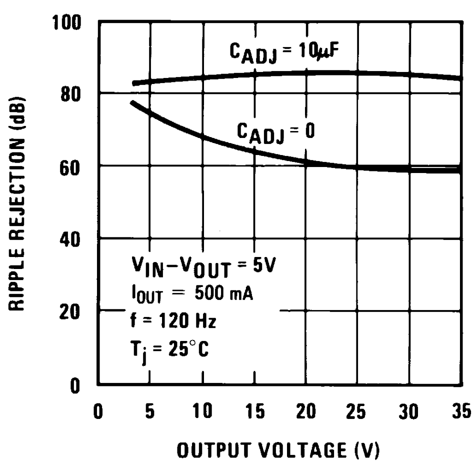
906341

Minimum Operating Current



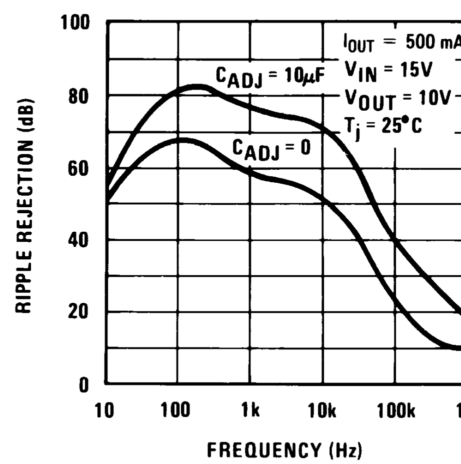
906342

Ripple Rejection



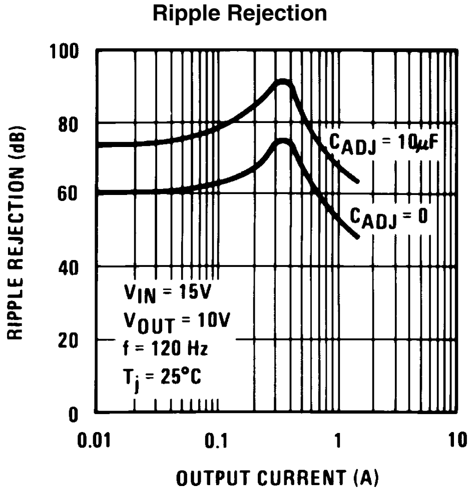
906343

Ripple Rejection



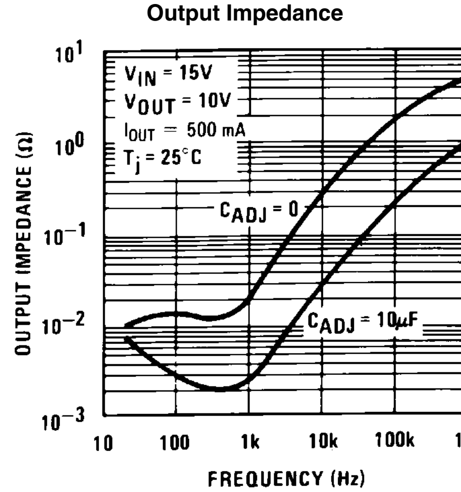
906344

Ripple Rejection



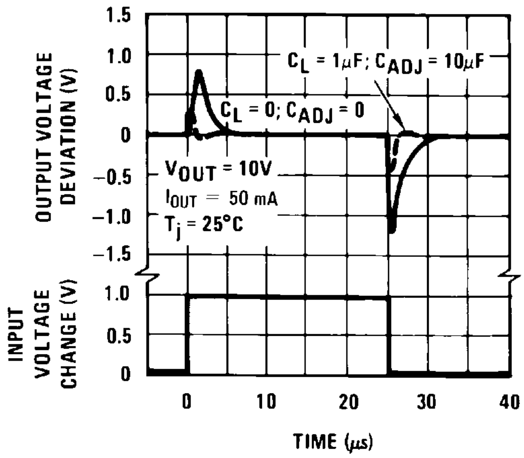
906345

Output Impedance



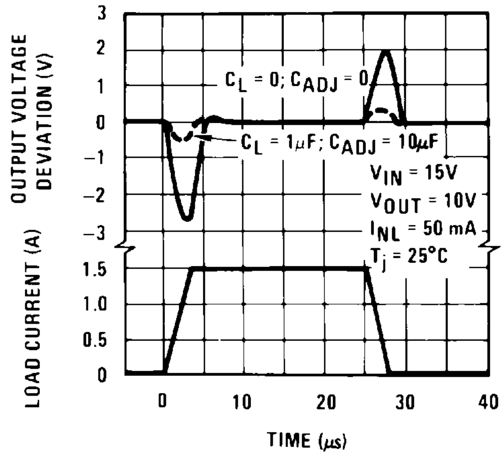
906346

Line Transient Response



906347

Load Transient Response

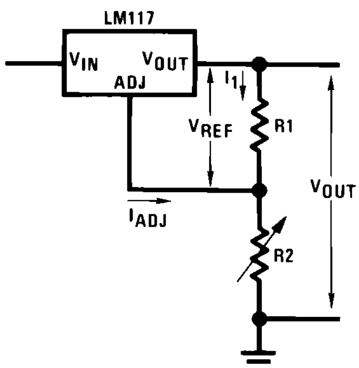


906348

Application Hints

In operation, the LM117 develops a nominal 1.25V reference voltage, V_{REF}, between the output and adjustment terminal. The reference voltage is impressed across program resistor R1 and, since the voltage is constant, a constant current I_1 then flows through the output set resistor R2, giving an output voltage of

$$V_{OUT} = V_{REF}\left(1 + \frac{R2}{R1}\right) + I_{ADJ}R2 \tag{1}$$



906305

FIGURE 1.

Since the 100μA current from the adjustment terminal represents an error term, the LM117 was designed to minimize I_{ADJ} and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output will rise.

EXTERNAL CAPACITORS

An input bypass capacitor is recommended. A 0.1μF disc or 1μF solid tantalum on the input is suitable input bypassing for almost all applications. The device is more sensitive to the absence of input bypassing when adjustment or output capacitors are used but the above values will eliminate the possibility of problems.

The adjustment terminal can be bypassed to ground on the LM117 to improve ripple rejection. This bypass capacitor prevents ripple from being amplified as the output voltage is increased. With a 10 μF bypass capacitor 80dB ripple rejection is obtainable at any output level. Increases over 10 μF do not appreciably improve the ripple rejection at frequencies above 120Hz. If the bypass capacitor is used, it is sometimes necessary to include protection diodes to prevent the capacitor from discharging through internal low current paths and damaging the device.

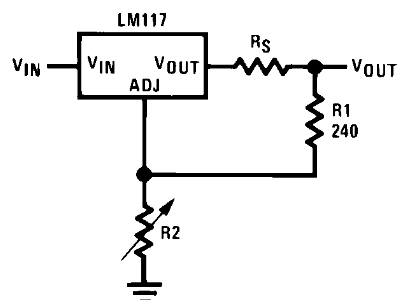
In general, the best type of capacitors to use is solid tantalum. Solid tantalum capacitors have low impedance even at high frequencies. Depending upon capacitor construction, it takes about 25 μF in aluminum electrolytic to equal 1μF solid tantalum at high frequencies. Ceramic capacitors are also good at high frequencies; but some types have a large decrease in capacitance at frequencies around 0.5 MHz. For this reason, 0.01 μF disc may seem to work better than a 0.1 μF disc as a bypass.

Although the LM117 is stable with no output capacitors, like any feedback circuit, certain values of external capacitance can cause excessive ringing. This occurs with values between 500 pF and 5000 pF. A 1 μF solid tantalum (or 25 μF aluminum electrolytic) on the output swamps this effect and insures stability. Any increase of the load capacitance larger than 10 μF will merely improve the loop stability and output impedance.

LOAD REGULATION

The LM117 is capable of providing extremely good load regulation but a few precautions are needed to obtain maximum performance. The current set resistor connected between the adjustment terminal and the output terminal (usually 240Ω) should be tied directly to the output (case) of the regulator rather than near the load. This eliminates line drops from appearing effectively in series with the reference and degrading regulation. For example, a 15V regulator with 0.05Ω resistance between the regulator and load will have a load regulation due to line resistance of 0.05Ω × I_L. If the set resistor is connected near the load the effective line resistance will be 0.05Ω (1 + R2/R1) or in this case, 11.5 times worse.

Figure 2 shows the effect of resistance between the regulator and 240Ω set resistor.



906306

FIGURE 2. Regulator with Line Resistance in Output Lead

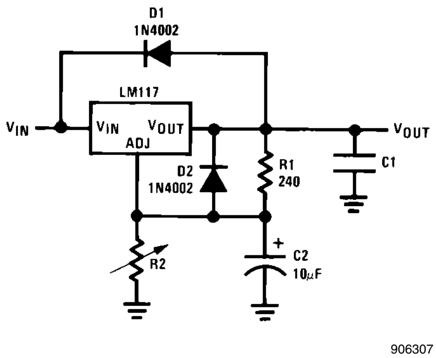
With the TO-3 package, it is easy to minimize the resistance from the case to the set resistor, by using two separate leads to the case. However, with the TO-39 package, care should be taken to minimize the wire length of the output lead. The ground of R2 can be returned near the ground of the load to provide remote ground sensing and improve load regulation.

PROTECTION DIODES

When external capacitors are used with any IC regulator it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. Most 10 μF capacitors have low enough internal series resistance to deliver 20A spikes when shorted. Although the surge is short, there is enough energy to damage parts of the IC.

When an output capacitor is connected to a regulator and the input is shorted, the output capacitor will discharge into the output of the regulator. The discharge current depends on the value of the capacitor, the output voltage of the regulator, and the rate of decrease of V_{IN}. In the LM117, this discharge path is through a large junction that is able to sustain 15A surge with no problem. This is not true of other types of positive regulators. For output capacitors of 25 μF or less, there is no need to use diodes.

The bypass capacitor on the adjustment terminal can discharge through a low current junction. Discharge occurs when *either* the input, or the output, is shorted. Internal to the LM117 is a 50Ω resistor which limits the peak discharge current. No protection is needed for output voltages of 25V or less and 10 μF capacitance. *Figure 3* shows an LM117 with protection diodes included for use with outputs greater than 25V and high values of output capacitance.



$$V_{OUT} = 1.25V \left(1 + \frac{R2}{R1}\right) + I_{ADJ}R2 \tag{2}$$

D1 protects against C1
D2 protects against C2

FIGURE 3. Regulator with Protection Diodes

HEATSINK REQUIREMENTS

The LM317 regulators have internal thermal shutdown to protect the device from over-heating. Under all operating conditions, the junction temperature of the LM317 should not exceed the rated maximum junction temperature (T_J) of 150°C for the LM117, or 125°C for the LM317A and LM317. A heatsink may be required depending on the maximum device power dissipation and the maximum ambient temperature of the application. To determine if a heatsink is needed, the power dissipated by the regulator, P_D, must be calculated:

$$P_D = ((V_{IN} - V_{OUT}) \times I_L) + (V_{IN} \times I_G) \tag{3}$$

Figure 4 shows the voltage and currents which are present in the circuit.

The next parameter which must be calculated is the maximum allowable temperature rise, $T_{R(MAX)}$:

$$T_{R(MAX)} = T_{J(MAX)} - T_{A(MAX)} \tag{4}$$

where $T_{J(MAX)}$ is the maximum allowable junction temperature (150°C for the LM117, or 125°C for the LM317A/LM317), and $T_{A(MAX)}$ is the maximum ambient temperature which will be encountered in the application.

Using the calculated values for $T_{R(MAX)}$ and P_D, the maximum allowable value for the junction-to-ambient thermal resistance (θ_{JA}) can be calculated:

$$\theta_{JA} = (T_{R(MAX)} / P_D) \tag{5}$$

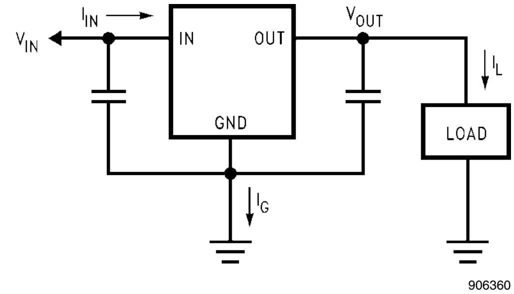


FIGURE 4. Power Dissipation Diagram

If the calculated maximum allowable thermal resistance is higher than the actual package rating, then no additional work is needed. If the calculated maximum allowable thermal resistance is lower than the actual package rating either the power dissipation (P_D) needs to be reduced, the maximum ambient temperature $T_{A(MAX)}$ needs to be reduced, the thermal resistance (θ_{JA}) must be lowered by adding a heatsink, or some combination of these.

If a heatsink is needed, the value can be calculated from the formula:

$$\theta_{HA} \leq (\theta_{JA} - (\theta_{CH} + \theta_{JC})) \tag{6}$$

where (θ_{CH} is the thermal resistance of the contact area between the device case and the heatsink surface, and θ_{JC} is thermal resistance from the junction of the die to surface of the package case.

When a value for $\theta_{(H-A)}$ is found using the equation shown, a heatsink must be selected that has a value that is less than, or equal to, this number.

The $\theta_{(H-A)}$ rating is specified numerically by the heatsink manufacturer in the catalog, or shown in a curve that plots temperature rise vs power dissipation for the heatsink.

HEATSINKING SURFACE MOUNT PACKAGES

The TO-263 (S), SOT-223 (EMP) and TO-252 (MDT) packages use a copper plane on the PCB and the PCB itself as a heatsink. To optimize the heat sinking ability of the plane and PCB, solder the tab of the package to the plane.

HEATSINKING THE SOT-223 PACKAGE

Figure 5 and *Figure 6* show the information for the SOT-223 package. *Figure 6* assumes a $\theta_{(J-A)}$ of 74°C/W for 1 ounce copper and 51°C/W for 2 ounce copper and a maximum junction temperature of 125°C. Please see AN-1028 for thermal enhancement techniques to be used with SOT-223 and TO-252 packages.

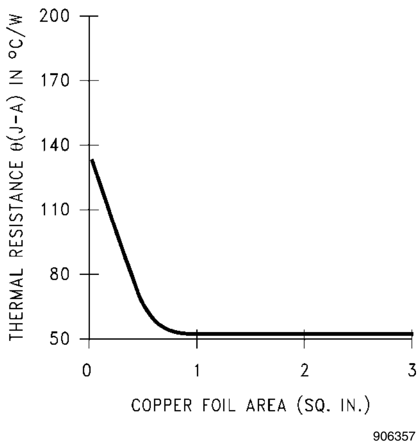


FIGURE 5. $\theta_{(J-A)}$ vs Copper (2 ounce) Area for the SOT-223 Package

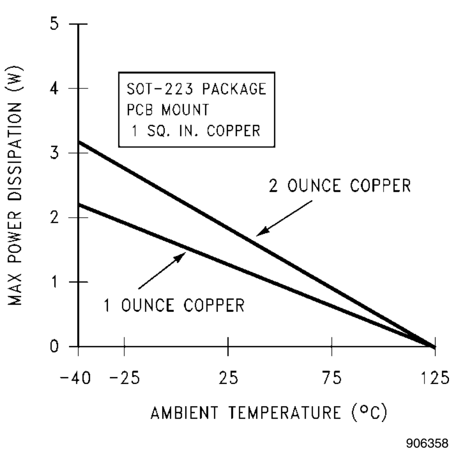


FIGURE 6. Maximum Power Dissipation vs T_{AMB} for the SOT-223 Package

HEATSINKING THE TO-263 PACKAGE

Figure 7 shows for the TO-263 the measured values of $\theta_{(J-A)}$ for different copper area sizes using a typical PCB with 1 ounce copper and no solder mask over the copper area used for heatsinking.

As shown in *Figure 7*, increasing the copper area beyond 1 square inch produces very little improvement. It should also be observed that the minimum value of $\theta_{(J-A)}$ for the TO-263 package mounted to a PCB is 32°C/W.

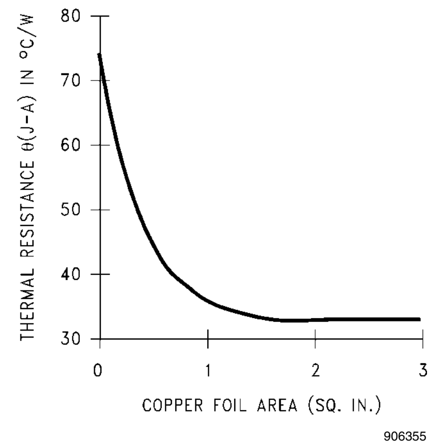


FIGURE 7. $\theta_{(J-A)}$ vs Copper (1 ounce) Area for the TO-263 Package

As a design aid, *Figure 8* shows the maximum allowable power dissipation compared to ambient temperature for the TO-263 device (assuming $\theta_{(J-A)}$ is 35°C/W and the maximum junction temperature is 125°C).

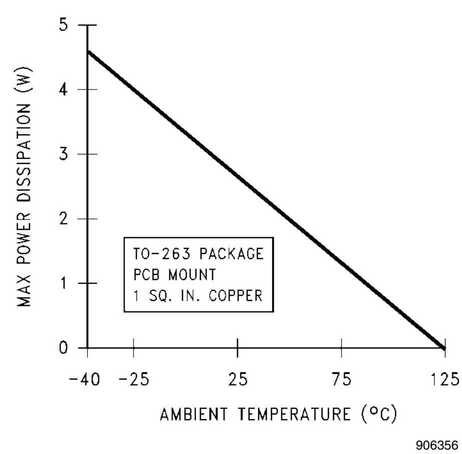


FIGURE 8. Maximum Power Dissipation vs T_{AMB} for the TO-263 Package

HEATSINKING THE TO-252 PACKAGE

If the maximum allowable value for θ_{JA} is found to be ≥103° C/W (Typical Rated Value) for TO-252 package, no heatsink is needed since the package alone will dissipate enough heat to satisfy these requirements. If the calculated value for θ_{JA} falls below these limits, a heatsink is required.

As a design aid, *Table 1* shows the value of the θ_{JA} of TO-252 for different heatsink area. The copper patterns that we used to measure these θ_{JA}s are shown at the end of the Application Notes Section. *Figure 9* reflects the same test results as what are in *Table 1*.

Figure 10 shows the maximum allowable power dissipation vs. ambient temperature for the TO-252 device. *Figure 11* shows the maximum allowable power dissipation vs. copper area (in^2) for the TO-252 device. Please see AN-1028 for thermal enhancement techniques to be used with SOT-223 and TO-252 packages.

TABLE 1. θ_{JA} Different Heatsink Area

Layout	Copper Area		Thermal Resistance
	Top Side (in2)*	Bottom Side (in2)	(θ_{JA}°C/W) TO-252
1	0.0123	0	103
2	0.066	0	87
3	0.3	0	60
4	0.53	0	54
5	0.76	0	52
6	1.0	0	47
7	0.066	0.2	84
8	0.066	0.4	70
9	0.066	0.6	63
10	0.066	0.8	57
11	0.066	1.0	57
12	0.066	0.066	89
13	0.175	0.175	72
14	0.284	0.284	61
15	0.392	0.392	55
16	0.5	0.5	53

Note: * Tab of device attached to topside of copper.

