Probador de Motores V1.1

Mectel Acotron

Dentro de este manual se encuentra la información necesaria para crear este proyecto desde cero, sin embargo si desea ahorrarse algunos pasos puede encontrar el proyecto completo con los diseños de los PCBS en el siguiente repositorio de GitHub.

https://github.com/Alex-Bermudez27/Probador-de-Motores

Una vez descargado el proyecto de PSoC Creator es necesario agregar la librería emFile para su funcionamiento, tal como se indica en la sección 3 de este manual, posteriormente de eso está listo para programarse.

Sección 1: Manual de Uso del Probador de Motores

Manual de Usuario

Probador de motores

Fecha: Diciembre 2021 Version: 1

Tabla de contenido

1.Objetivo.

Establecer los pasos a seguir para la utilización correcta del probador de motores para su optimo funcionamiento, con el fin de que el usuario pueda utilizar de manera satisfactoria el producto para obtener valores adecuados de los motores y pueda definir el estado actual de estos mismos, sin dañar el probador en el proceso.

2.Definiciones.

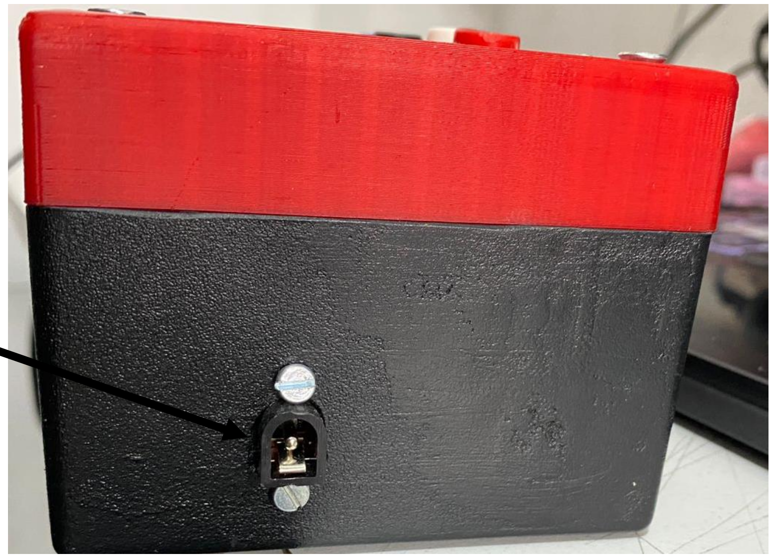
Datalogger: Un Datalogger es un grabador independiente típicamente pequeño y relativamente económico que monitorea y registra datos en tiempo real, tales como voltaje, temperatura y corriente. Se elige un registrador de datos en lugar de un sistema de adquisición de datos cuando la aplicación no requiere grabación de alta velocidad, pero sí requiere tiempos de grabación prolongados.

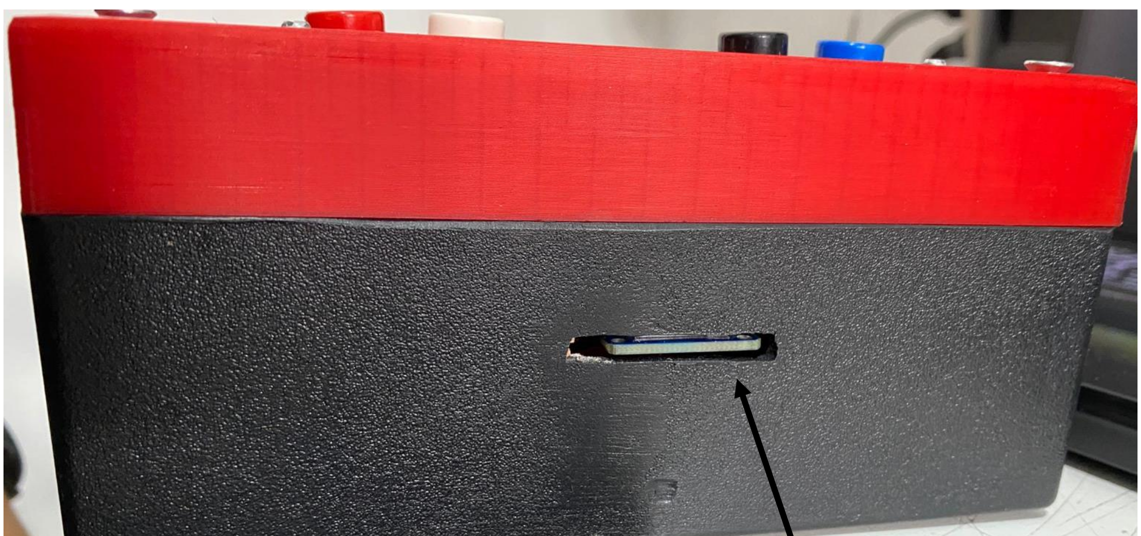
Toggle: La traducción de tal palabra es "alternar", "conmutar", "turnar" como verbo o "interruptor", "conmutador" como nombre, sirve para cambiar entre dos opciones o estados de algún sistema o programa.