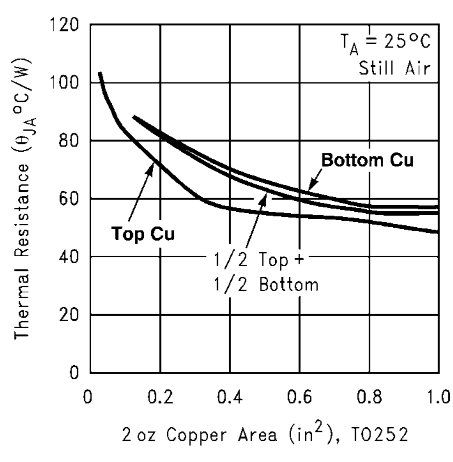


FIGURE 9. θ_{JA} vs 2oz Copper Area for TO-252

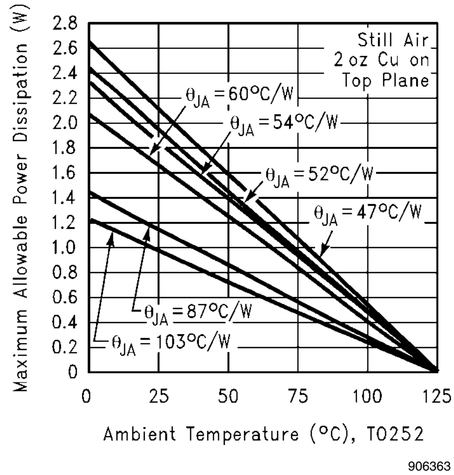


FIGURE 10. Maximum Allowable Power Dissipation vs. Ambient Temperature for TO-252

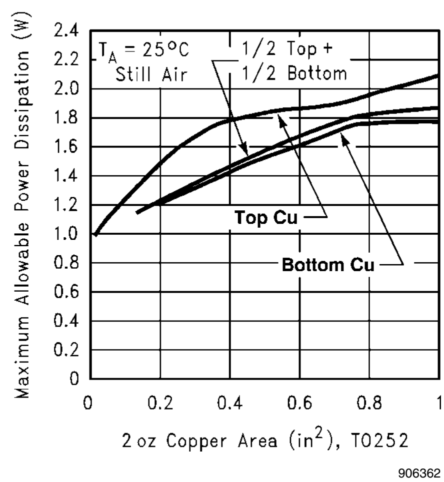


FIGURE 11. Maximum Allowable Power Dissipation vs. 2oz Copper Area for TO-252

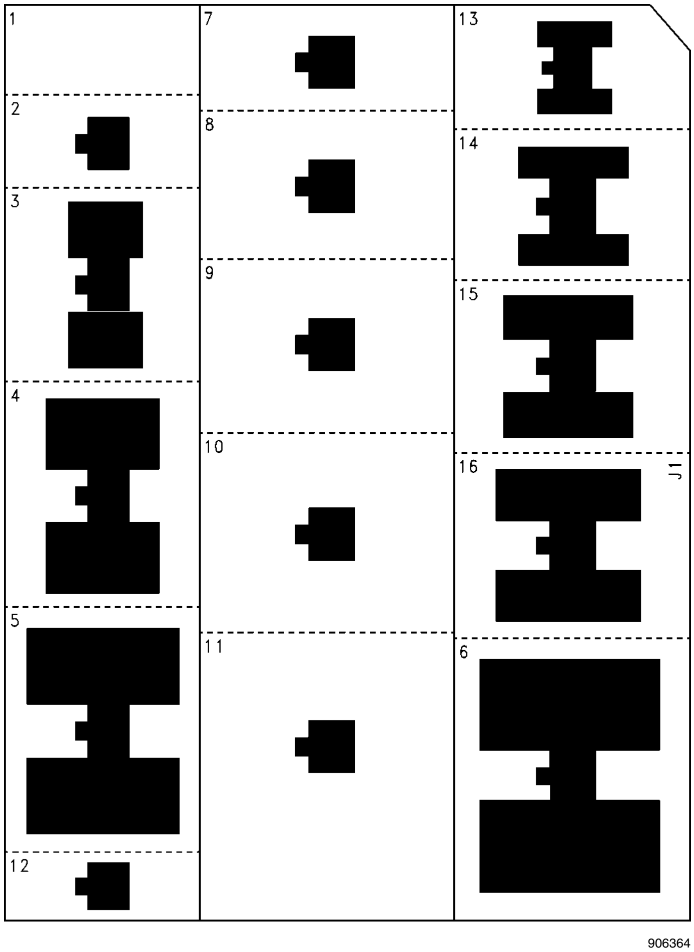
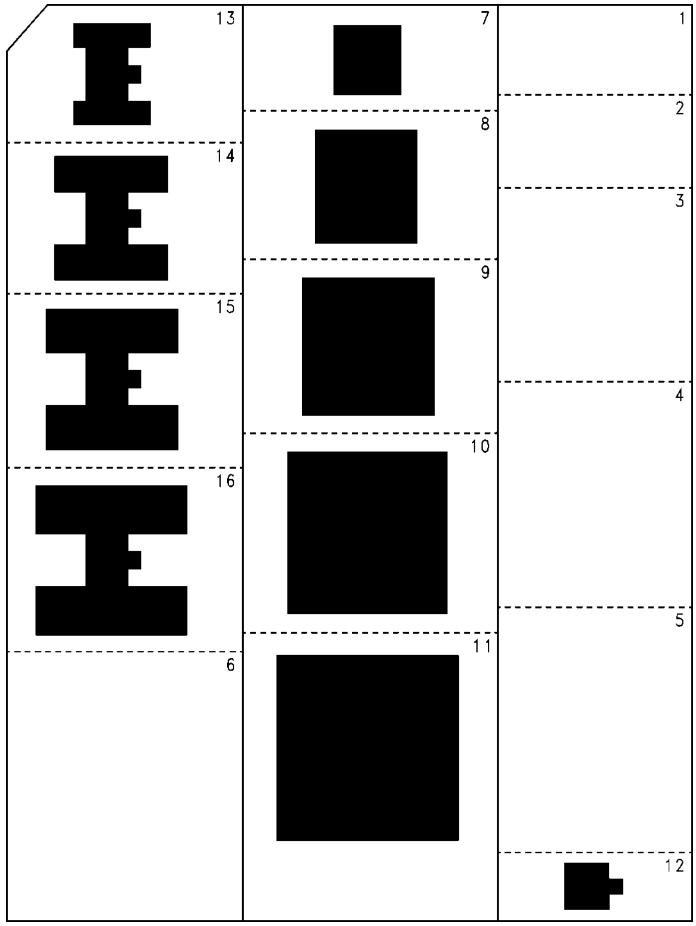


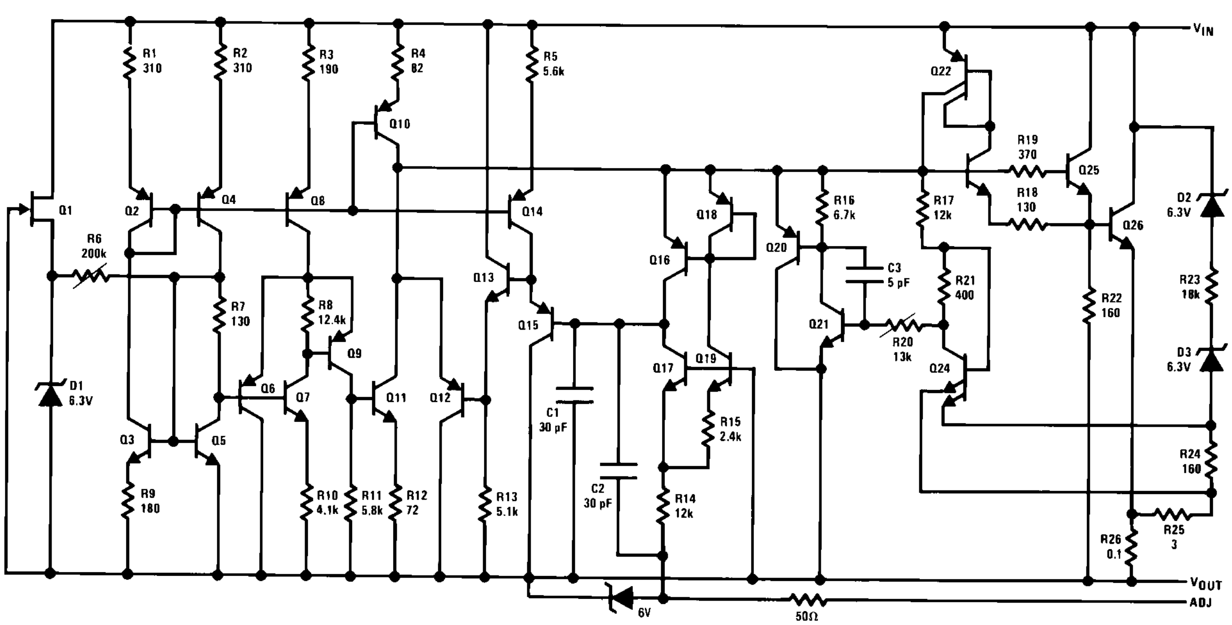
FIGURE 12. Top View of the Thermal Test Pattern in Actual Scale



906365

FIGURE 13. Bottom View of the Thermal Test Pattern in Actual Scale

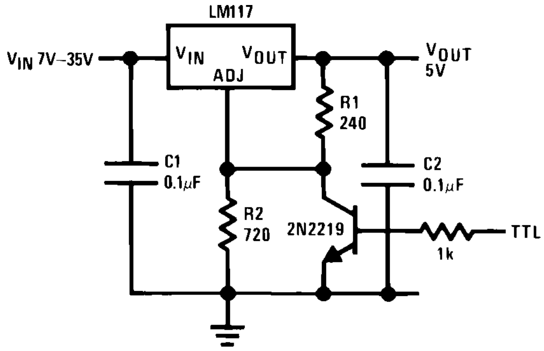
Schematic Diagram



906308

Typical Applications

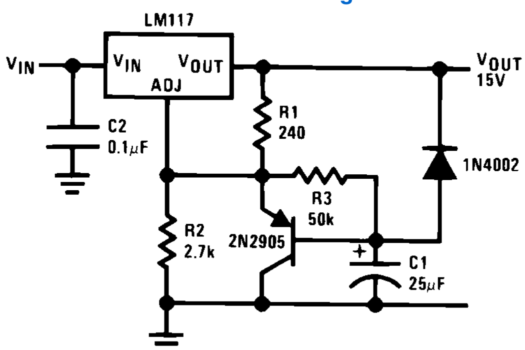
5V Logic Regulator with Electronic Shutdown*



906303

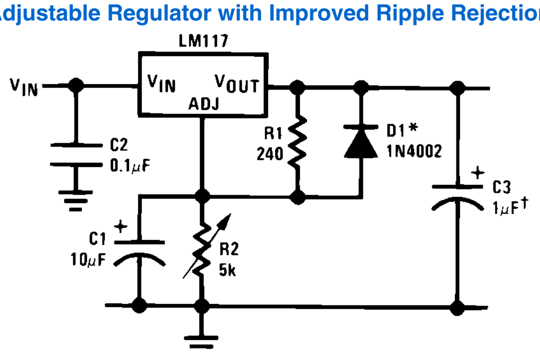
*Min. output ≅ 1.2V

Slow Turn-On 15V Regulator



906309

Adjustable Regulator with Improved Ripple Rejection

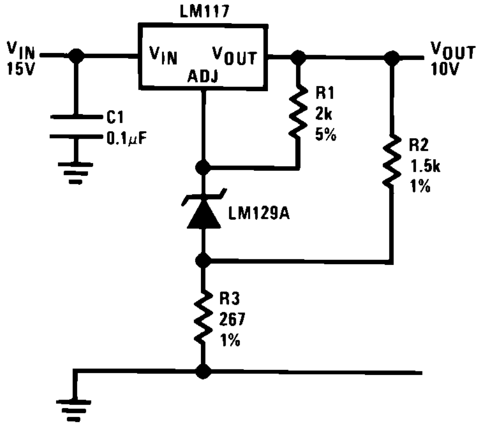


906310

†Solid tantalum

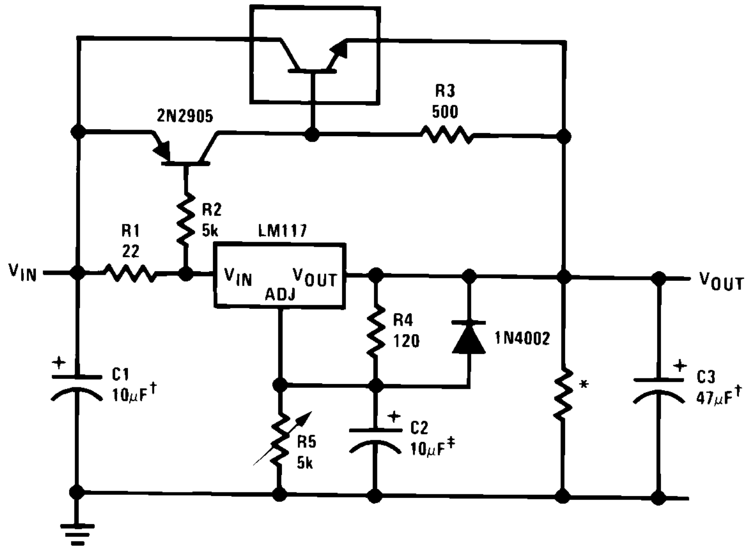
*Discharges C1 if output is shorted to ground

High Stability 10V Regulator



906311

High Current Adjustable Regulator



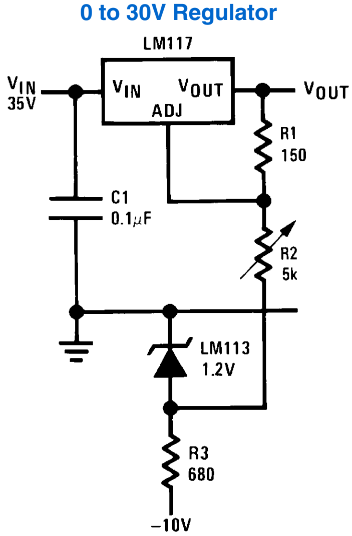
906312

‡Optional—improves ripple rejection

†Solid tantalum

*Minimum load current = 30 mA

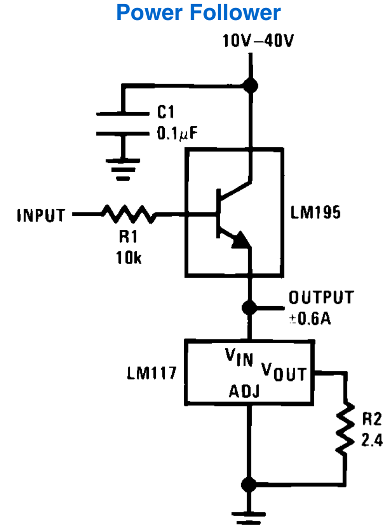
0 to 30V Regulator



906313

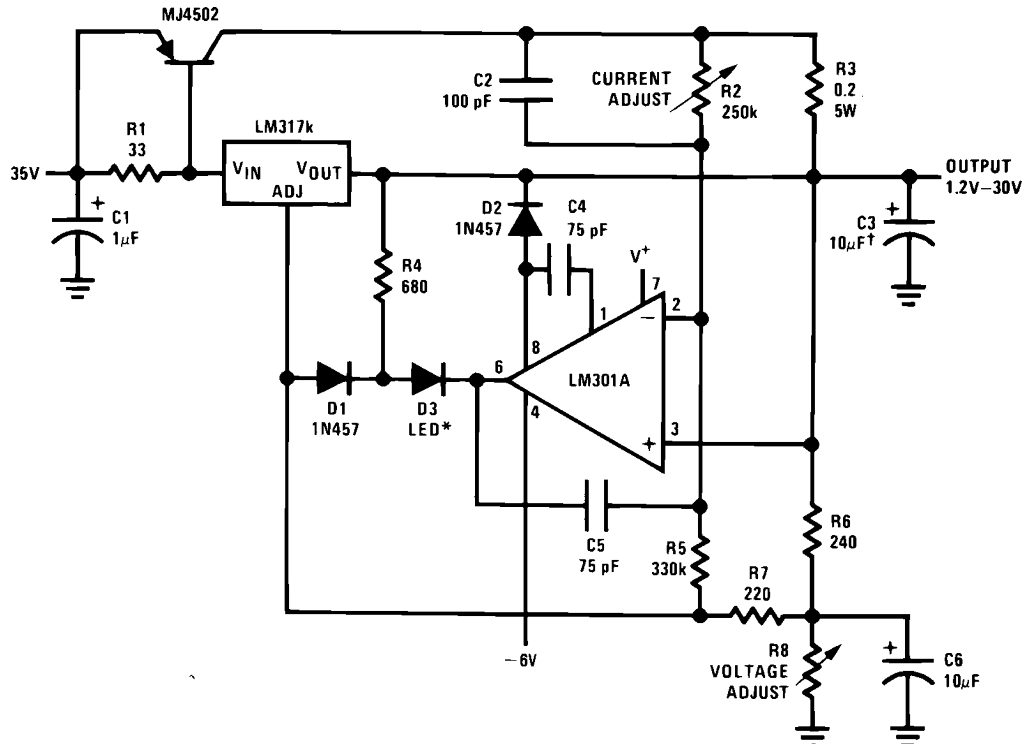
Full output current not available at high input-output voltages

Power Follower



906314

5A Constant Voltage/Constant Current Regulator

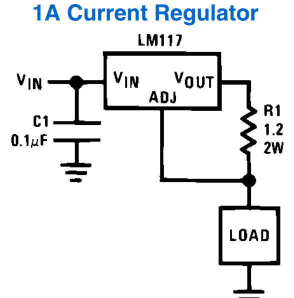


906315

†Solid tantalum

*Lights in constant current mode

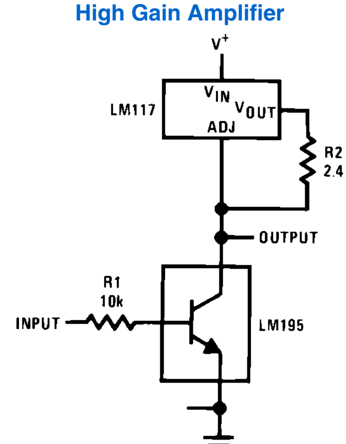
1A Current Regulator



906316

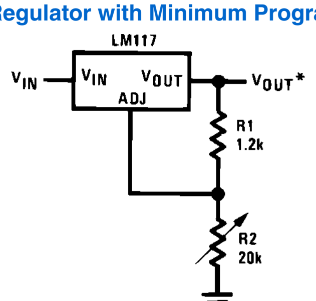
*Minimum load current ≅ 4 mA

High Gain Amplifier



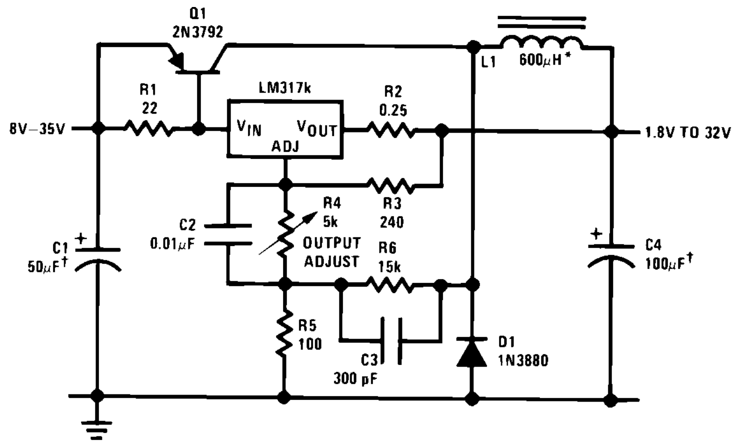
906318

1.2V–20V Regulator with Minimum Program Current



906317

Low Cost 3A Switching Regulator

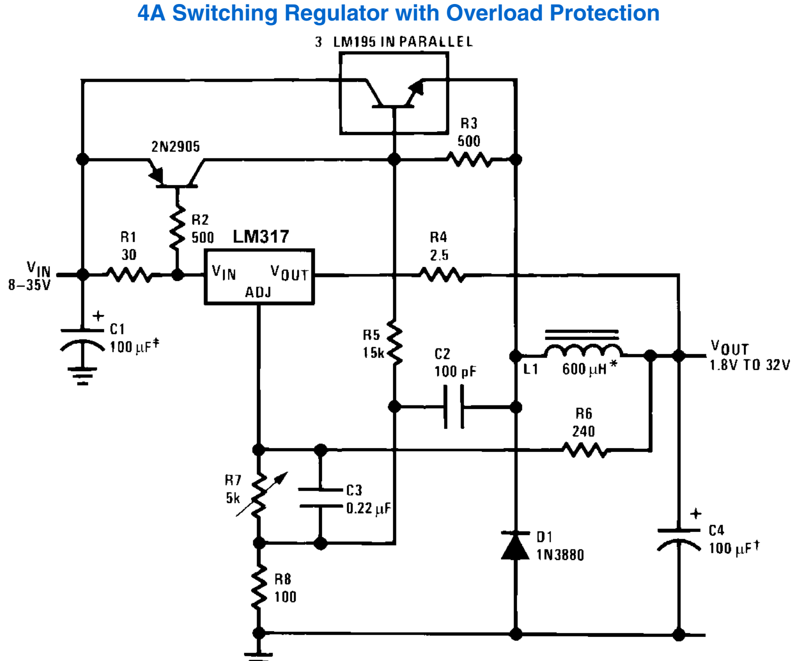


906319

†Solid tantalum

*Core—Arnold A-254168-2 60 turns

4A Switching Regulator with Overload Protection

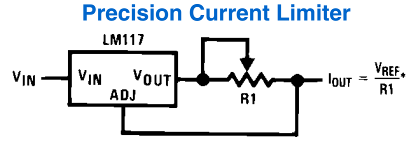


906320

†Solid tantalum

*Core—Arnold A-254168-2 60 turns

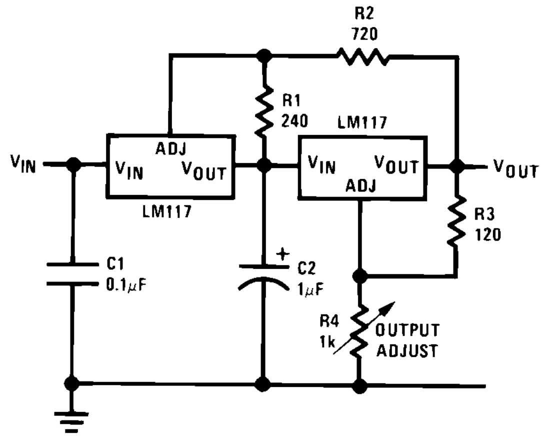
Precision Current Limiter



*0.8Ω ≤ R1 ≤ 120Ω

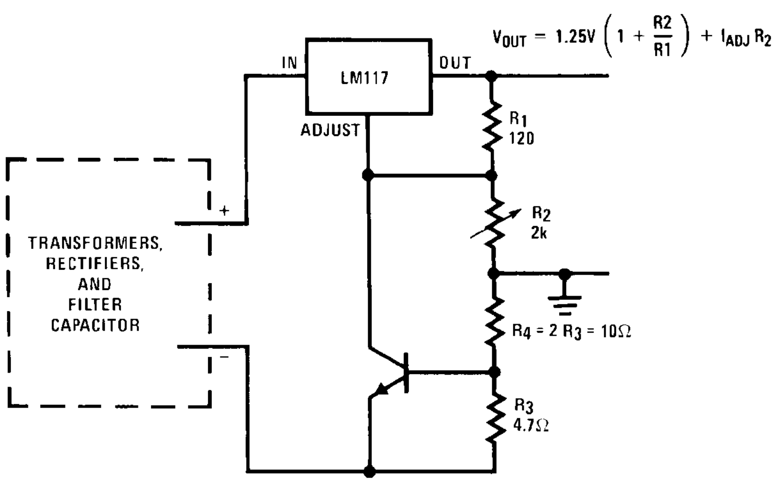
906321

Tracking Preregulator



906322

Current Limited Voltage Regulator



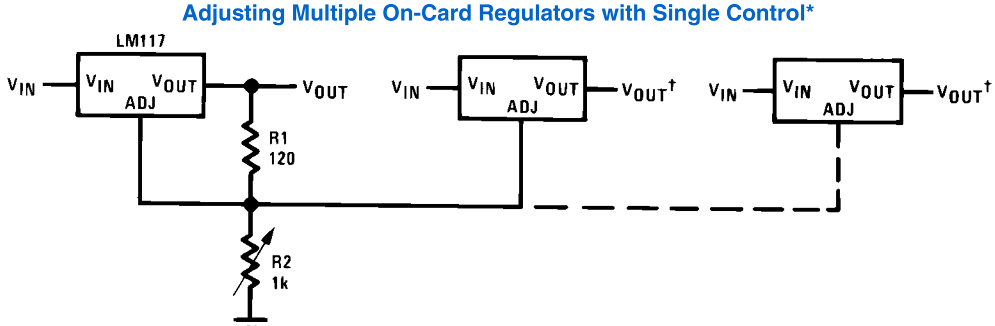
906323

– Short circuit current is approximately $\frac{600\text{ mV}}{R3}$, or 120 mA

(Compared to LM117's higher current limit)

—At 50 mA output only ¾ volt of drop occurs in R_3 and R_4

Adjusting Multiple On-Card Regulators with Single Control*

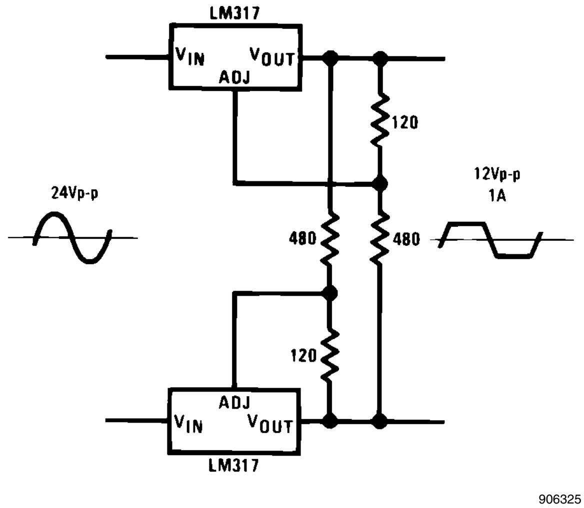


906324

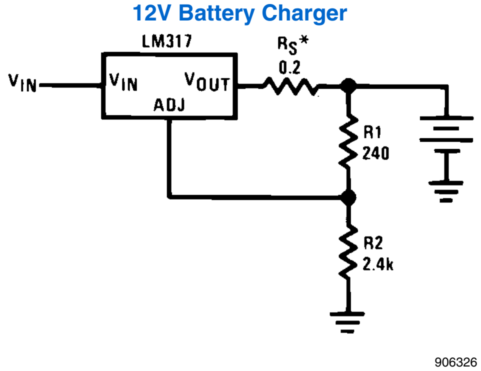
*All outputs within ±100 mV

†Minimum load—10 mA

AC Voltage Regulator



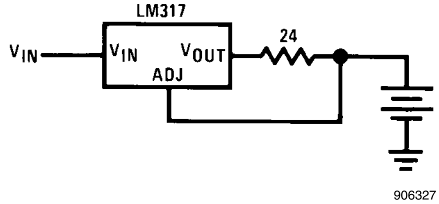
12V Battery Charger



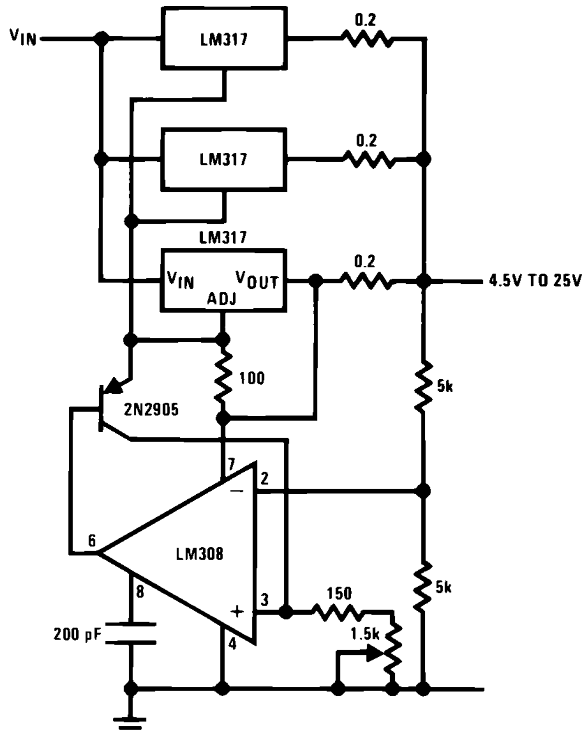
$^*R_S$—sets output impedance of charger: $Z_{OUT} = R_S\left(1 + \frac{R2}{R1}\right)$

Use of R_S allows low charging rates with fully charged battery.

50mA Constant Current Battery Charger

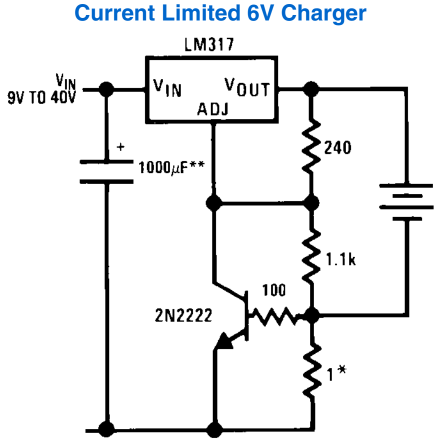


Adjustable 4A Regulator



906328

Current Limited 6V Charger

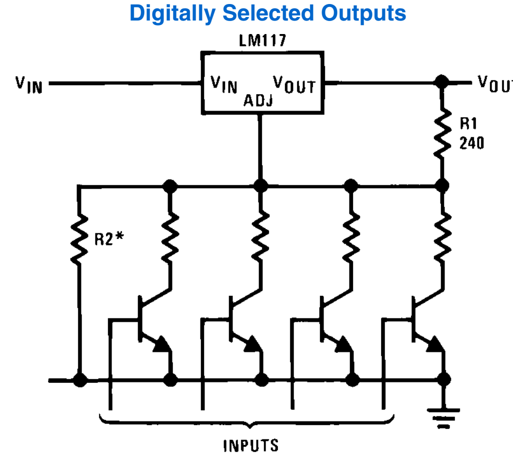


906329

*Sets peak current (0.6A for 1Ω)

**The 1000µF is recommended to filter out input transients

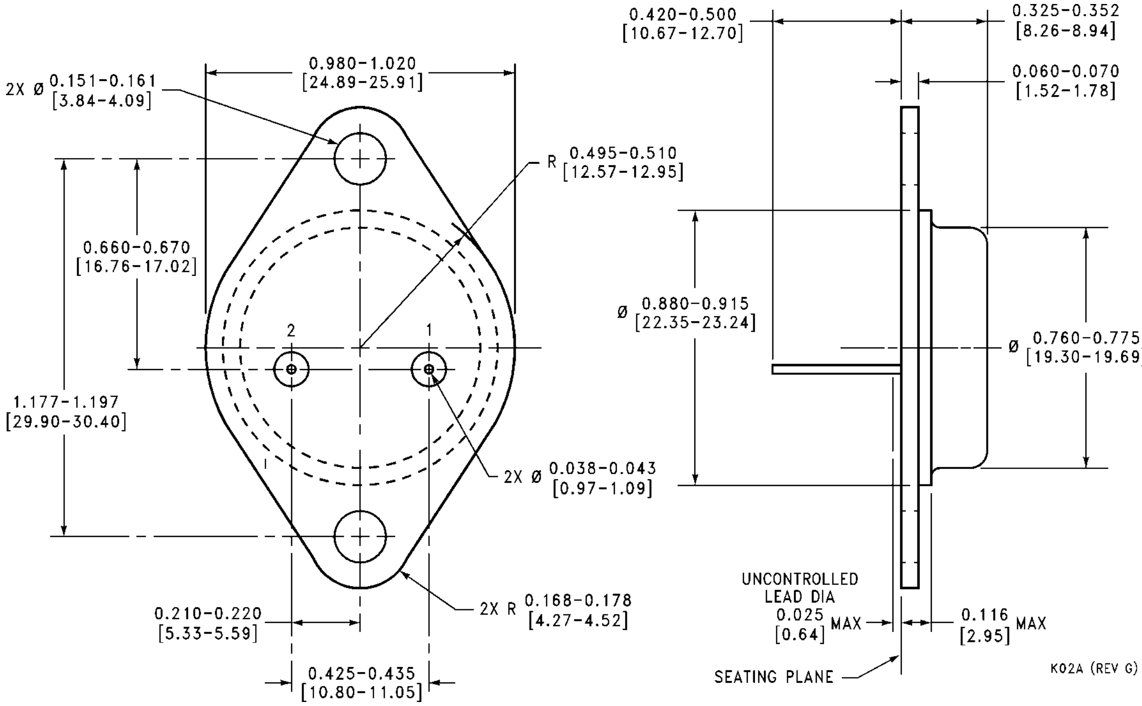
Digitally Selected Outputs



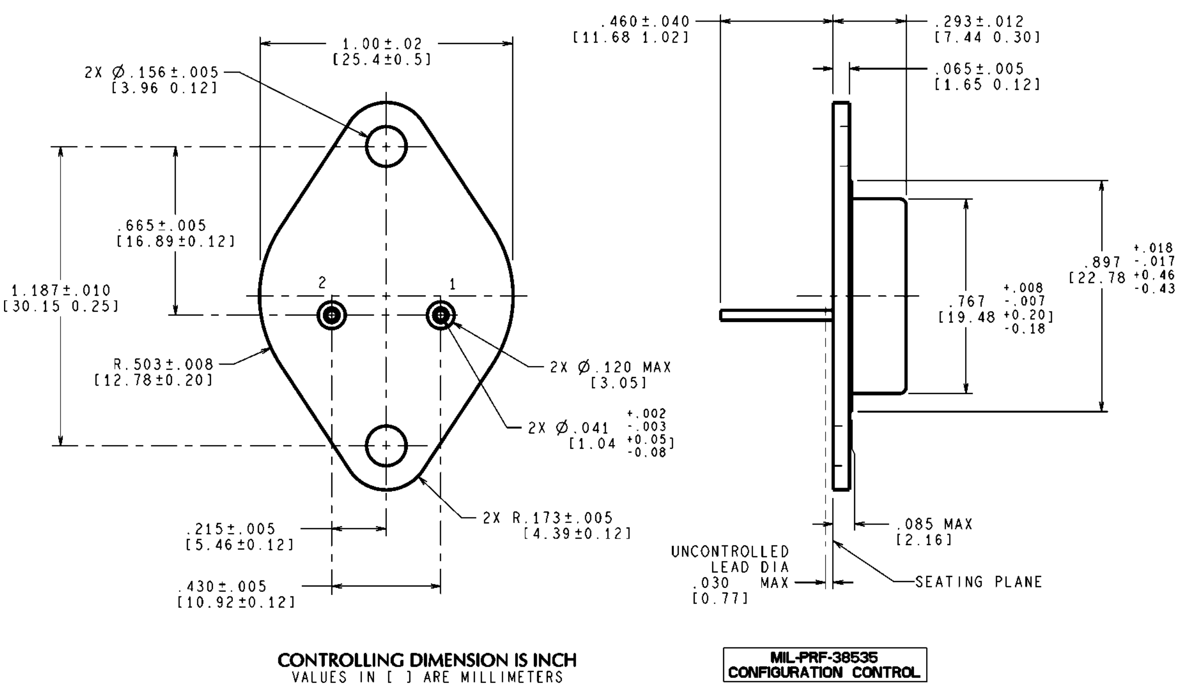
906302

*Sets maximum V_{OUT}

Physical Dimensions inches (millimeters) unless otherwise noted

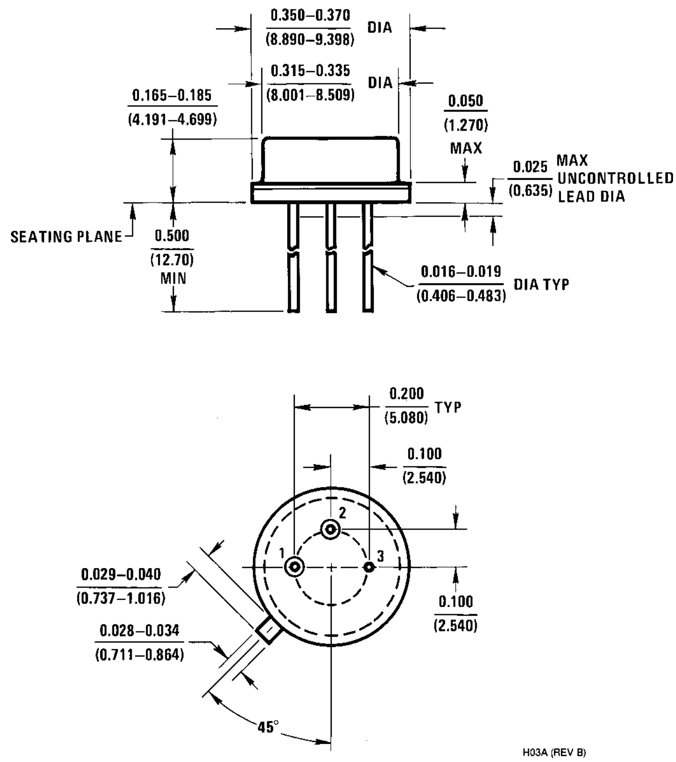


TO-3 Metal Can Package (K)
NS Package Number K02A

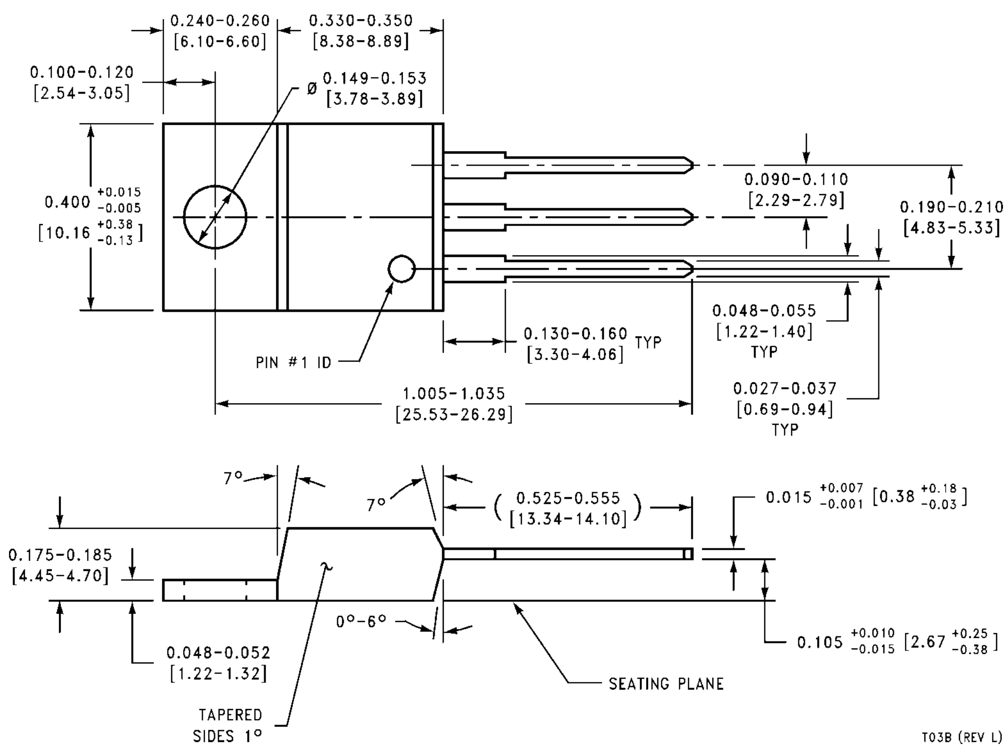


K02C (Rev E)

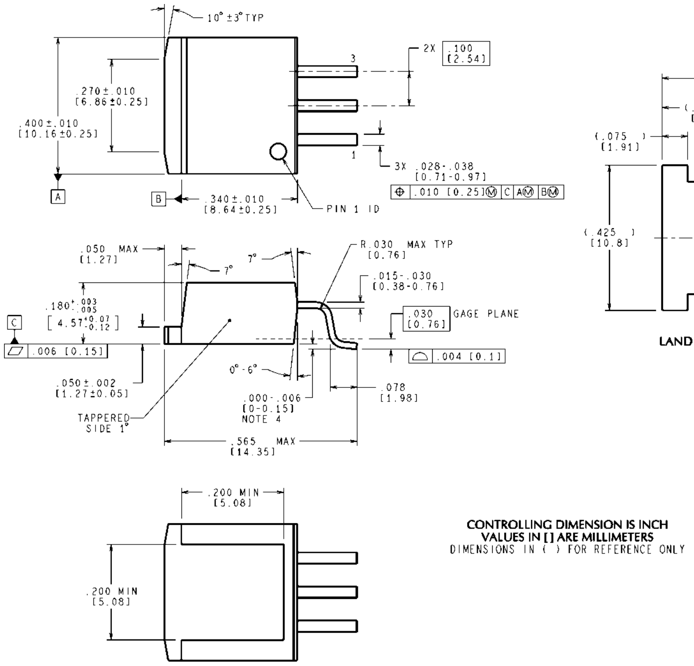
TO-3 Metal Can Package (K)
Mil-Aero Product
NS Package Number K02C