3.Desarrollo de Manual de Usuario.

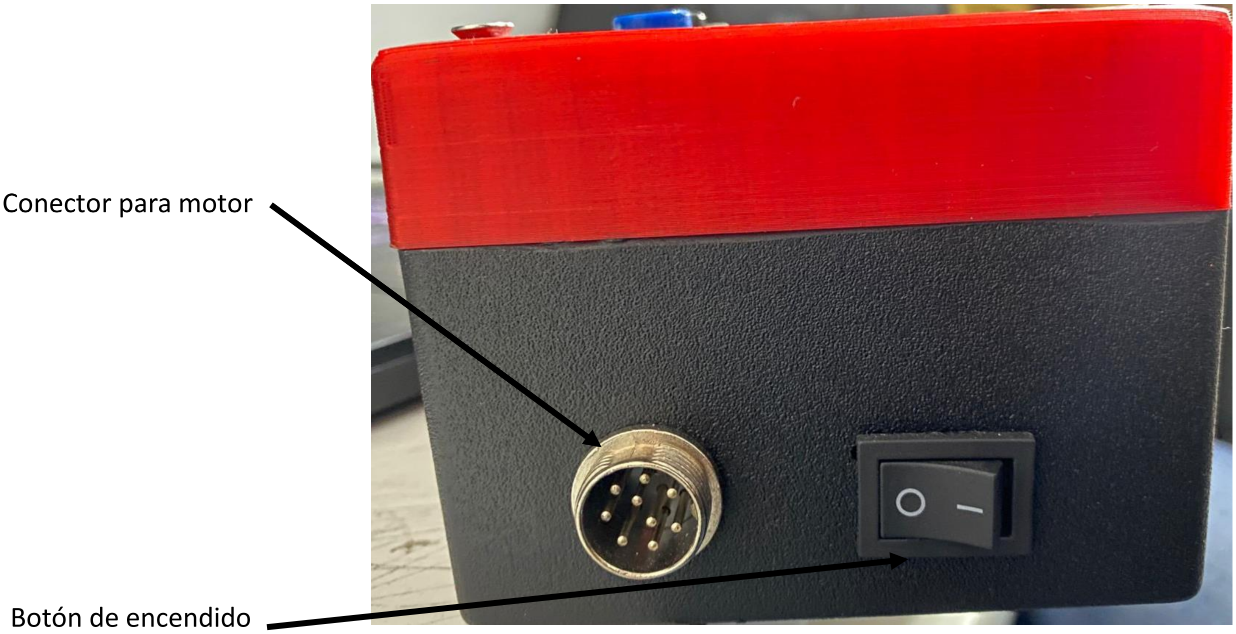
3.1 Partes del probador.

Puerto de carga





Ranura memoria micro-SD



3.2 Método de uso.

Al encender el dispositivo se mostrara un mensaje de bienvenida y posteriormente deificará si existe una memoria micro SD con el formato adecuado en la ranura del dispositivo, en dado caso de que no cuente con una memoria o la memoria tengo un formato diferente al mencionado anteriormente se mostrara un mensaje de “Memoria SD error”, por lado contrario si existe una memoria con el formato adecuado mostrara un mensaje de “Memoria SD correcto”, esto no afecta a el funcionamiento, únicamente hará que se escriba en la memoria los datos del sensor de corriente y los valores de voltaje del potenciómetro.

Después de los mensajes del estado de la memoria se llegará a el menú en donde podrás elegir entre dos modos de uso y dos tipos de motor, estando en el menú el método de funcionamiento de los botones de usuario serian el siguiente:

- Botón de usuario 1: Servirá como botón de OK, para aceptar el tipo de motor seleccionado.

- Botón de usuario 2: Cambia el modo de operación entre modo manual y modo automático, hace un toggle entre sus

- Botón de usuario 3: Se utiliza para elegir el tipo de motor que se vaya a probar.

- Botón de usuario 4: Se utiliza para elegir el tipo de motor que se vaya a probar.