TO-39 Metal Can Package (H)
NS Package Number H03A

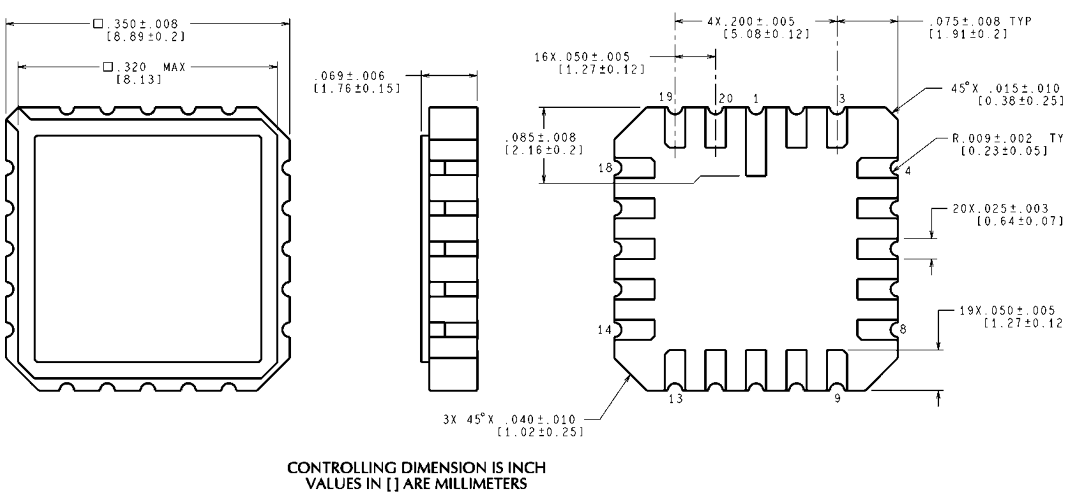


3-Lead TO-220 (T)
NS Package Number T03B



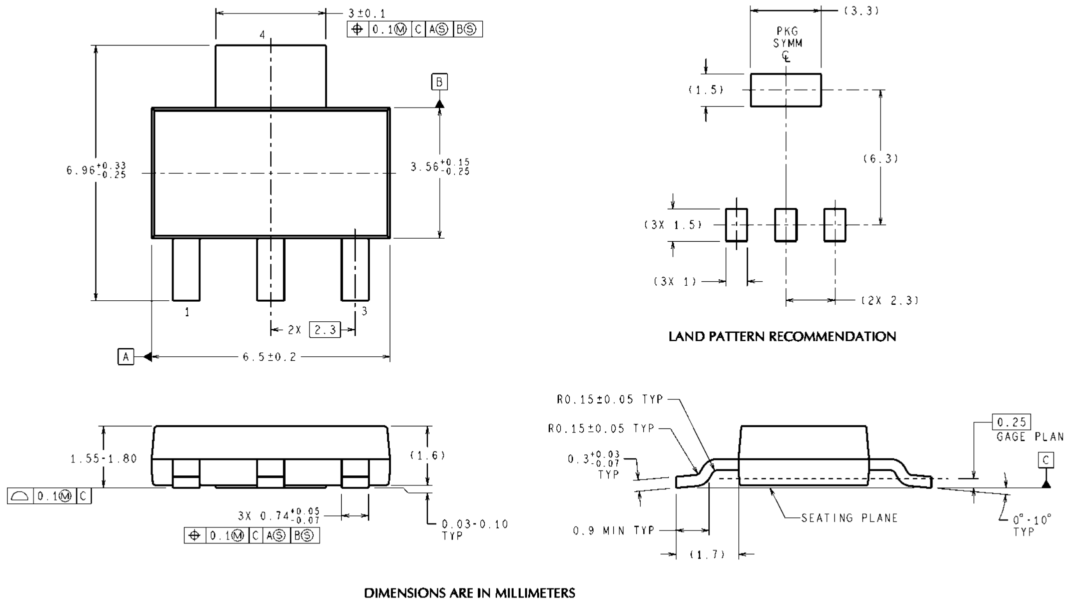
TS3B (Rev F)

3-Lead TO-263 (S)
NS Package Number TS3B



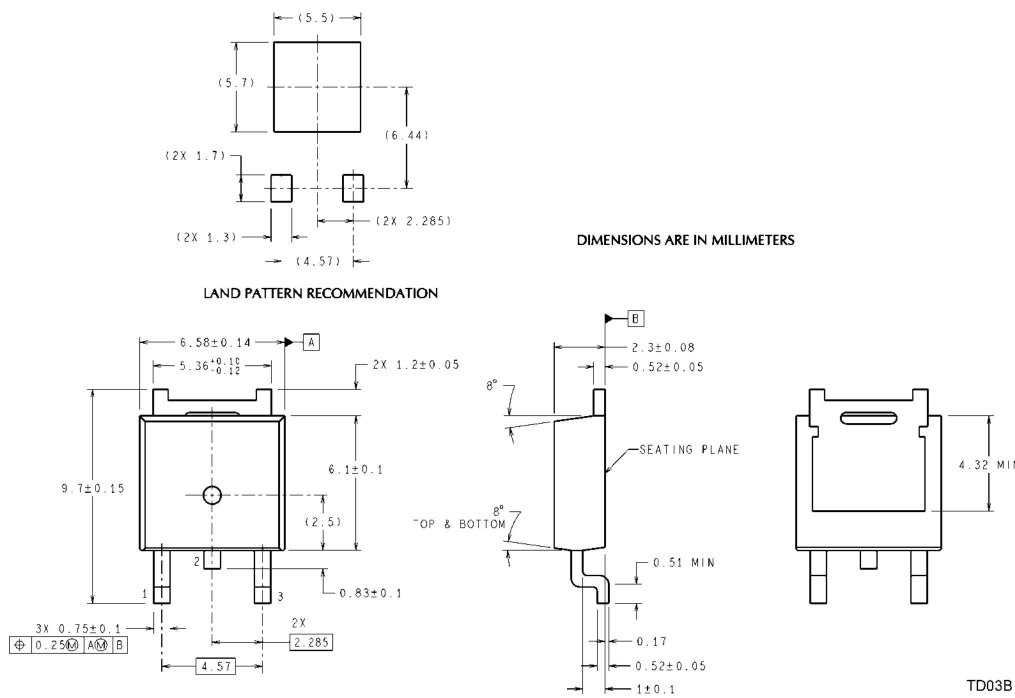
E20A (Rev F)

Ceramic Leadless Chip Carrier (E)
NS Package Number E20A



MP04A (Rev B)

4-Lead SOT-223 (EMP)
NS Package Number MP04A



TD03B (Rev D)

3-Lead D-Pack (MDT)
NS Package Number TD03B

Notes

Notes

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FAIRCHILD SEMICONDUCTOR®

April 2010

LM78XX/LM78XXA
3-Terminal 1A Positive Voltage Regulator

Features

- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

General Description

The LM78XX series of three terminal positive regulators are available in the TO-220 package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

Ordering Information

Product Number	Output Voltage Tolerance	Package	Operating Temperature
LM7805CT	±4%	TO-220	-40°C to +125°C
LM7806CT			
LM7808CT			
LM7809CT			
LM7810CT			
LM7812CT			
LM7815CT			
LM7818CT			
LM7824CT			
LM7805ACT	±2%		0°C to +125°C
LM7806ACT			
LM7808ACT			
LM7809ACT			
LM7810ACT			
LM7812ACT			
LM7815ACT			
LM7818ACT			
LM7824ACT			

Block Diagram

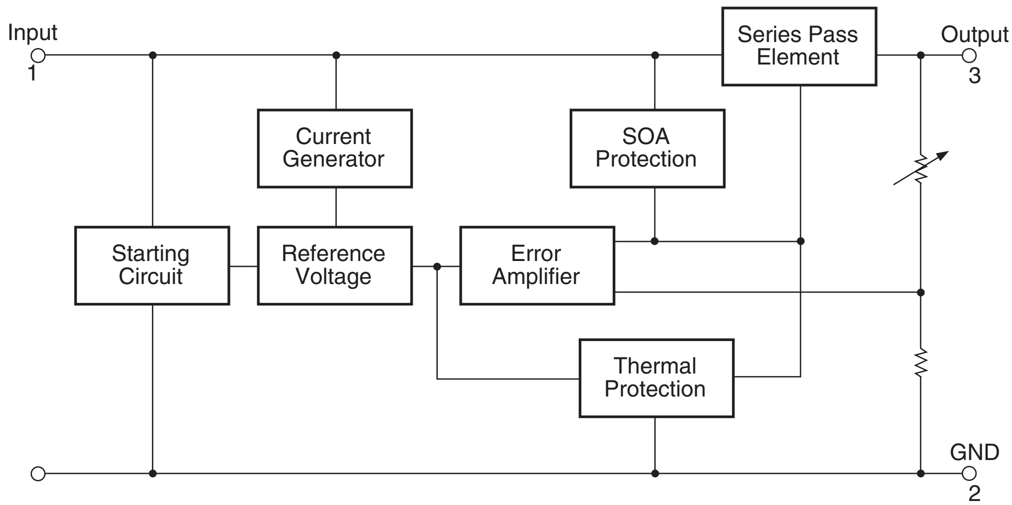


Figure 1.

Pin Assignment

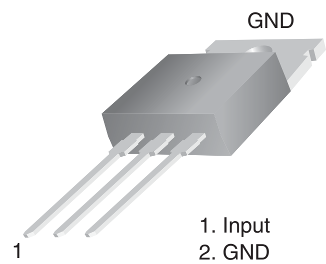


Figure 2.

Absolute Maximum Ratings

Absolute maximum ratings are those values beyond which damage to the device may occur. The datasheet specifications should be met, without exception, to ensure that the system design is reliable over its power supply, temperature, and output/input loading variables. Fairchild does not recommend operation outside datasheet specifications.

Symbol	Parameter		Value	Unit
V_I	Input Voltage	V_O = 5V to 18V	35	V
		V_O = 24V	40	V
$R_{\theta JC}$	Thermal Resistance Junction-Cases (TO-220)		5	°C/W
$R_{\theta JA}$	Thermal Resistance Junction-Air (TO-220)		65	°C/W
T_{OPR}	Operating Temperature Range	LM78xx	-40 to +125	°C
		LM78xxA	0 to +125	
T_{STG}	Storage Temperature Range		-65 to +150	°C

Electrical Characteristics (LM7805)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 10V, C_I = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		4.8	5.0	5.2	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 7V to 20V		4.75	5.0	5.25	
Regline	Line Regulation(1)	T_J = +25°C	V_O = 7V to 25V	–	4.0	100	mV
			V_I = 8V to 12V	–	1.6	50.0	
Regload	Load Regulation(1)	T_J = +25°C	I_O = 5mA to 1.5A	–	9.0	100	mV
			I_O = 250mA to 750mA	–	4.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.0	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	0.03	0.5	mA
		V_I = 7V to 25V		–	0.3	1.3	
$\Delta V_O/\Delta T$	Output Voltage Drift(2)	I_O = 5mA		–	-0.8	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	42.0	–	µV/V_O
RR	Ripple Rejection(2)	f = 120Hz, V_O = 8V to 18V		62.0	73.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(2)	f = 1kHz		–	15.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	230	–	mA
I_{PK}	Peak Current(2)	T_J = +25°C		–	2.2	–	A

Notes:

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
2. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7806) (Continued)

Refer to the test circuits. $-40°C < T_J < 125°C$, $I_O = 500mA$, $V_I = 11V$, $C_I = 0.33\mu F$, $C_O = 0.1\mu F$, unless otherwise specified.

Symbol	Parameter	Conditions		Min	Typ.	Max.	Unit
V_O	Output Voltage	$T_J = +25°C$		5.75	6.0	6.25	V
		$5mA \le I_O \le 1A$, $P_O \le 15W$, $V_I = 8.0V$ to $21V$		5.7	6.0	6.3	
Regline	Line Regulation[3]	$T_J = +25°C$	$V_I = 8V$ to $25V$	–	5.0	120	mV
			$V_I = 9V$ to $13V$	–	1.5	60.0	
Regload	Load Regulation[3]	$T_J = +25°C$	$I_O = 5mA$ to $1.5A$	–	9.0	120	mV
			$I_O = 250mA$ to $750mA$	–	3.0	60.0	
I_Q	Quiescent Current	$T_J = +25°C$		–	5.0	8.0	mA
ΔI_Q	Quiescent Current Change	$I_O = 5mA$ to $1A$		–	–	0.5	mA
		$V_I = 8V$ to $25V$		–	–	1.3	
$\Delta V_O/\Delta T$	Output Voltage Drift[4]	$I_O = 5mA$		–	-0.8	–	mV/°C
V_N	Output Noise Voltage	$f = 10Hz$ to $100kHz$, $T_A = +25°C$		–	45.0	–	$\mu V/V_O$
RR	Ripple Rejection[4]	$f = 120Hz$, $V_O = 8V$ to $18V$		62.0	73.0	–	dB
V_{DROP}	Dropout Voltage	$I_O = 1A$, $T_J = +25°C$		–	2.0	–	V
r_O	Output Resistance[4]	$f = 1kHz$		–	19.0	–	mΩ
I_{SC}	Short Circuit Current	$V_I = 35V$, $T_A = +25°C$		–	250	–	mA
I_{PK}	Peak Current[4]	$T_J = +25°C$		–	2.2	–	A

Notes:

3. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
4. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7808) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 14V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		7.7	8.0	8.3	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 10.5V to 23V		7.6	8.0	8.4	
Regline	Line Regulation(5)	T_J = +25°C	V_I = 10.5V to 25V	–	5.0	160	mV
			V_I = 11.5V to 17V	–	2.0	80.0	
Regload	Load Regulation(5)	T_J = +25°C	I_O = 5mA to 1.5A	–	10.0	160	mV
			I_O = 250mA to 750mA	–	5.0	80.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.0	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	0.05	0.5	mA
		V_I = 10.5V to 25V		–	0.5	1.0	
$\Delta V_O/\Delta T$	Output Voltage Drift(6)	I_O = 5mA		–	-0.8	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	52.0	–	µV/V_O
RR	Ripple Rejection(6)	f = 120Hz, V_O = 11.5V to 21.5V		56.0	73.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(6)	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	230	–	mA
I_{PK}	Peak Current(6)	T_J = +25°C		–	2.2	–	A

Notes:

5. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
6. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7809) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 15V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		8.65	9.0	9.35	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 11.5V to 24V		8.6	9.0	9.4	
Regline	Line Regulation(7)	T_J = +25°C	V_I = 11.5V to 25V	–	6.0	180	mV
			V_I = 12V to 17V	–	2.0	90.0	
Regload	Load Regulation(7)	T_J = +25°C	I_O = 5mA to 1.5A	–	12.0	180	mV
			I_O = 250mA to 750mA	–	4.0	90.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.0	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 11.5V to 26V		–	–	1.3	
$\Delta V_O/\Delta T$	Output Voltage Drift(8)	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	58.0	–	µV/V_O
RR	Ripple Rejection(8)	f = 120Hz, V_O = 13V to 23V		56.0	71.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(8)	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(8)	T_J = +25°C		–	2.2	–	A

Notes:

7. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
8. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7810) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 16V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		9.6	10.0	10.4	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 12.5V to 25V		9.5	10.0	10.5	
Regline	Line Regulation(9)	T_J = +25°C	V_I = 12.5V to 25V	–	10.0	200	mV
			V_I = 13V to 25V	–	3.0	100	
Regload	Load Regulation(9)	T_J = +25°C	I_O = 5mA to 1.5A	–	12.0	200	mV
			I_O = 250mA to 750mA	–	4.0	400	
I_Q	Quiescent Current	T_J = +25°C		–	5.1	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 12.5V to 29V		–	–	1.0	
$\Delta V_O/\Delta T$	Output Voltage Drift(10)	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	58.0	–	µV/V_O
RR	Ripple Rejection(10)	f = 120Hz, V_O = 13V to 23V		56.0	71.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(10)	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(10)	T_J = +25°C		–	2.2	–	A

Notes:

9. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
10. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7812) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 19V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		11.5	12.0	12.5	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 14.5V to 27V		11.4	12.0	12.6	
Regline	Line Regulation[11]	T_J = +25°C	V_I = 14.5V to 30V	–	10.0	240	mV
			V_I = 16V to 22V	–	3.0	120	
Regload	Load Regulation[11]	T_J = +25°C	I_O = 5mA to 1.5A	–	11.0	240	mV
			I_O = 250mA to 750mA	–	5.0	120	
I_Q	Quiescent Current	T_J = +25°C		–	5.1	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	0.1	0.5	mA
		V_I = 14.5V to 30V		–	0.5	1.0	
$\Delta V_O/\Delta T$	Output Voltage Drift[12]	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	76.0	–	µV/V_O
RR	Ripple Rejection[12]	f = 120Hz, V_I = 15V to 25V		55.0	71.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance[12]	f = 1kHz		–	18.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	230	–	mA
I_{PK}	Peak Current[12]	T_J = +25°C		–	2.2	–	A

Notes:

11. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
12. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7815) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 23V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		14.4	15.0	15.6	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 17.5V to 30V		14.25	15.0	15.75	
Regline	Line Regulation(13)	T_J = +25°C	V_I = 17.5V to 30V	–	11.0	300	mV
			V_I = 20V to 26V	–	3.0	150	
Regload	Load Regulation(13)	T_J = +25°C	I_O = 5mA to 1.5A	–	12.0	300	mV
			I_O = 250mA to 750mA	–	4.0	150	
I_Q	Quiescent Current	T_J = +25°C		–	5.2	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 17.5V to 30V		–	–	1.0	
$\Delta V_O/\Delta T$	Output Voltage Drift(14)	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	90.0	–	µV/V_O
RR	Ripple Rejection(14)	f = 120Hz, V_I = 18.5V to 28.5V		54.0	70.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(14)	f = 1kHz		–	19.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(14)	T_J = +25°C		–	2.2	–	A

Notes:

13. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
14. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7818) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 27V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		17.3	18.0	18.7	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 21V to 33V		17.1	18.0	18.9	
Regline	Line Regulation(15)	T_J = +25°C	V_I = 21V to 33V	–	15.0	360	mV
			V_I = 24V to 30V	–	5.0	180	
Regload	Load Regulation(15)	T_J = +25°C	I_O = 5mA to 1.5A	–	15.0	360	mV
			I_O = 250mA to 750mA	–	5.0	180	
I_Q	Quiescent Current	T_J = +25°C		–	5.2	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 21V to 33V		–	–	1.0	
$\Delta V_O/\Delta T$	Output Voltage Drift(16)	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	110	–	µV/V_O
RR	Ripple Rejection(16)	f = 120Hz, V_I = 22V to 32V		53.0	69.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(16)	f = 1kHz		–	22.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(16)	T_J = +25°C		–	2.2	–	A

Notes:

15. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
16. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7824) (Continued)

Refer to the test circuits. -40°C < T_J < 125°C, I_O = 500mA, V_I = 33V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		23.0	24.0	25.0	V
		5mA ≤ I_O ≤ 1A, P_O ≤ 15W, V_I = 27V to 38V		22.8	24.0	25.25	
Regline	Line Regulation(17)	T_J = +25°C	V_I = 27V to 38V	–	17.0	480	mV
			V_I = 30V to 36V	–	6.0	240	
Regload	Load Regulation(17)	T_J = +25°C	I_O = 5mA to 1.5A	–	15.0	480	mV
			I_O = 250mA to 750mA	–	5.0	240	
I_Q	Quiescent Current	T_J = +25°C		–	5.2	8.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	0.1	0.5	mA
		V_I = 27V to 38V		–	0.5	1.0	
$\Delta V_O/\Delta T$	Output Voltage Drift(18)	I_O = 5mA		–	-1.5	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	60.0	–	µV/V_O
RR	Ripple Rejection(18)	f = 120Hz, V_I = 28V to 38V		50.0	67.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
rO	Output Resistance(18)	f = 1kHz		–	28.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	230	–	mA
I_{PK}	Peak Current(18)	T_J = +25°C		–	2.2	–	A

Notes:

17. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
18. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7805A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 10V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		4.9	5.0	5.1	V
		I_O = 5mA to 1A, P_O ≤ 15W, V_I = 7.5V to 20V		4.8	5.0	5.2	
Regline	Line Regulation(19)	V_I = 7.5V to 25V, I_O = 500mA		–	5.0	50.0	mV
		V_I = 8V to 12V		–	3.0	50.0	
		T_J = +25°C	V_I = 7.3V to 20V	–	5.0	50.0	
			V_I = 8V to 12V	–	1.5	25.0	
Regload	Load Regulation(19)	T_J = +25°C, I_O = 5mA to 1.5A		–	9.0	100	mV
		I_O = 5mA to 1A		–	9.0	100	
		I_O = 250mA to 750mA		–	4.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.0	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 8V to 25V, I_O = 500mA		–	–	0.8	
		V_I = 7.5V to 20V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift(20)	I_O = 5mA		–	-0.8	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	µV/V_O
RR	Ripple Rejection(20)	f = 120Hz, I_O = 500mA, V_I = 8V to 18V		–	68.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(20)	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(20)	T_J = +25°C		–	2.2	–	A

Notes:

19. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
20. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7806A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 11V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		5.58	6.0	6.12	V
		I_O = 5mA to 1A, P_O ≤ 15W, V_I = 8.6V to 21V		5.76	6.0	6.24	
Regline	Line Regulation[21]	V_I = 8.6V to 25V, I_O = 500mA		–	5.0	60.0	mV
		V_I = 9V to 13V		–	3.0	60.0	
		T_J = +25°C	V_I = 8.3V to 21V	–	5.0	60.0	
			V_I = 9V to 13V	–	1.5	30.0	
Regload	Load Regulation[21]	T_J = +25°C, I_O = 5mA to 1.5A		–	9.0	100	mV
		I_O = 5mA to 1A		–	9.0	100	
		I_O = 250mA to 750mA		–	5.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	4.3	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 19V to 25V, I_O = 500mA		–	–	0.8	
		V_I = 8.5V to 21V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift[22]	I_O = 5mA		–	-0.8	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	µV/V_O
RR	Ripple Rejection[22]	f = 120Hz, I_O = 500mA, V_I = 9V to 19V		–	65.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance[22]	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current[22]	T_J = +25°C		–	2.2	–	A

Notes:

21. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
22. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7808A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 14V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_O	Output Voltage	T_J = +25°C		7.84	8.0	8.16	V
		I_O = 5mA to 1A, P_O ≤ 15W, V_I = 10.6V to 23V		7.7	8.0	8.3	
Regline	Line Regulation(23)	V_I = 10.6V to 25V, I_O = 500mA		–	6.0	80.0	mV
		V_I = 11V to 17V		–	3.0	80.0	
		T_J = +25°C	V_I = 10.4V to 23V	–	6.0	80.0	
			V_I = 11V to 17V	–	2.0	40.0	
Regload	Load Regulation(23)	T_J = +25°C, I_O = 5mA to 1.5A		–	12.0	100	mV
		I_O = 5mA to 1A		–	12.0	100	
		I_O = 250mA to 750mA		–	5.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.0	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 11V to 25V, I_O = 500mA		–	–	0.8	
		V_I = 10.6V to 23V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift(24)	I_O = 5mA		–	-0.8	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	µV/V_O
RR	Ripple Rejection(24)	f = 120Hz, I_O = 500mA, V_I = 11.5V to 21.5V		–	62.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(24)	f = 1kHz		–	18.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(24)	T_J = +25°C		–	2.2	–	A

Notes:

23. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
24. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7809A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 15V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
V_O	Output Voltage	T_J = +25°C		8.82	9.0	9.16	V
		I_O = 5mA to 1A, P_O ≤ 15W, V_I = 11.2V to 24V		8.65	9.0	9.35	
Regline	Line Regulation(25)	V_I = 11.7V to 25V, I_O = 500mA		–	6.0	90.0	mV
		V_I = 12.5V to 19V		–	4.0	45.0	
		T_J = +25°C	V_I = 11.5V to 24V	–	6.0	90.0	
			V_I = 12.5V to 19V	–	2.0	45.0	
Regload	Load Regulation(25)	T_J = +25°C, I_O = 5mA to 1.5A		–	12.0	100	mV
		I_O = 5mA to 1A		–	12.0	100	
		I_O = 250mA to 750mA		–	5.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.0	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 12V to 25V, I_O = 500mA		–	–	0.8	
		V_I = 11.7V to 25V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift(26)	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	µV/V_O
RR	Ripple Rejection(26)	f = 120Hz, I_O = 500mA, V_I = 12V to 22V		–	62.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(26)	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(26)	T_J = +25°C		–	2.2	–	A

Notes:

25. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
26. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7810A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 16V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
V_O	Output Voltage	T_J = +25°C		9.8	10.0	10.2	V
		I_O = 5mA to 1A, $P_O \leq$ 15W, V_I = 12.8V to 25V		9.6	10.0	10.4	
Regline	Line Regulation[27]	V_I = 12.8V to 26V, I_O = 500mA		–	8.0	100	mV
		V_I = 13V to 20V		–	4.0	50.0	
		T_J = +25°C	V_I = 12.5V to 25V	–	8.0	100	
			V_I = 13V to 20V	–	3.0	50.0	
Regload	Load Regulation[27]	T_J = +25°C, I_O = 5mA to 1.5A		–	12.0	100	mV
		I_O = 5mA to 1A		–	12.0	100	
		I_O = 250mA to 750mA		–	5.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.0	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 12.8V to 25V, I_O = 500mA		–	–	0.8	
		V_I = 13V to 26V, T_J = +25°C		–	–	0.5	
$\Delta V_O/\Delta T$	Output Voltage Drift[28]	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	µV/V_O
RR	Ripple Rejection[28]	f = 120Hz, I_O = 500mA, V_I = 14V to 24V		–	62.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance[28]	f = 1kHz		–	17.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current[28]	T_J = +25°C		–	2.2	–	A

Notes:

27. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
28. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7812A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 19V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
V_O	Output Voltage	T_J = +25°C		11.75	12.0	12.25	V
		I_O = 5mA to 1A, P_O ≤ 15W, V_I = 14.8V to 27V		11.5	12.0	12.5	
Regline	Line Regulation[29]	V_I = 14.8V to 30V, I_O = 500mA		–	10.0	120	mV
		V_I = 16V to 22V		–	4.0	120	
		T_J = +25°C	V_I = 14.5V to 27V	–	10.0	120	
			V_I = 16V to 22V	–	3.0	60.0	
Regload	Load Regulation[29]	T_J = +25°C, I_O = 5mA to 1.5A		–	12.0	100	mV
		I_O = 5mA to 1A		–	12.0	100	
		I_O = 250mA to 750mA		–	5.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.1	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 14V to 27V, I_O = 500mA		–	–	0.8	
		V_I = 15V to 30V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift[30]	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	µV/V_O
RR	Ripple Rejection[30]	f = 120Hz, I_O = 500mA, V_I = 14V to 24V		–	60.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance[30]	f = 1kHz		–	18.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current[30]	T_J = +25°C		–	2.2	–	A

Note:

29. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
30. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7815A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 23V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
V_O	Output Voltage	T_J = +25°C		14.75	15.0	15.3	V
		I_O = 5mA to 1A, P_O ≤ 15W, V_I = 17.7V to 30V		14.4	15.0	15.6	
Regline	Line Regulation(31)	V_I = 17.4V to 30V, I_O = 500mA		–	10.0	150	mV
		V_I = 20V to 26V		–	5.0	150	
		T_J = +25°C	V_I = 17.5V to 30V	–	11.0	150	
			V_I = 20V to 26V	–	3.0	75.0	
Regload	Load Regulation(31)	T_J = +25°C, I_O = 5mA to 1.5A		–	12.0	100	mV
		I_O = 5mA to 1A		–	12.0	100	
		I_O = 250mA to 750mA		–	5.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.2	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 17.5V to 30V, I_O = 500mA		–	–	0.8	
		V_I = 17.5V to 30V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift(32)	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	µV/V_O
RR	Ripple Rejection(32)	f = 120Hz, I_O = 500mA, V_I = 18.5V to 28.5V		–	58.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance(32)	f = 1kHz		–	19.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current(32)	T_J = +25°C		–	2.2	–	A

Notes:

31. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
32. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7818A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 27V, C_I = 0.33µF, C_O = 0.1µF, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
V_O	Output Voltage	T_J = +25°C		17.64	18.0	18.36	V
		I_O = 5mA to 1A, P_O ≤ 15W, V_I = 21V to 33V		17.3	18.0	18.7	
Regline	Line Regulation[33]	V_I = 21V to 33V, I_O = 500mA		–	15.0	180	mV
		V_I = 21V to 33V		–	5.0	180	
		T_J = +25°C	V_I = 20.6V to 33V	–	15.0	180	
			V_I = 24V to 30V	–	5.0	90.0	
Regload	Load Regulation[33]	T_J = +25°C, I_O = 5mA to 1.5A		–	15.0	100	mV
		I_O = 5mA to 1A		–	15.0	100	
		I_O = 250mA to 750mA		–	7.0	50.0	
I_Q	Quiescent Current	T_J = +25°C		–	5.2	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A		–	–	0.5	mA
		V_I = 12V to 33V, I_O = 500mA		–	–	0.8	
		V_I = 12V to 33V, T_J = +25°C		–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift[34]	I_O = 5mA		–	-1.0	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C		–	10.0	–	$\mu V/V_O$
RR	Ripple Rejection[34]	f = 120Hz, I_O = 500mA, V_I = 22V to 32V		–	57.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C		–	2.0	–	V
r_O	Output Resistance[34]	f = 1kHz		–	19.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C		–	250	–	mA
I_{PK}	Peak Current[34]	T_J = +25°C		–	2.2	–	A

Notes:

33. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
34. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7824A) (Continued)

Refer to the test circuits. 0°C < T_J < 125°C, I_O = 1A, V_I = 33V, C_I = 0.33μF, C_O = 0.1μF, unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
V_O	Output Voltage	T_J = +25°C	23.5	24.0	24.5	V
		I_O = 5mA to 1A, P_O ≤ 15W, V_I = 27.3V to 38V	23.0	24.0	25.0	
Regline	Line Regulation(35)	V_I = 27V to 38V, I_O = 500mA	–	18.0	240	mV
		V_I = 21V to 33V	–	6.0	240	
		T_J = +25°C, V_I = 26.7V to 38V	–	18.0	240	
		T_J = +25°C, V_I = 30V to 36V	–	6.0	120	
Regload	Load Regulation(35)	T_J = +25°C, I_O = 5mA to 1.5A	–	15.0	100	mV
		I_O = 5mA to 1A	–	15.0	100	
		I_O = 250mA to 750mA	–	7.0	50.0	
I_Q	Quiescent Current	T_J = +25°C	–	5.2	6.0	mA
ΔI_Q	Quiescent Current Change	I_O = 5mA to 1A	–	–	0.5	mA
		V_I = 27.3V to 38V, I_O = 500mA	–	–	0.8	
		V_I = 27.3V to 38V, T_J = +25°C	–	–	0.8	
$\Delta V_O/\Delta T$	Output Voltage Drift(36)	I_O = 5mA	–	-1.5	–	mV/°C
V_N	Output Noise Voltage	f = 10Hz to 100kHz, T_A = +25°C	–	10.0	–	μV/V_O
RR	Ripple Rejection(36)	f = 120Hz, I_O = 500mA, V_I = 28V to 38V	–	54.0	–	dB
V_{DROP}	Dropout Voltage	I_O = 1A, T_J = +25°C	–	2.0	–	V
r_O	Output Resistance(36)	f = 1kHz	–	20.0	–	mΩ
I_{SC}	Short Circuit Current	V_I = 35V, T_A = +25°C	–	250	–	mA
I_{PK}	Peak Current(36)	T_J = +25°C	–	2.2	–	A

Notes:

35. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.
36. These parameters, although guaranteed, are not 100% tested in production.

Typical Performance Characteristics

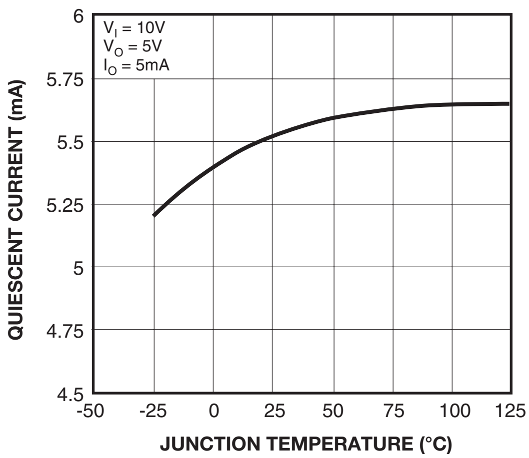


Figure 3. Quiescent Current

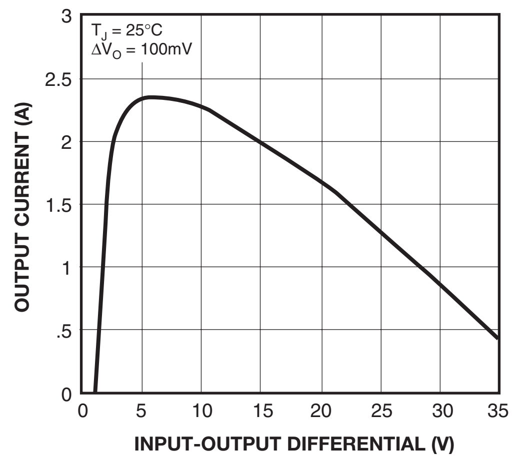


Figure 4. Peak Output Current

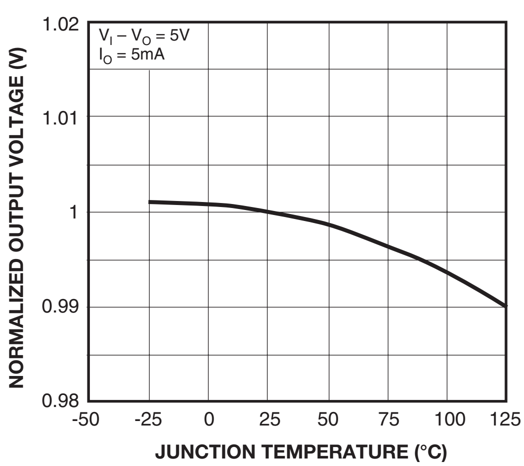


Figure 5. Output Voltage

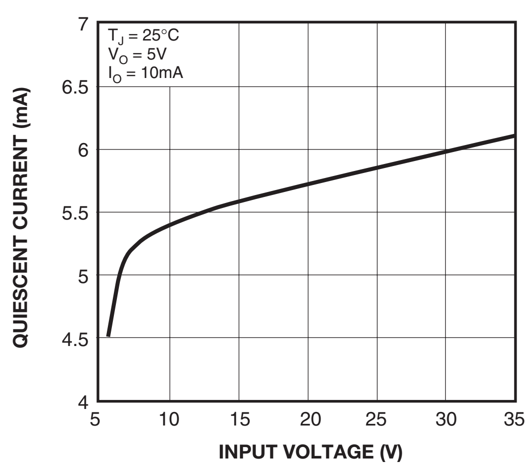


Figure 6. Quiescent Current

Typical Applications

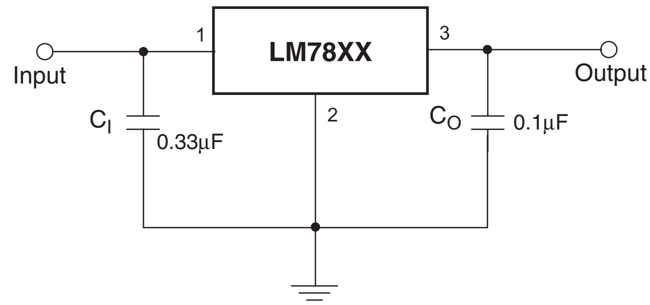


Figure 7. DC Parameters

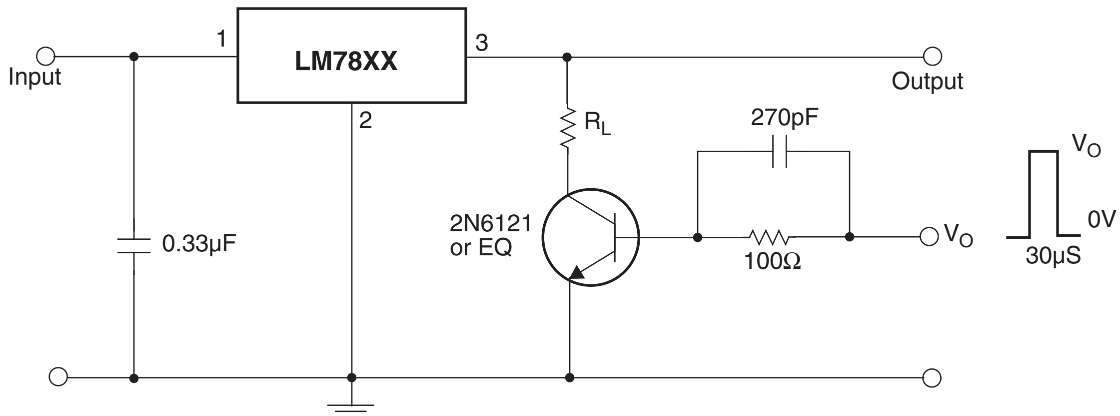


Figure 8. Load Regulation

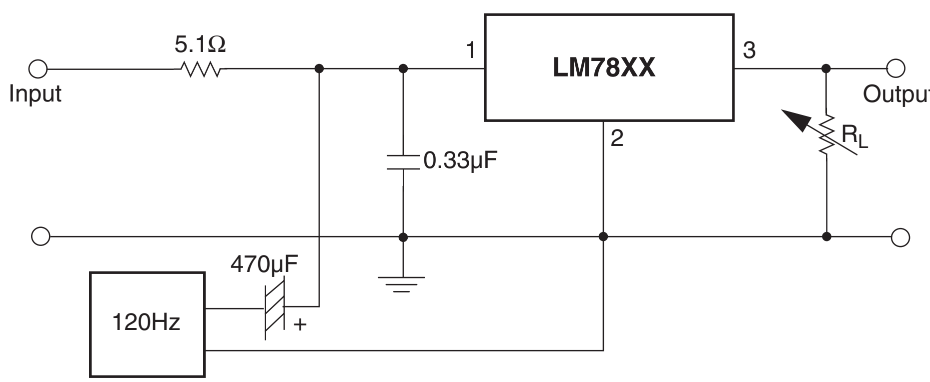


Figure 9. Ripple Rejection

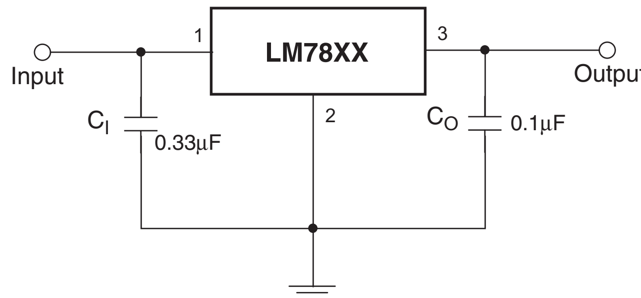
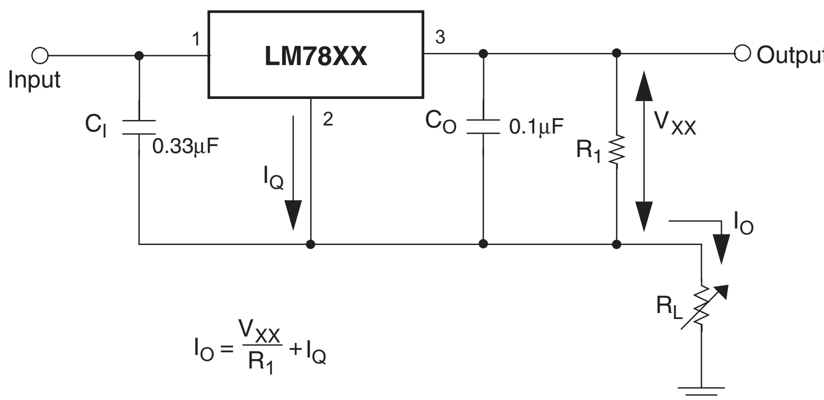


Figure 10. Fixed Output Regulator



Notes:
1. To specify an output voltage, substitute voltage value for "XX." A common ground is required between the input and the output voltage. The input voltage must remain typically 2.0V above the output voltage even during the low point on the input ripple voltage.
2. C_I is required if regulator is located an appreciable distance from power supply filter.
3. C_O improves stability and transient response.

Figure 11.