Una vez presionado el botón de usuario 1 en el tipo de motor y el modo seleccionado, cambiaran las funciones de los botones, lo cual se explicará a continuación, solamente cambian en cuestión del modo seleccionado, y que el tipo de motor seleccionado no influye en su funcionamiento.

3.2.1 Modo Manual.

En el modo manual el usuario tendrá total control sobre el movimiento del motor, al seleccionar este modo se mostrara una gráfica en la pantalla, en donde el eje de las x será representado por el tiempo transcurrido y el eje de las y por el voltaje del potenciómetro, además de en la parte superior de la pantalla la corriente que consume el motor(esto último únicamente en el caso de motor de imán permanente), una vez que se entra en este modo el funcionamiento de los botones cambian y serian el siguiente:

- Botón de usuario 1: Dentro de este modo el botón de usuario 1 no tiene ninguna función.

- Botón de usuario 2: Sirve para regresar al menú y salir del modo seleccionado.

- Botón de usuario 3: Sirve para que el motor gire en sentido antihorario siempre y cuando se tenga presionado, si se deja de presionar el motor se parara.

- Botón de usuario 4: Sirve para que el motor gire en sentido horario siempre y cuando se tenga presionado, si se deja de presionar el motor se parara.

3.2.2 Modo Automático.

En el modo automático el usuario únicamente observara el proceso de evaluación del motor, al seleccionar este modo se mostrará el mensaje de “Probando motor” mientras este mensaje está en la pantalla el motor será llevado a su posicion inicial para tener un punto de referencia en cuanto a los valores que se tomaran más adelante, en cuanto el motor llegue a su posicion inicial en la pantalla se mostrara la misma interfaz que se describió en el modo manual, con la diferencia que aquí comenzara a moverse solo, inicialmente en sentido horario, hasta que llegue a el otro extremo del motor, una vez llegue ahí comenzara a girar en sentido antihorario, estando así el motor en todas sus posiciones posibles, logrando ver en la pantalla si en algún momento lee algún valor fuera de lo común, de igual manera que en el modo manual, una vez que se entra en este modo el funcionamiento de los botones cambian y serían los siguientes:

- Botón de usuario 1: Este botón es utilizado como pausa/continuar en el modo automático, si se presiona una vez se parará el proceso en donde se quedó y al volver a presionarse continuará con el proceso.

- Botón de usuario 2: Sirve para regresar al menú y salir del modo seleccionado.

- Botón de usuario 3: Dentro de este modo el botón de usuario 1 no tiene ninguna función.

- Botón de usuario 4: Dentro de este modo el botón de usuario 1 no tiene ninguna función.

3.3 Uso de la memoria.

3.3.1 Preparar la memoria.

Inicialmente el probador cuenta con una memoria microSD de 8GB, no es necesario un tamaño mínimo, ya que los archivos generados son de un tamaño muy pequeño, así que se puede utilizar hasta una memoria del más bajo tamaño, sin embargo es necesario configurar la memoria a el formato adecuado para que lo lea el probador, cuando se vaya a introducir una memoria nueva <u>es necesario ingresarla a una computadora y formatearla con formato de FAT32 o similar</u>, esto es muy importante ya que si no se formatea así la memoria no será leída por el probador.

3.3.2 Leer archivos generados.

Una vez haya terminado de utilizar el probador y desea leer los archivos generados es necesario ingresar la memoria en una computadora por medio del adaptador que desee, una vez ingresada la memoria a la computadora encontrara un archivo con extensión .csv, en el cual se guardaron los datos, este archivo puede ser leído con cualquier editor de texto, sin embargo, es recomendable abrirlo con algún programa para hojas de cálculo para que pueda ser visualizado con el formato adecuado.

3.4 Cargado de baterías .

Un plus con el que cuenta este probador es que tiene la capacidad de ser portátil, ya que cuenta con 3 baterías recargables de Litio de 1200mAh, sin embargo estas baterías después de cierto uso se descargan y los motores llegan a moverse más lento de lo habitual, por lo tanto cuenta con indicador de batería que se encuentra en la esquina superior derecha de la pantalla, para poder recargar estas baterías se cuenta con un puerto de carga indicado con anterioridad en la sección 3.1, se entregara con un cargador de baterías, pero en dado caso si este llegara a fallar o es necesario conseguir uno nuevo se debe de tener en cuenta que tenga las siguiente especificaciones:

- Voltaje de salida: 14-16 VDC.
- Corriente máxima : 1A.