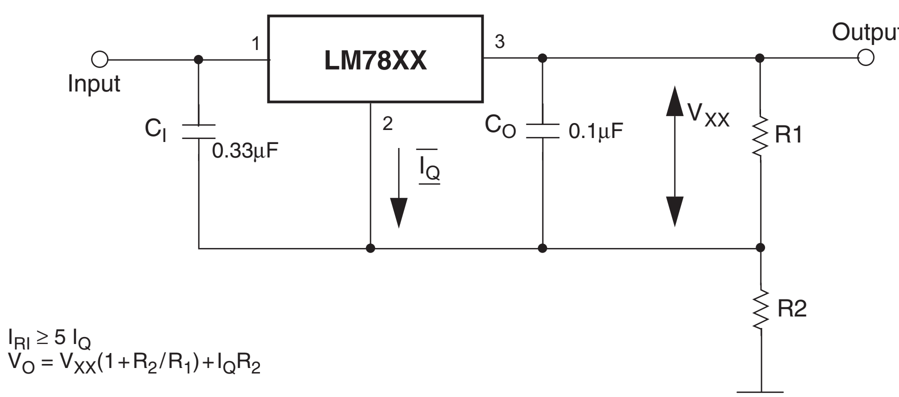


Figure 12. Circuit for Increasing Output Voltage

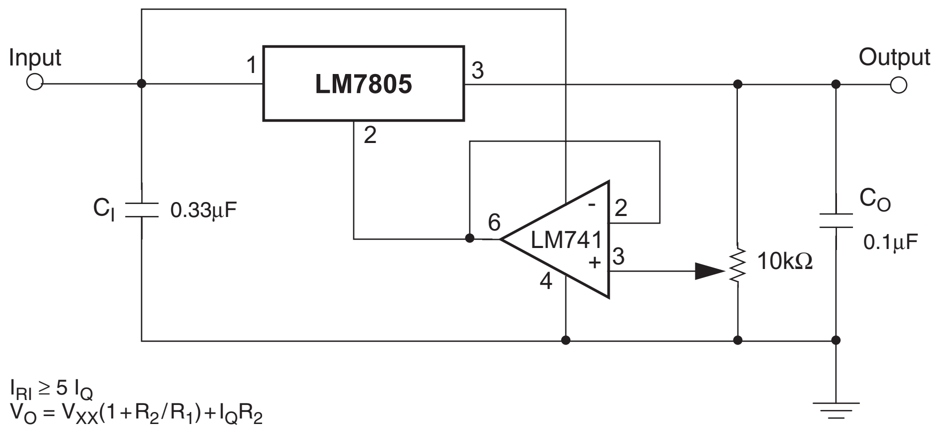


Figure 13. Adjustable Output Regulator (7V to 30V)

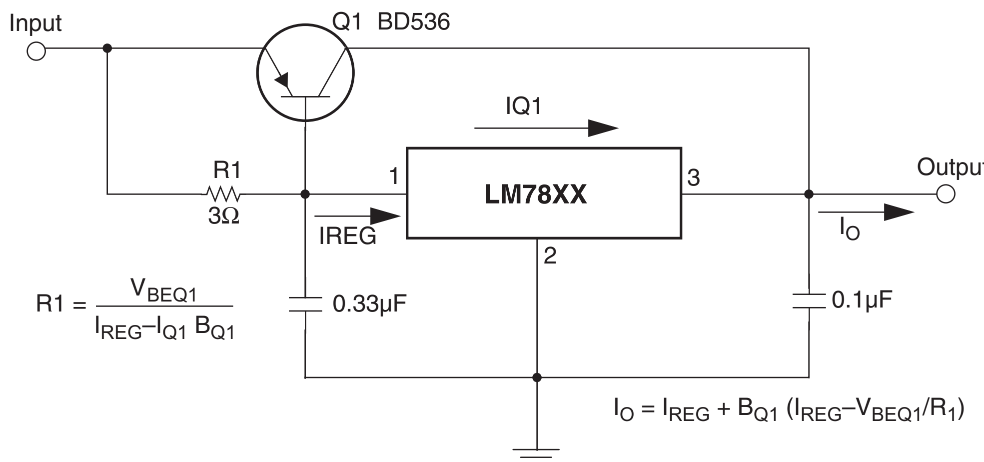


Figure 14. High Current Voltage Regulator

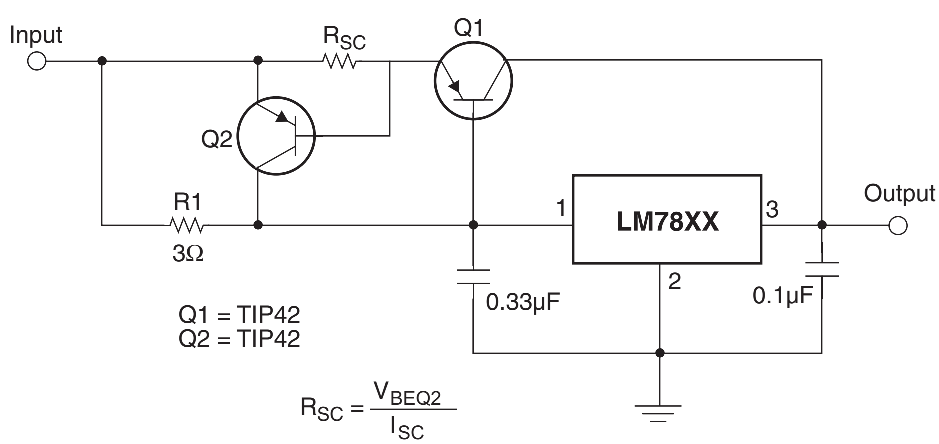


Figure 15. High Output Current with Short Circuit Protection

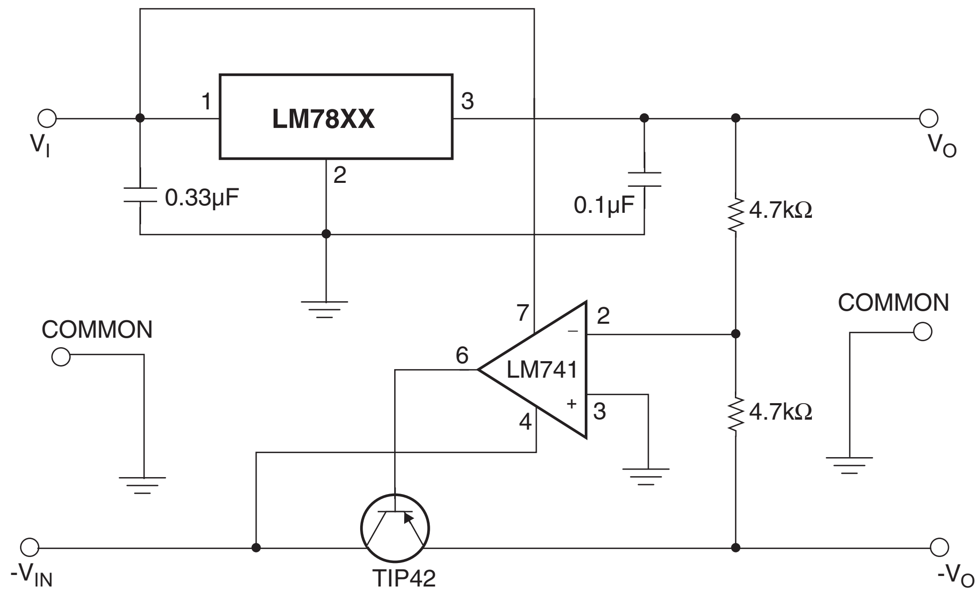


Figure 16. Tracking Voltage Regulator

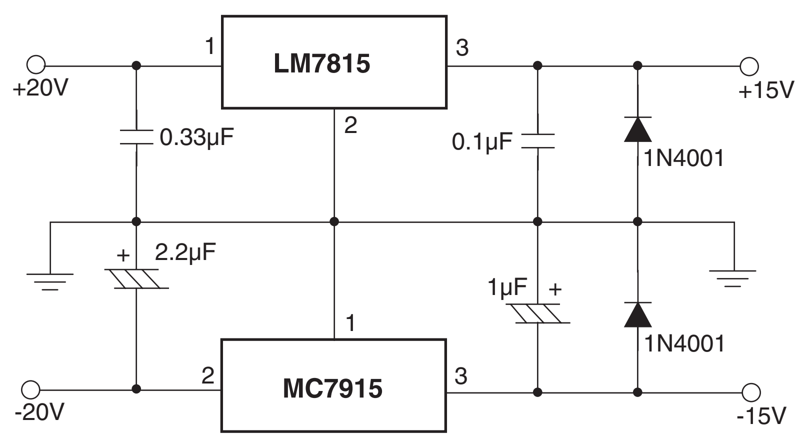


Figure 17. Split Power Supply (±15V – 1A)

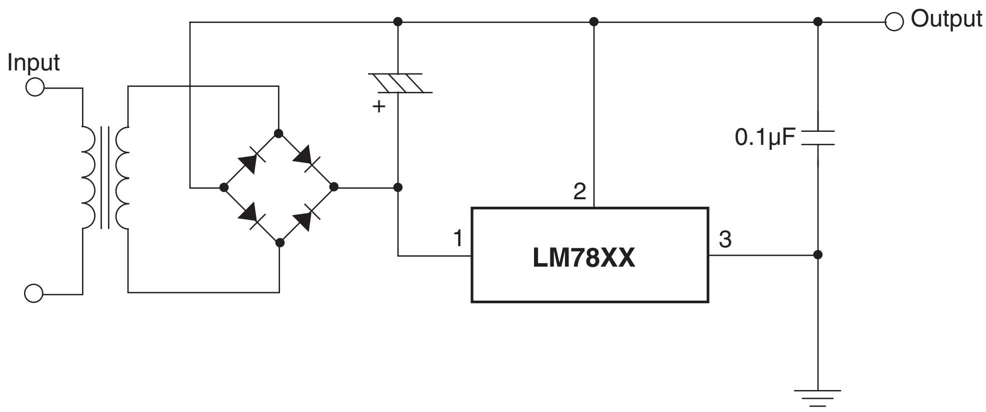


Figure 18. Negative Output Voltage Circuit

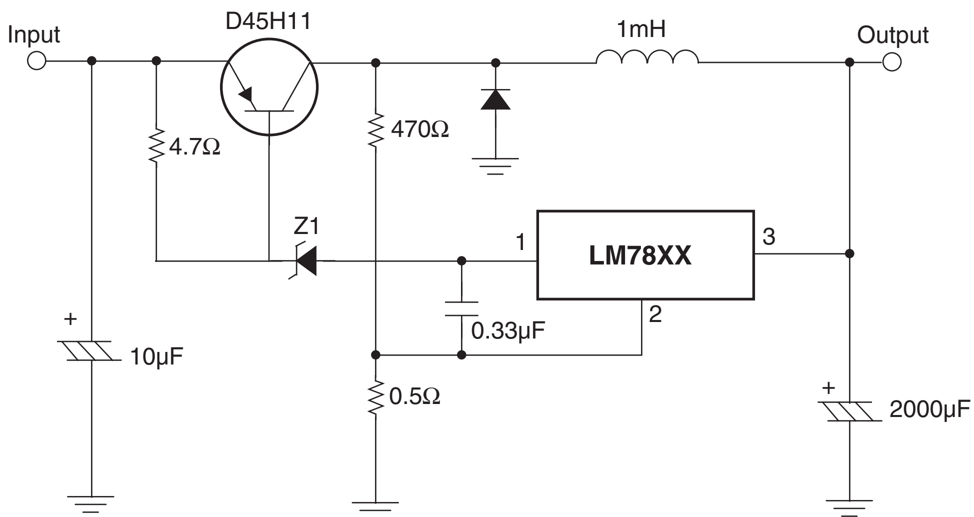
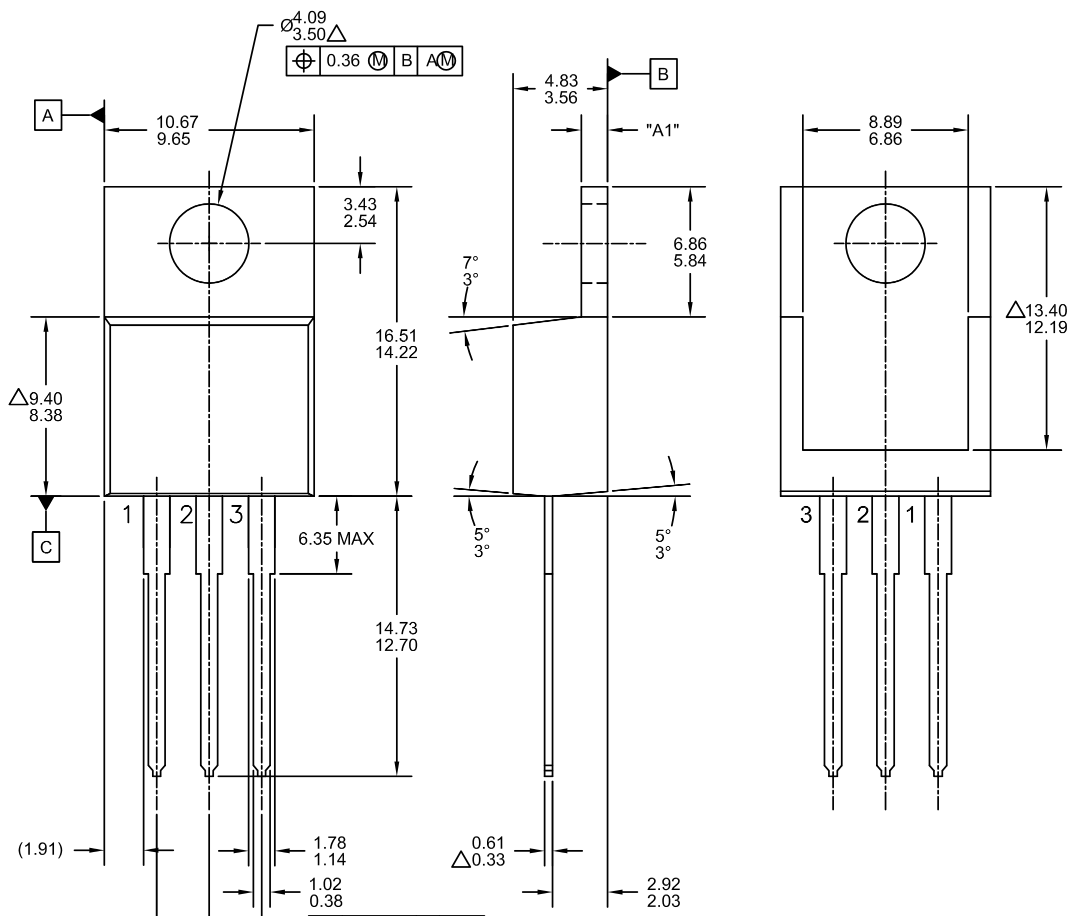


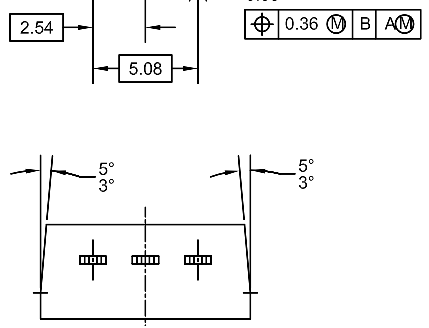
Figure 19. Switching Regulator

Mechanical Dimensions

Dimensions in millimeters

TO-220 [SINGLE GAUGE]





NOTES: UNLESS OTHERWISE SPECIFIED
A) REFERENCE JEDEC, TO-220, ISSUE K, VARIATION AB, DATED APRIL, 2002.
B) ALL DIMENSIONS ARE IN MILLIMETERS.
C) DIMENSIONING AND TOLERANCING PER ANSI Y14.5 - 1973
D) LOCATION OF THE PIN HOLE MAY VARY (LOWER LEFT CORNER, LOWER CENTER AND CENTER OF THE PACKAGE)
E) DOES NOT COMPLY JEDEC STANDARD VALUE.
F) "A1" DIMENSIONS REPRESENT LIKE BELOW:
SINGLE GAUGE = 0.51 - 0.61
DUAL GAUGE = 1.14 - 1.40
G) DRAWING FILE NAME: TO220B03REV6

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PRODUCT STATUS DEFINITIONS

Definition of Terms

Datasheet Identification	Product Status	Definition
Advance Information	Formative / In Design	Datasheet contains the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First Production	Datasheet contains preliminary data; supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve design.
No Identification Needed	Full Production	Datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve the design.
Obsolete	Not In Production	Datasheet contains specifications on a product that is discontinued by Fairchild Semiconductor. The datasheet is for reference information only.

Rev. I47

PL-2303
USB TO SERIAL BRIDGE CONTROLLER

OVERVIEW

The PL-2303 USB-to-Serial Bridge Controller is a low cost and high performance single chip solution. It provides a simple and easy way to use bridge/connectivity between the Universal Serial Bus (USB) and Serial Port interface.

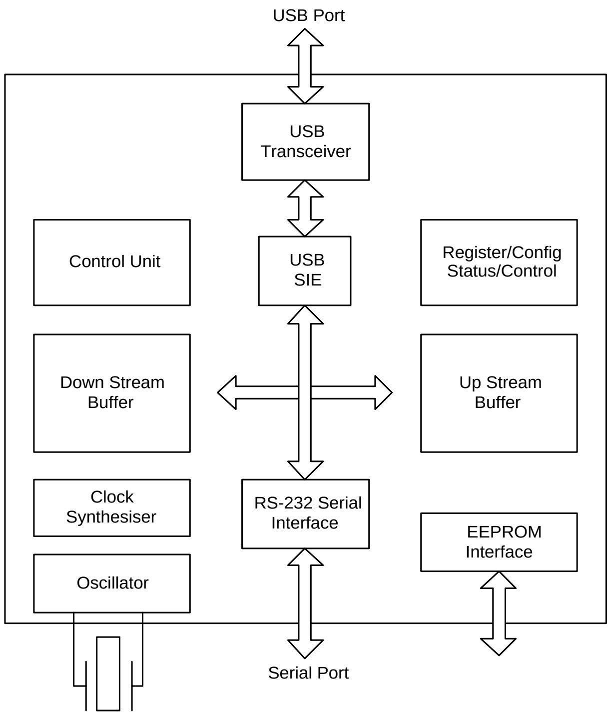
With the advantage of USB port, users have the capability to utilize the peripheral with serial port interface in an easy-to-use environment such as plug and play & hot swap function. This single chip is designed for ideal connections to Cellular Phone, Digital Camera, Modems or ISDN terminal adapters with over 1Mbps data transfer rate.

The PL-2303 device and software drivers are capable of providing a no-firmware-change feature that enable USB interface to be transparent to serial port peripherals with minimum modifications.

FEATURES

- Full compliance with the USB Specification v1.1(0) and USB CDC v1.1
- Support the RS232 Serial interface
- Support automatic handshake mode
- Over 1Mbps data transfer rate
- Support Remote wake-up and power management
- 96 bytes buffer each for upstream and downstream data flow
- Support default ROM or external EEPROM for device configuration
- On chip USB transceiver
- On chip crystal oscillator running at 12M Hz
- Single chip solution in a 28 Pins SOIC package

PL-2303 Block Diagram



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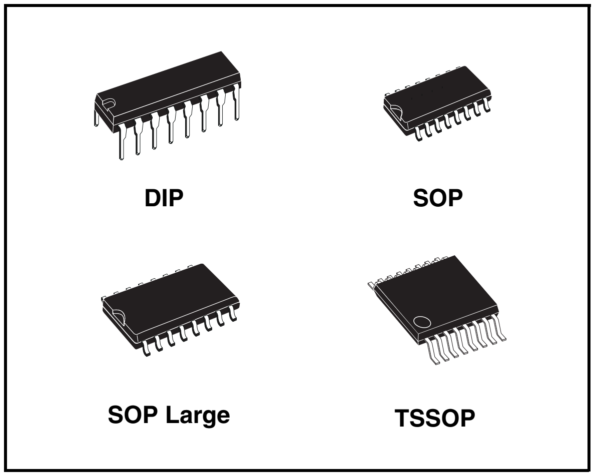
Fax : 886-2-2654-6161
E-mail : sales@prolific.com.tw
http://www.prolific.com.tw

ST232B
ST232C

5 V powered multi-channel RS-232 drivers and receivers

Features

- Supply voltage range: 4.5 to 5.5 V
- Supply current no load (typ.): 5 mA
- Transmitter output voltage swing (typ): ±7.8 V
- Controlled output slew rate
- Receiver input voltage range: ± 30 V
- Data rate (typ.): 220 kbps
- Operating temperature range:
  - -40 ° to 85 °C
  - 0 ° to 70 °C
- Compatible with MAX232 and MAX202



Description

The ST232 is a 2 driver, 2 receiver device following EIA/TIA-232 and V.28 communication standard. It is particularly suitable for applications where ±12 V is not available. The ST232 uses a single 5 V power supply and only four external capacitors (0.1 µF). Typical applications are in: portable computers, low power modems, interfaces translation, battery powered RS-232 system, multi-drop RS-232 networks.

Table 1. Device summary

Order code	Temperature range	Package	Packaging
ST232CN	0 to 70 °C	DIP-16	25 parts per tube / 40 tube per box
ST232CDR	0 to 70 °C	SO-16 (tape and reel)	2500 parts per reel
ST232BDR	-40 to 85 °C	SO-16 (tape and reel)	2500 parts per reel
ST232CWR	0 to 70 °C	SO-16 Large (tape and reel)	1000 parts per reel
ST232BWR	-40 to 85 °C	SO-16 Large (tape and reel)	1000 parts per reel
ST232CTR	0 to 70 °C	TSSOP16 (tape and reel)	2500 parts per reel
ST232BTR	-40 to 85 °C	TSSOP16 (tape and reel)	2500 parts per reel

Contents

1 Pin configuration

Figure 1. Pin connections (top view)

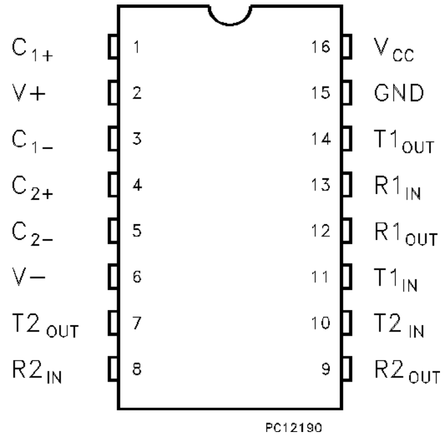


Table 2. Pin description

Pin n°	Symbol	Note
1	C_1+	Positive terminal for the first charge pump capacitor
2	V+	Doubled voltage terminal
3	C_1-	Negative terminal for the first charge pump capacitor
4	C_2+	Positive terminal for the second charge pump capacitor
5	C_2-	Negative terminal for the second charge pump capacitor
6	V-	Inverted voltage terminal
7	$T2_{OUT}$	Second transmitter output voltage
8	$R2_{IN}$	Second receiver input voltage
9	$R2_{OUT}$	Second receiver output voltage
10	$T2_{IN}$	Second transmitter input voltage
11	$T1_{IN}$	First transmitter input voltage
12	$R1_{OUT}$	First receiver output voltage
13	$R1_{IN}$	First receiver input voltage
14	$T1_{OUT}$	First transmitter output voltage
15	GND	Ground
16	V_{CC}	Supply voltage

2 Maximum ratings

Table 3. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	-0.3 to 6	V
T_{IN}	Transmitter input voltage range	-0.3 to (V_{CC} + 0.3)	V
R_{IN}	Receiver input voltage range	± 30	V
T_{OUT}	Transmitter output voltage range	(V_+ + 0.3) to (V_- - 0.3)	V
R_{OUT}	Receiver output voltage range	-0.3 to (V_{CC} + 0.3)	V
T_{SCTOUT}	Short circuit duration on T_{OUT}	infinite	
T_{STG}	Storage temperature range	-65 to + 150	

Note: 1 Absolute maximum ratings are those values beyond which damage to the device may occur. Functional operation under these condition is not implied.