3.5 Precauciones y datos a considerar.

Debe de tener en cuenta que este probador es un prototipo en desarrollo, por lo cual contiene partes frágiles que pueden ser dañadas si no se usa de la manera adecuada, por lo cual es importante cuidar la integridad de dicho probador y evitar golpes, caídas, polvo excesivo, humedad, fluidos o agitaciones demasiadas bruscas, ya que si este último sucede las baterías podrían salirse de su lugar y apagar el probador si es que se está usando, dichos problemas se están trabajado para ser solucionados en una próxima version de este dispositivo, pero por lo pronto es importante considerar dichas acotaciones.

4.Conclusiones.

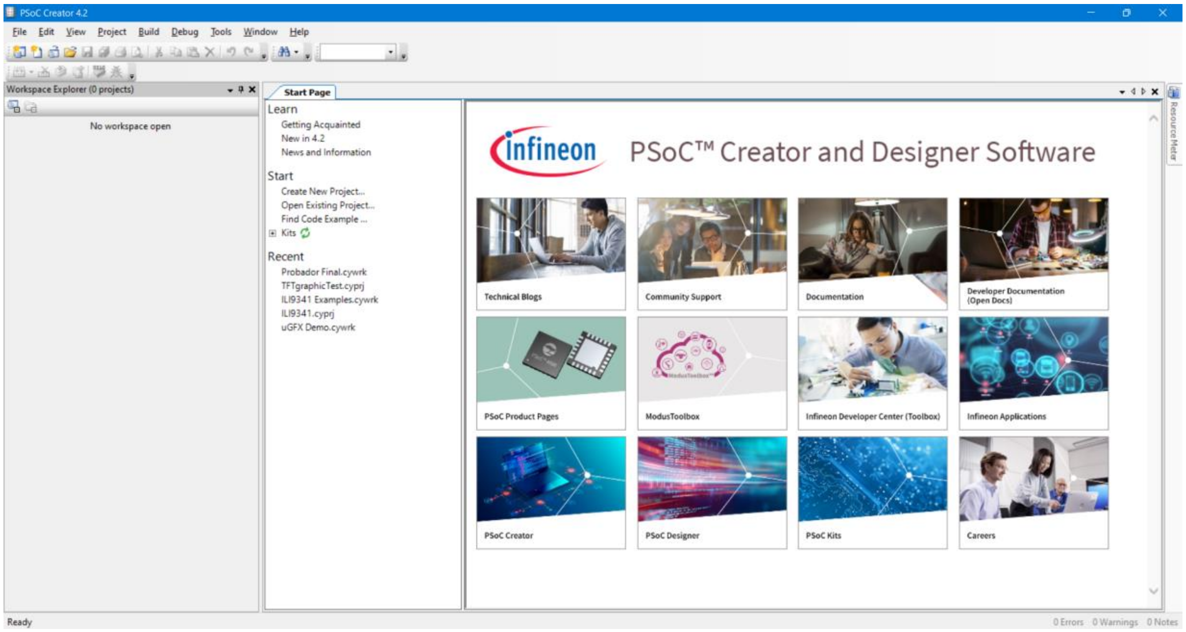
Se espera que disfrute del producto y funcione como se espera, sin embargo, se esperan retroalimentaciones de sus usuarios para solucionar posibles problemas que salgan durante su uso, se espera que lo disfrute.

Sección 2: Creación del Proyecto, Componentes y Código.

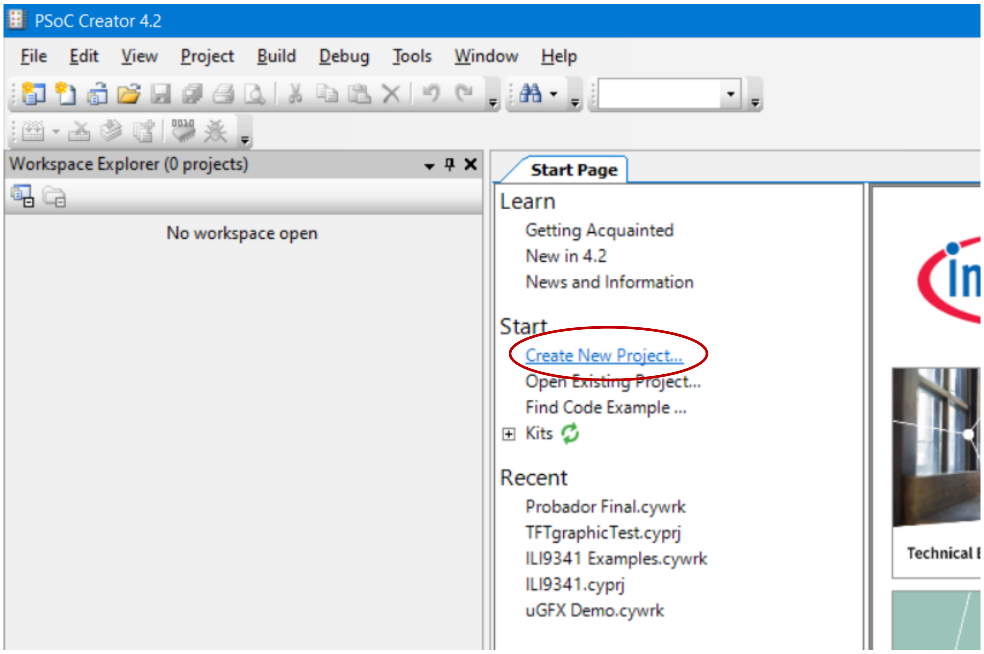
Para la creación del proyecto primero es necesario tener instalado el PSoC Creator 4.2 o posterior, es un software de licencia libre que lo puede encontrar en el siguiente enlace, únicamente es necesario crear un cuenta gratuita:

https://www.infineon.com/cms/en/design-support/tools/sdk/psoc-software/psoc-creator/?utm_source=cypress&utm_medium=referral&utm_campaign=202110_globe_en_all_integration-product_families

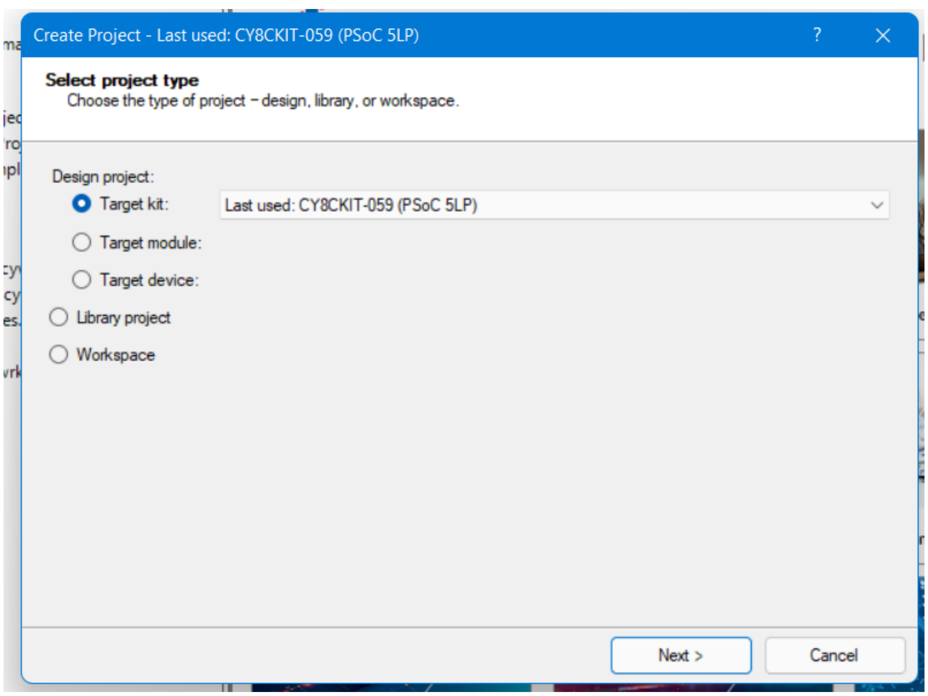
Una vez instalado el software nos aparecerá la pantalla de inicio:



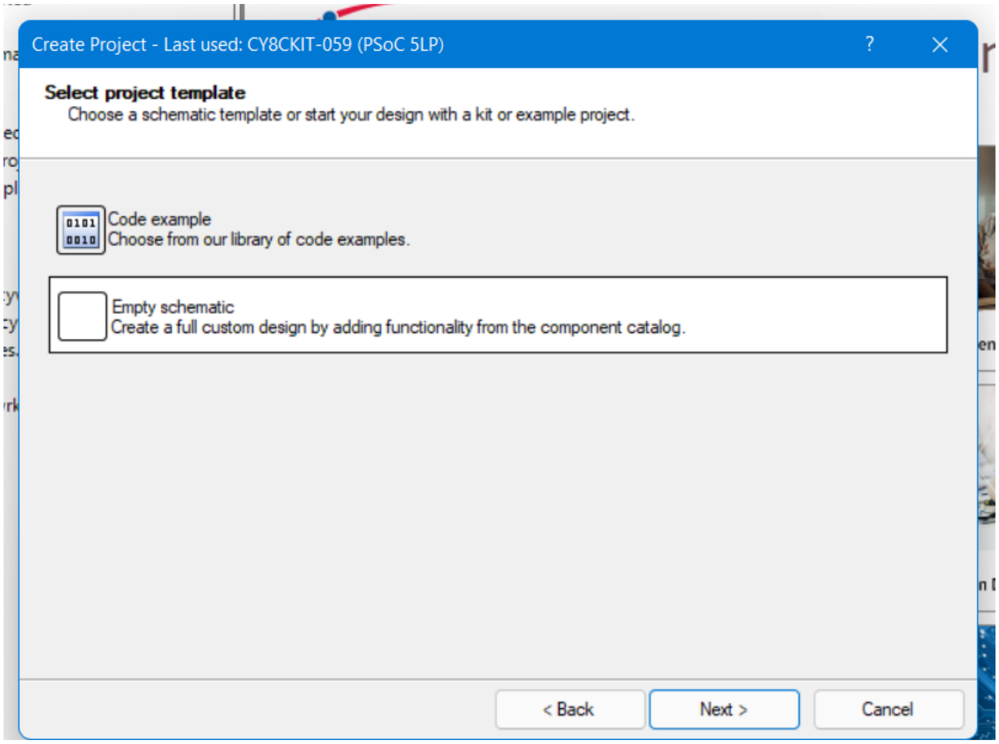
Darán click en Create new Project tal como se ve en la siguiente imagen:



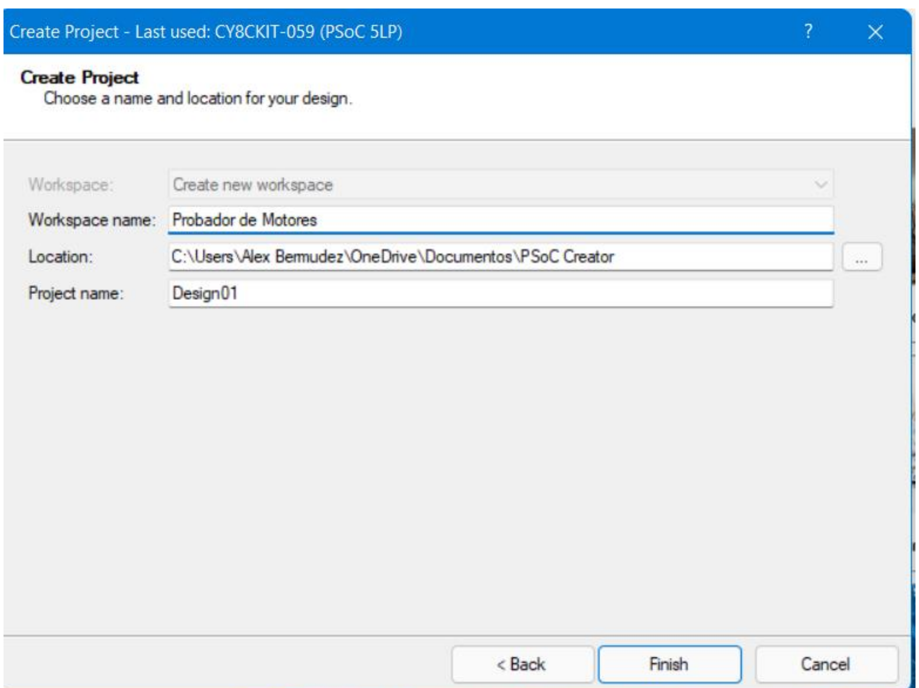
Se abrirá una ventana en la cual se elegirá el dispositivo con el que se va a trabajar, en nuestro caso se configurará tal como se muestra en la siguiente imagen y posteriormente se dará click en next.



Posteriormente se mostrará la opción si empezar desde un código de ejemplo o si desde un esquemático vacío, elegiremos la opción de esquemático vacío y le daremos en next.



Nos aparecerá la opción de nombrar el Espacio de trabajo, nombre como usted desee pero le recomendamos nombrarlo de una manera que sea fácil de identificar para usted, una vez nombrado le daremos en finalizar.