2 No external supply can be applied to V+ terminal and V- terminal.

3 Electrical characteristics

Table 4. Electrical characteristics
(C_1 - C_4 = 0.1 µF, V_{CC} = 5 V ± 10 %, T_A = -40 to 85 °C, unless otherwise specified. Typical values are referred to T_A = 25 °C).

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
I_{SUPPLY}	V_{CC} Power supply current	No Load, T_A = 25°C		5	10	mA

Table 5. Transmitter electrical characteristics
(C_1 - C_4 = 0.1 µF, V_{CC} = 5 V ± 10 %, T_A = -40 to 85 °C, unless otherwise specified. Typical values are referred to T_A = 25 °C).

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
V_{TOUT}	Output voltage swing	All transmitter outputs are loaded with 3kΩ to GND	±5	±7.8		V
I_{TIL}	Input leakage current				±40	µA
V_{TIL}	Input logic threshold low		0.8			V
V_{TIH}	Input logic threshold high				2	V
SR_T	Transition slew rate	T_A = 25°C, V_{CC} = 5V R_L = 3 to 7kΩ, C_L = 50 to 2500pF (1)		7	30	V/µs
D_R	Data rate	(2)	120	220		kbits/s
R_{TOUT}	Transmitter output resistance	V_{CC} = V+ = V- = 0V V_{OUT} = ±2V	300			Ω
I_{SC}	Transmitter output short circuit current	One T_{XOUT} to GND		±10	±60	mA

1. Measured from 3 V to -3 V or from -3 V to 3 V
2. One transmitter output is loaded with R_L = 3 kΩ to 7 kΩ, C_L = 50 to 1000 pF

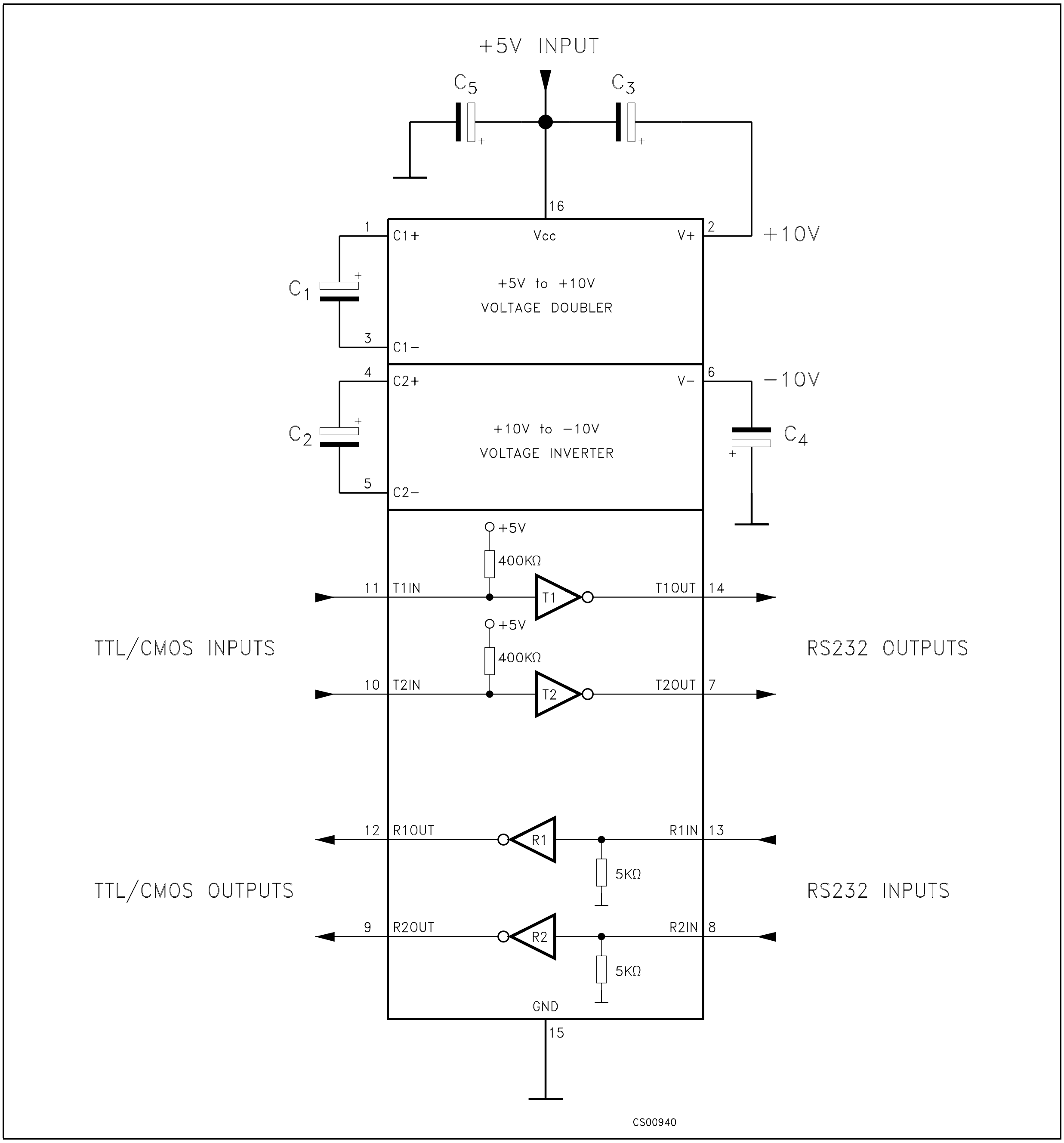
Table 6. Receiver electrical characteristics
(C_1 - C_4 = 0.1 µF, V_{CC} = 5 V ± 10 %, T_A = -40 to 85 °C, unless otherwise specified. Typical values are referred to T_A = 25 °C).

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
V_{RIN}	Receiver input voltage operating range		-30		30	V
R_{RIN}	RS-232 input resistance	T_A = 25°C, V_{CC} = 5 V, V_{RIN} = 5V	3	5	7	kΩ
V_{RIL}	RS-232 input threshold low	T_A = 25°C, V_{CC} = 5 V	0.8	1.2		V
V_{RIH}	RS-232 input threshold high	T_A = 25°C, V_{CC} = 5 V		1.7	2.4	V
V_{RIHYS}	RS-232 input hysteresis	V_{CC} = 5V	0.2	0.5	1	V
V_{ROL}	TTL/CMOS output voltage low	I_{OUT} = 3.2mA (to V_{CC})			0.4	V
V_{ROH}	TTL/CMOS output voltage high	I_{OUT} = -1mA (to GND)	3.5	V_{CC}-0.4		V
I_{SCR}	Receiver output short circuit current			±10		mA
t_{DR}	Receiver propagation delay	C_L = 150pF [(1)]		0.3	1	µs

1. RS-232 in to TTL-CMOS out (from 50% to 50%)

4 Typical application

Figure 2. Application circuit (1) (2)



1. C_{1-4} capacitors can even be 1µF ones
2. C_{1-4} can be common or biased capacitors

Table 7. Capacitance value (µF)

C1	C2	C3	C4	C5
0.1	0.1	0.1	0.1	0.1

5 Typical performance characteristics

(Unless otherwise specified T_J = 25 °C)

Figure 3. Supply current vs temperature

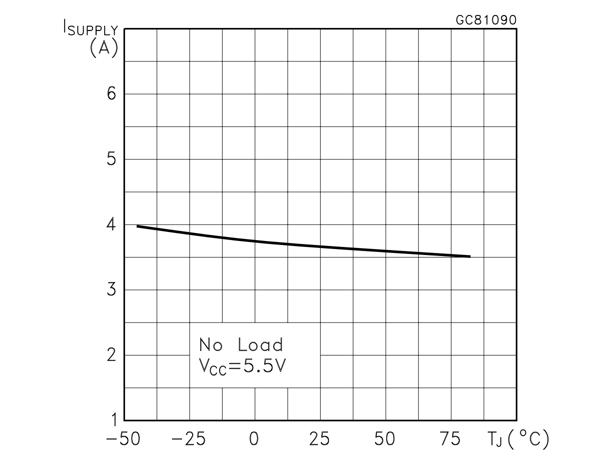


Figure 4. Data rate vs temperature

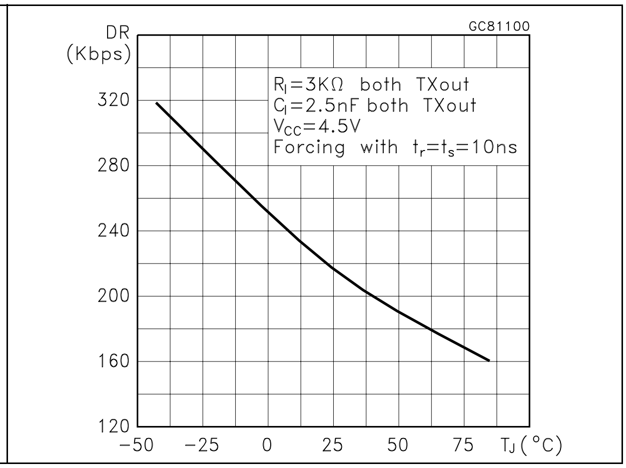


Figure 5. Receiver propagation delay

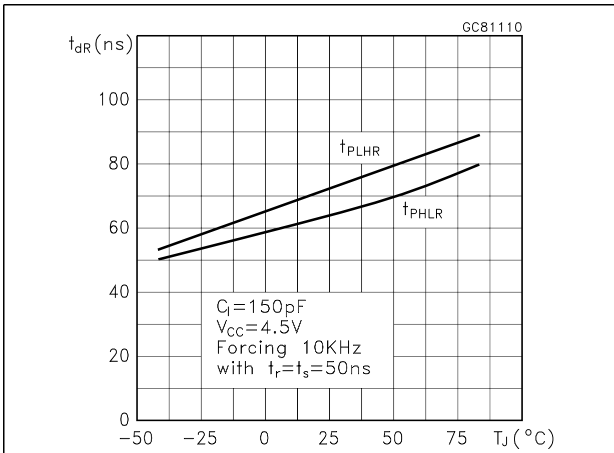


Figure 6. Driver propagation delay

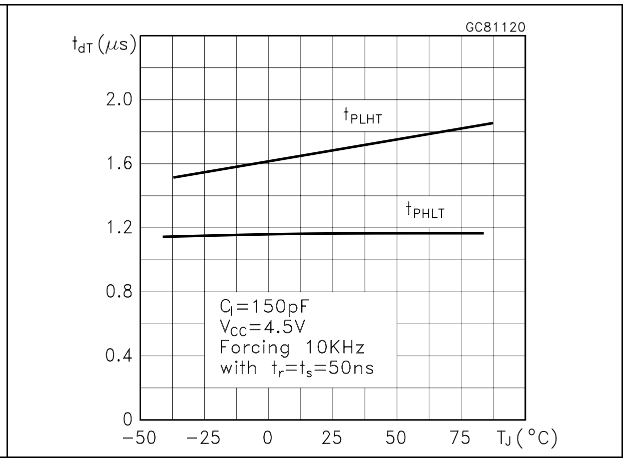


Figure 7. High level output voltage swing vs temperature

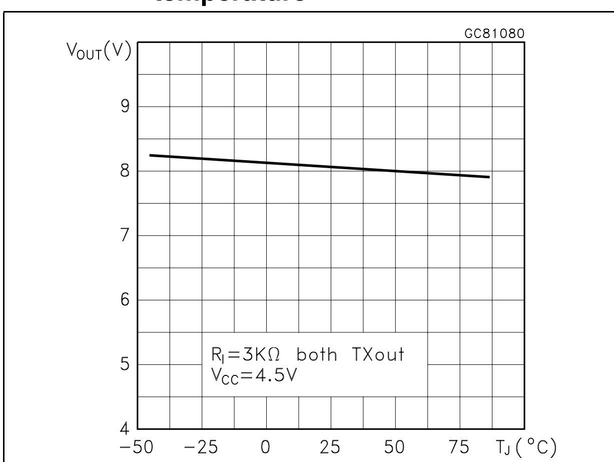


Figure 8. Low level output voltage swing vs temperature

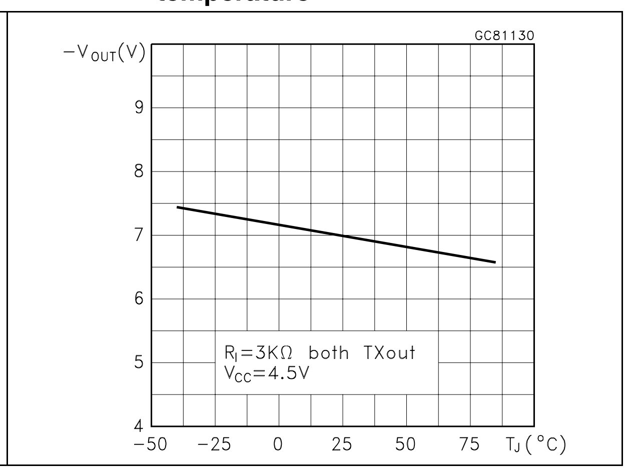


Figure 9. High level transmitter output short circuit current vs temperature

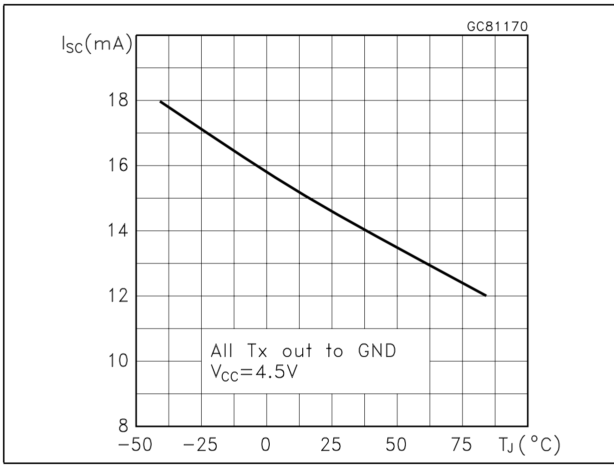


Figure 10. Low level transmitter output short circuit current vs temperature

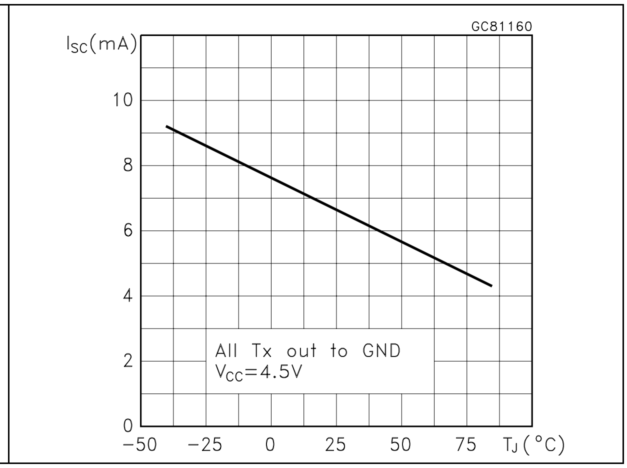


Figure 11. High level receiver output short circuit current vs temperature

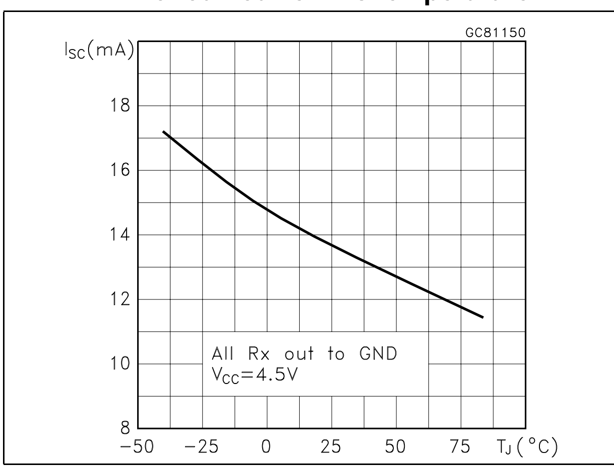
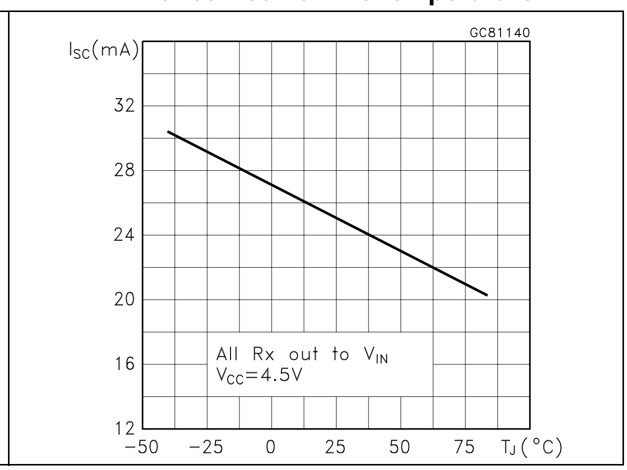


Figure 12. Low level receiver output short circuit current vs temperature

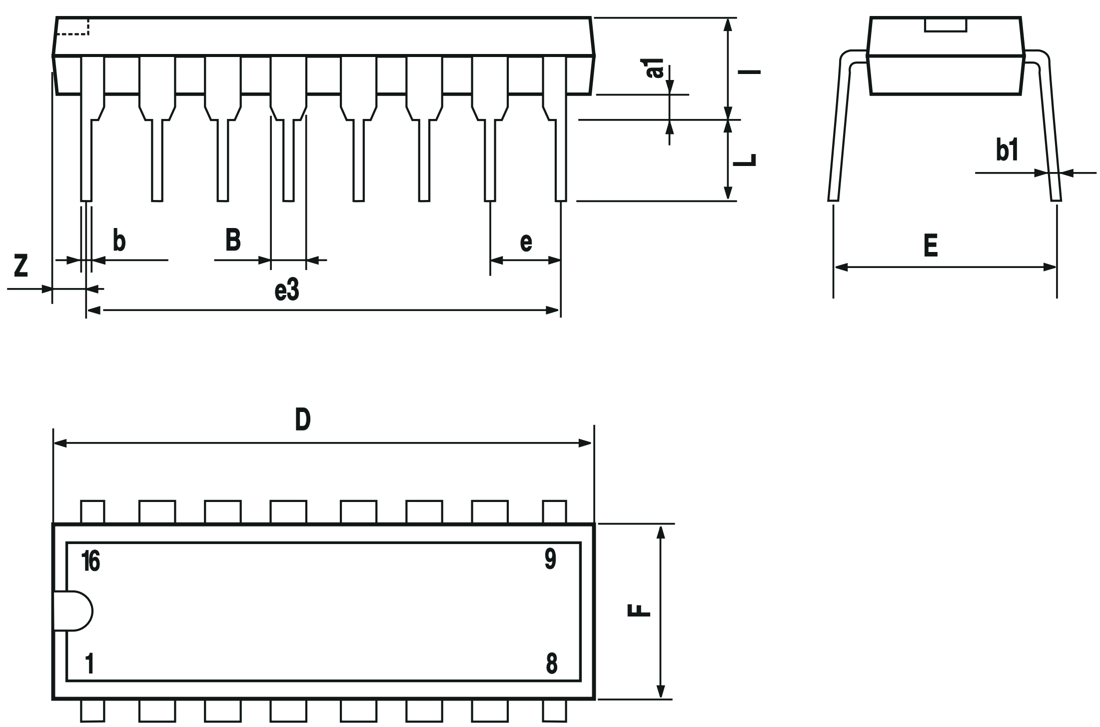


6 Package mechanical data

In order to meet environmental requirements, ST offers these devices in ECOPACK® packages. These packages have a lead-free second level interconnect. The category of second Level Interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an ST trademark. ECOPACK specifications are available at: www.st.com.