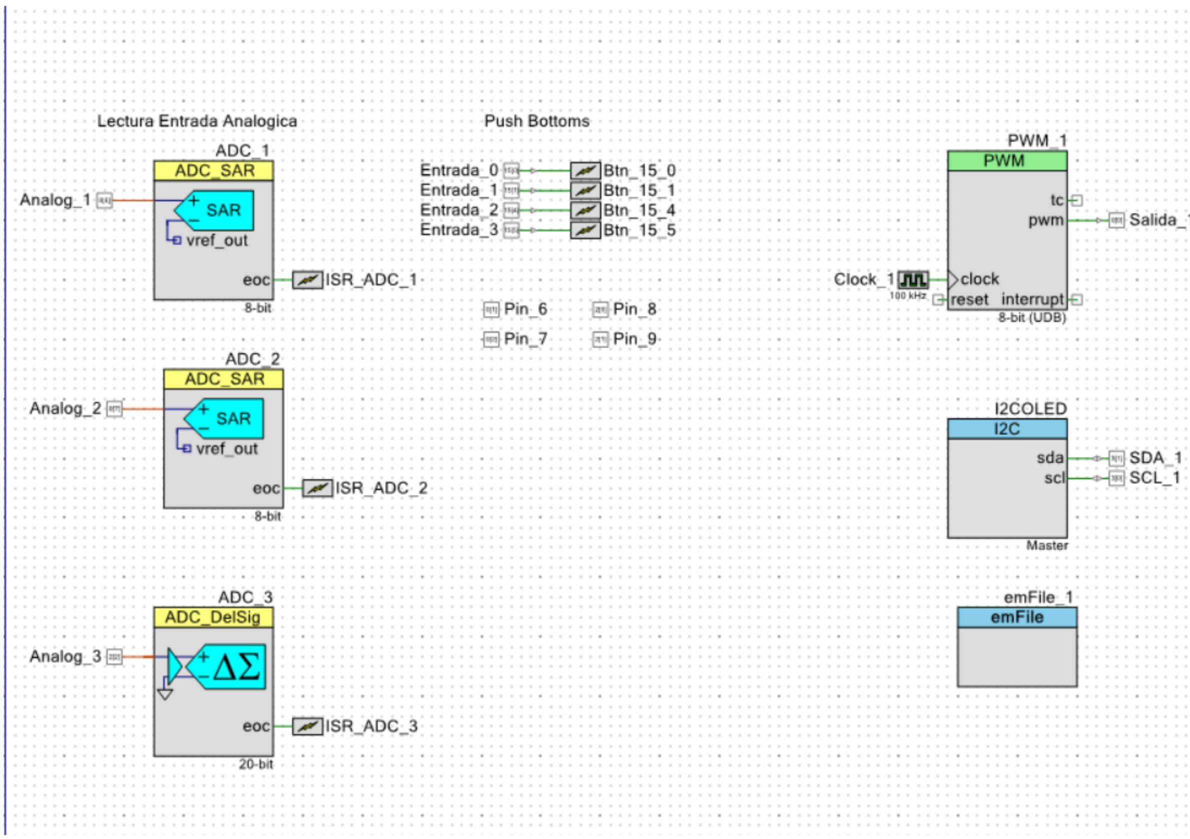


Y listo su programa estará creado, ahora será necesario agregar los componentes necesarios para posteriormente agregar el código y las librerías necesarias.

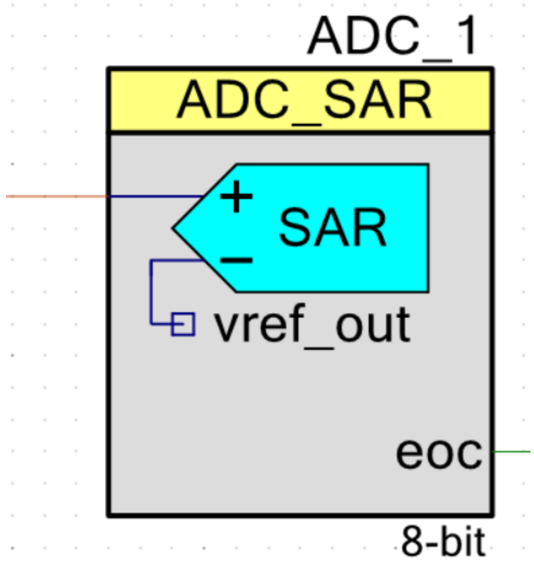
Configuración de componentes en PSoC Creator Probador de motores version 1.1