Plastic DIP-16 (0.25) mechanical data

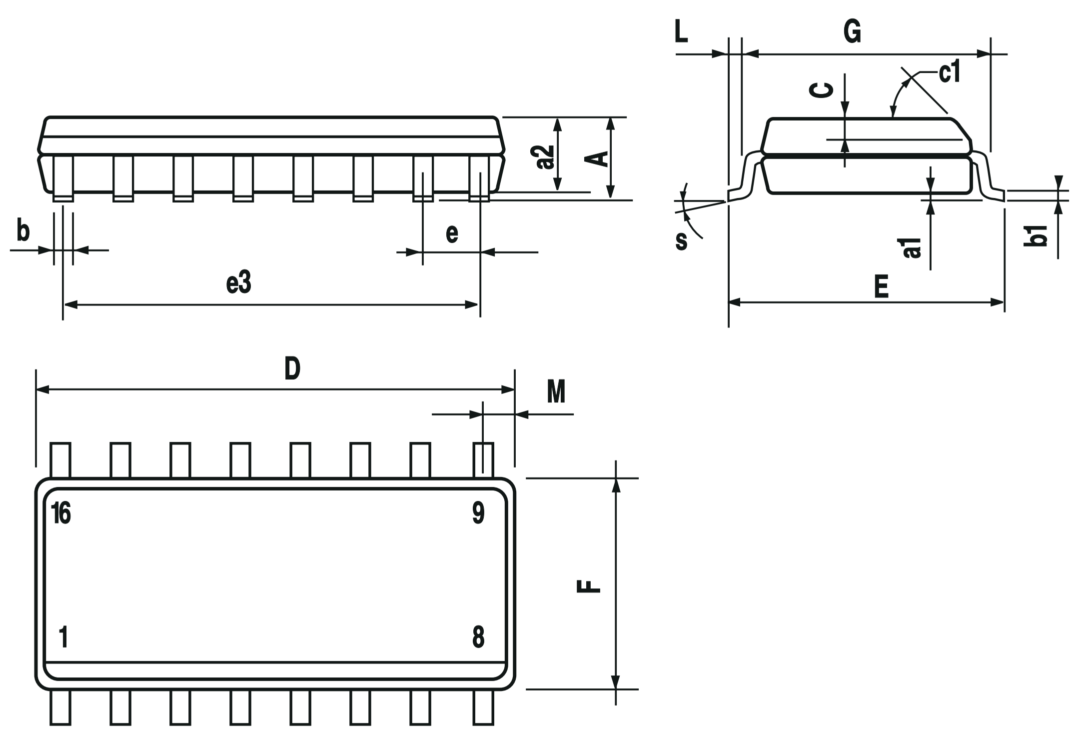
Dim.	mm.			inch.		
	Min.	Typ.	Max.	Min.	Typ.	Max.
a1	0.51			0.020		
B	0.77		1.65	0.030		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		17.78			0.700	
F			7.1			0.280
I			5.1			0.201
L		3.3			0.130	
Z			1.27			0.050



P001C

SO-16 mechanical data

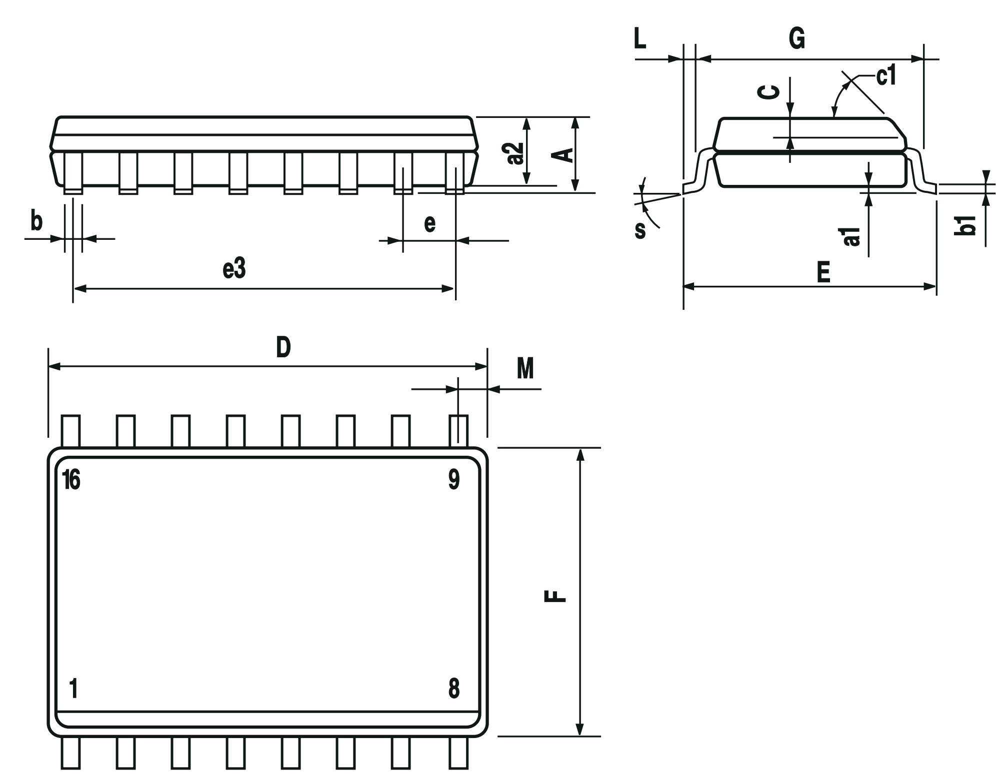
Dim.	mm.			inch.		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.068
a1	0.1		0.25	0.004		0.010
a2			1.64			0.063
b	0.35		0.46	0.013		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.019	
c1	45° (typ.)					
D	9.8		10	0.385		0.393
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		8.89			0.350	
F	3.8		4.0	0.149		0.157
G	4.6		5.3	0.181		0.208
L	0.5		1.27	0.019		0.050
M			0.62			0.024
S	8° (max.)					



0016020D

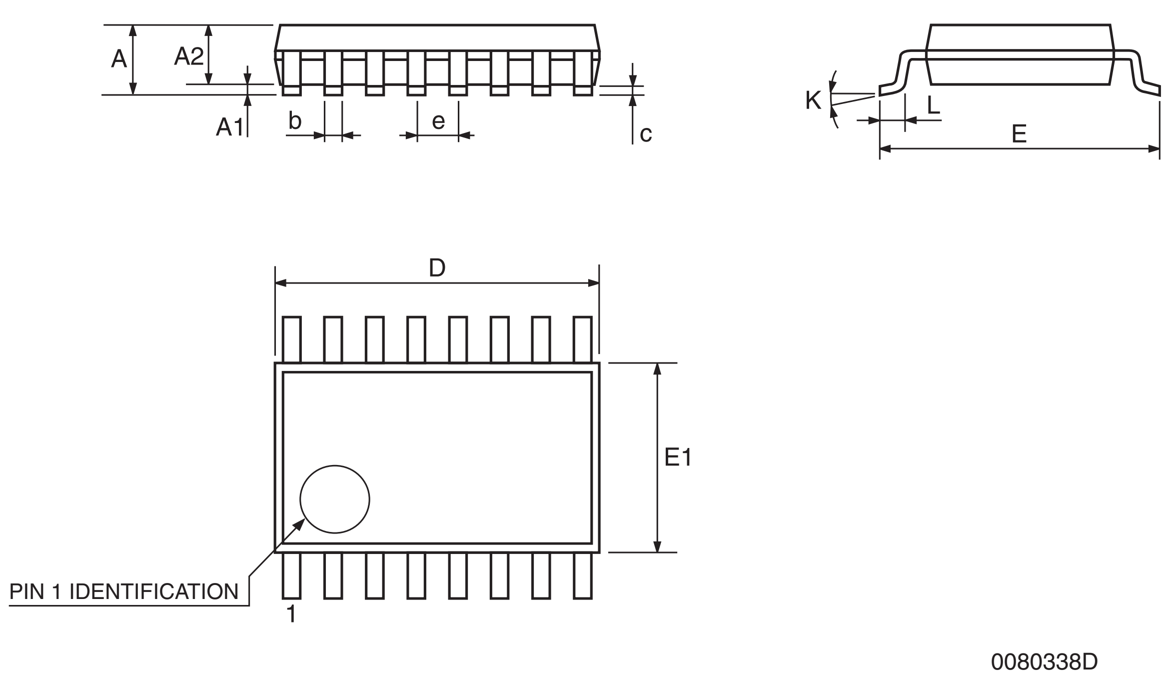
SO-16L mechanical data

Dim.	mm.			inch.		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			2.65			0.104
a1	0.1		0.2	0.004		0.008
a2			2.45			0.096
b	0.35		0.49	0.014		0.019
b1	0.23		0.32	0.009		0.012
C		0.5			0.020	
c1	45° (typ.)					
D	10.1		10.5	0.397		0.413
E	10.0		10.65	0.393		0.419
e		1.27			0.050	
e3		8.89			0.350	
F	7.4		7.6	0.291		0.300
G						
L	0.5		1.27	0.020		0.050
M			0.75			0.029
S	8° (max.)					



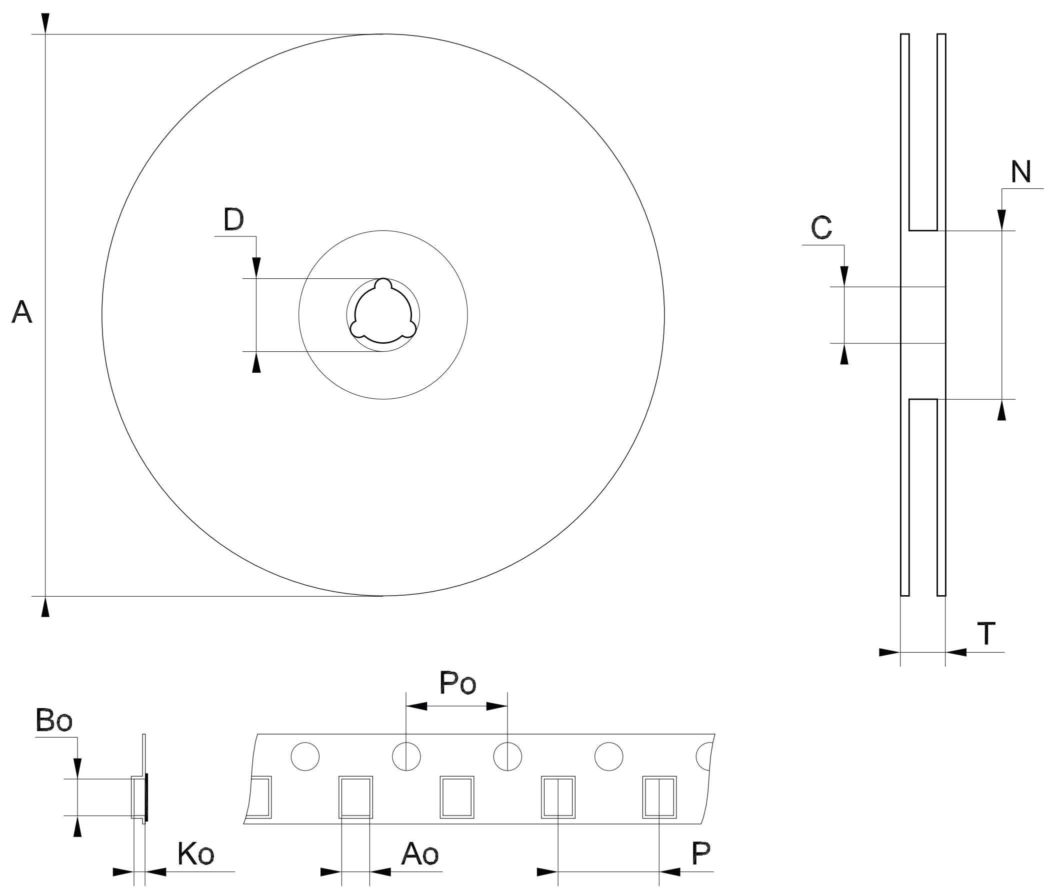
TSSOP16 mechanical data

Dim.	mm.			inch.		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.2			0.047
A1	0.05		0.15	0.002	0.004	0.006
A2	0.8	1	1.05	0.031	0.039	0.041
b	0.19		0.30	0.007		0.012
c	0.09		0.20	0.004		0.0079
D	4.9	5	5.1	0.193	0.197	0.201
E	6.2	6.4	6.6	0.244	0.252	0.260
E1	4.3	4.4	4.48	0.169	0.173	0.176
e		0.65 BSC			0.0256 BSC	
K	0°		8°	0°		8°
L	0.45	0.60	0.75	0.018	0.024	0.030



Tape & reel SO-16 mechanical data

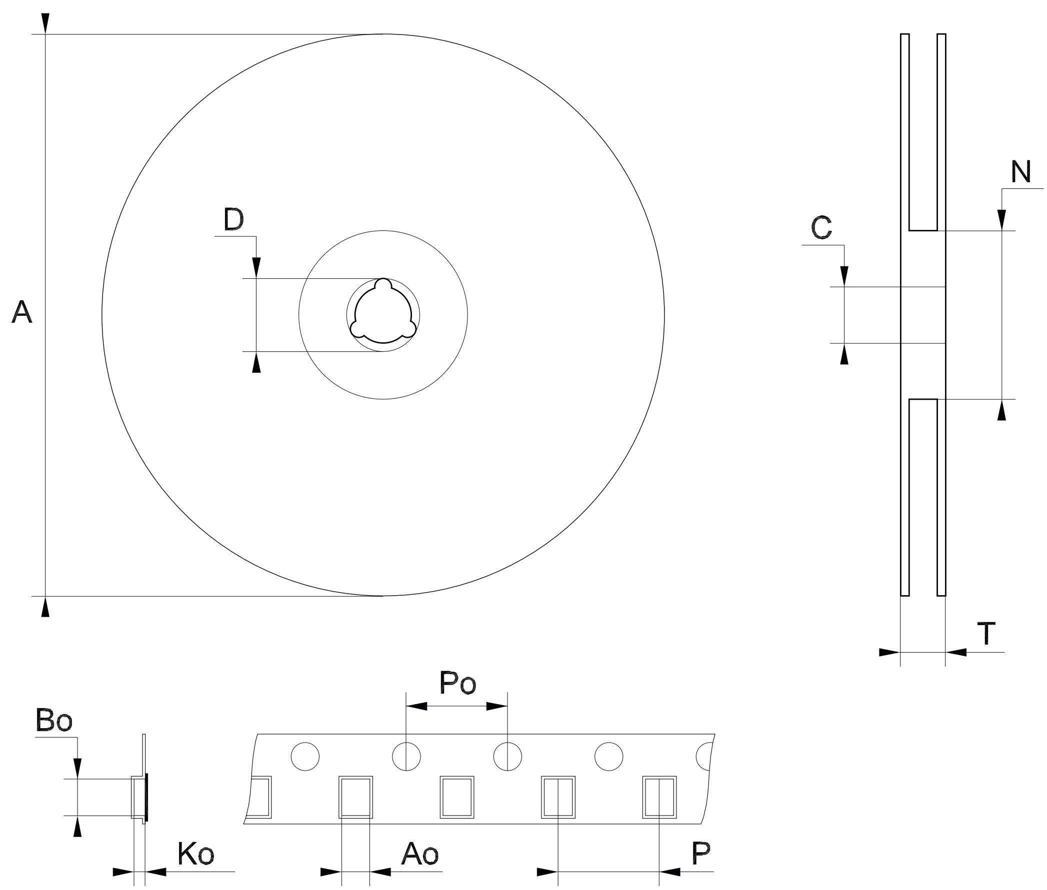
Dim.	mm.			inch.		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			330			12.992
C	12.8		13.2	0.504		0.519
D	20.2			0.795		
N	60			2.362		
T			22.4			0.882
Ao	6.45		6.65	0.254		0.262
Bo	10.3		10.5	0.406		0.414
Ko	2.1		2.3	0.082		0.090
Po	3.9		4.1	0.153		0.161
P	7.9		8.1	0.311		0.319



Note: Drawing not in scale

Tape & reel SO-16L mechanical data

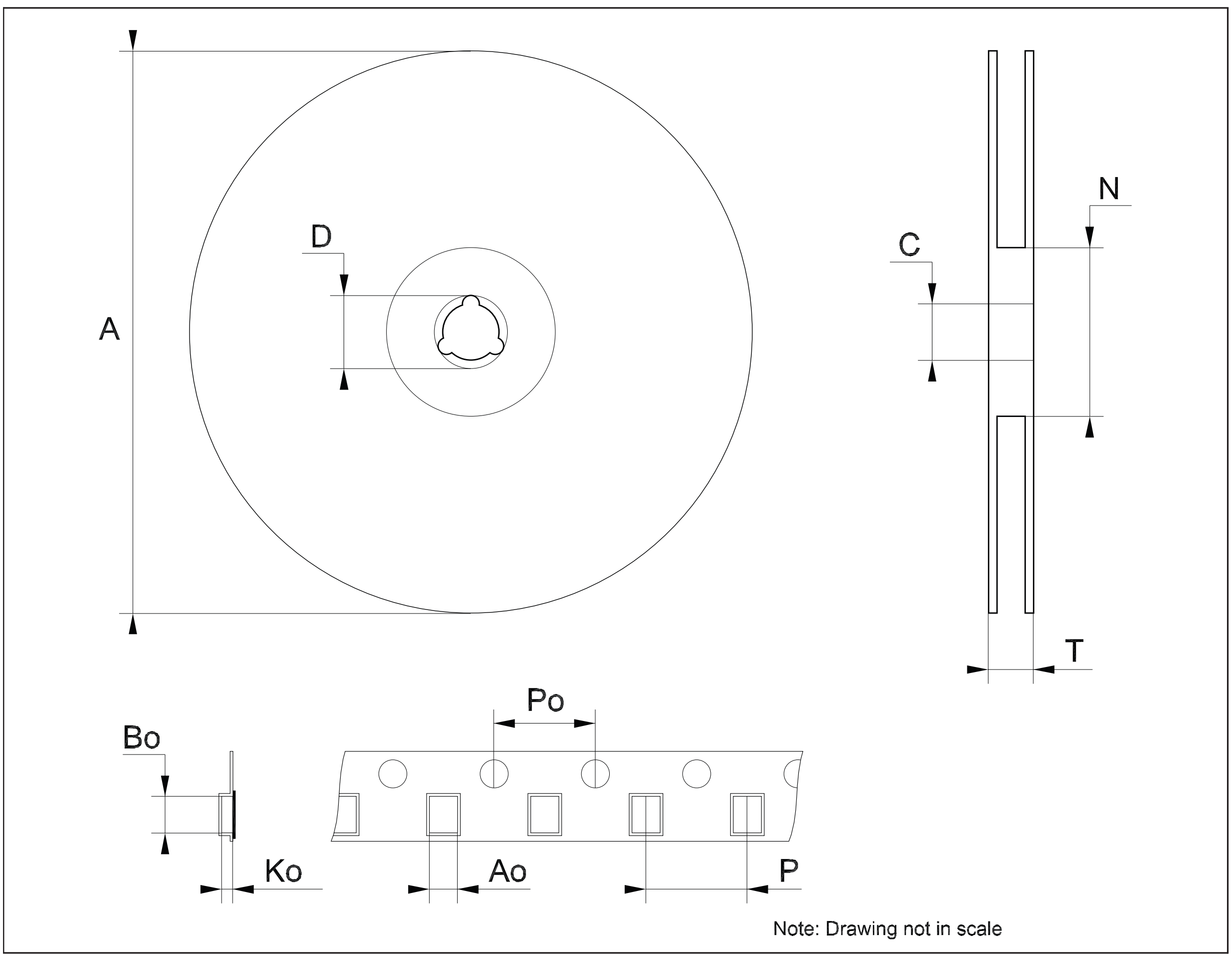
Dim.	mm.			inch.		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			330			12.992
C	12.8		13.2	0.504		0.519
D	20.2			0.795		
N	60			2.362		
T			22.4			0.882
Ao	10.8		11.0	0.425		0.433
Bo	10.7		10.9	0.421		0.429
Ko	2.9		3.1	0.114		0.122
Po	3.9		4.1	0.153		0.161
P	11.9		12.1	0.468		0.476



Note: Drawing not in scale

Tape & reel TSSOP16 mechanical data

Dim.	mm.			inch.		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			330			12.992
C	12.8		13.2	0.504		0.519
D	20.2			0.795		
N	60			2.362		
T			22.4			0.882
Ao	6.7		6.9	0.264		0.272
Bo	5.3		5.5	0.209		0.217
Ko	1.6		1.8	0.063		0.071
Po	3.9		4.1	0.153		0.161
P	7.9		8.1	0.311		0.319



7 Revision history

Table 8. Document revision history

Date	Revision	Changes
02-Sep-2005	11	Mistake I_{TIL} max. on table 5.
27-Oct-2006	12	Order codes updated.
14-Nov-2007	13	Added *Table 1*.
08-Feb-2008	14	Modified: *Table 1 on page 1*.