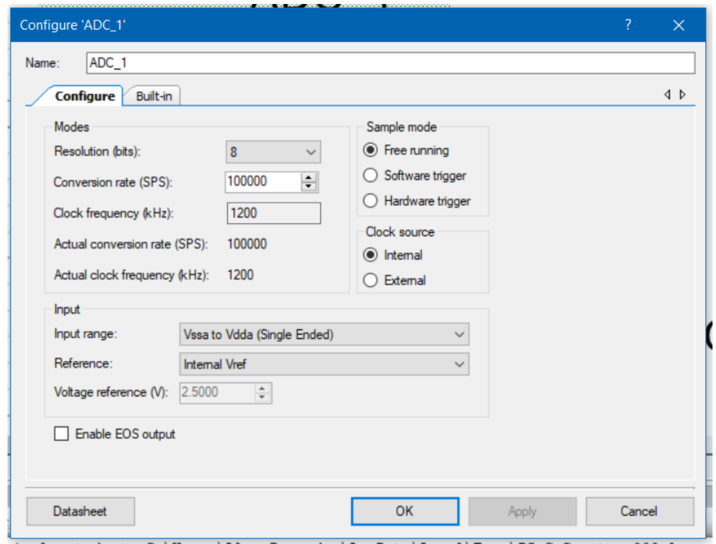
-Total de componentes utilizados en el proyecto, el nombre entre paréntesis en cada componente en el listado de ellos es el nombre con el que lo puedes encontrar en el buscador de componentes, además de que los componentes deben de tener el mismo nombre que tiene en la imagen siguiente y en las descripciones siguientes(el nombre del componente es el que aparece a un lado de este).

Toda la configuración de Built-in de todos los componentes se dejo por default, en caso de no especificar alguna configuración de algún componente es por que se dejó en default.

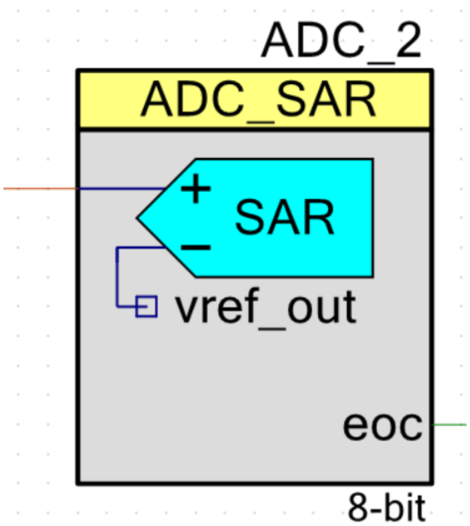


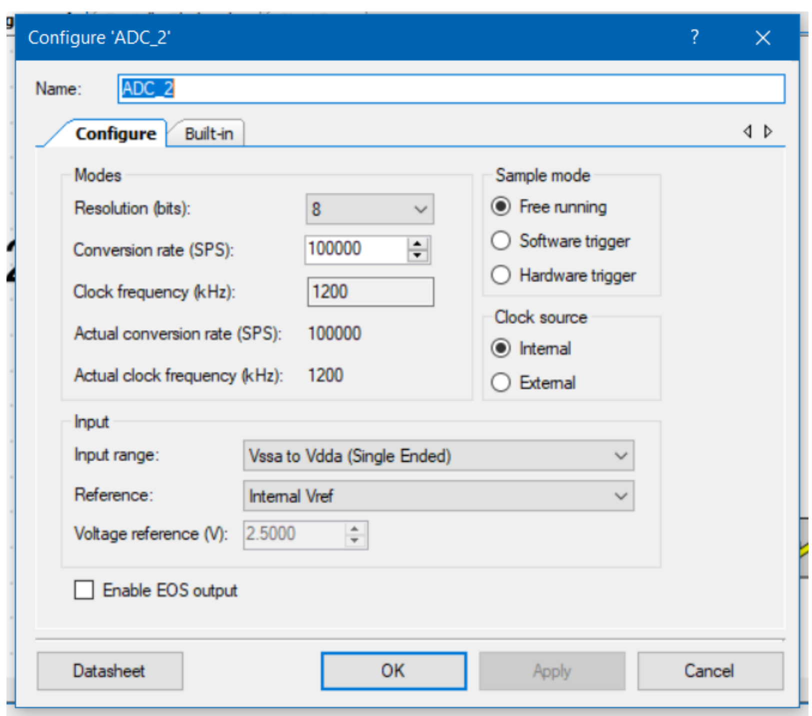
-ADC_1 (SAR ADC).



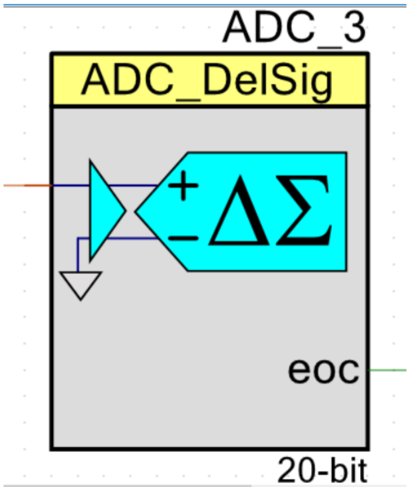


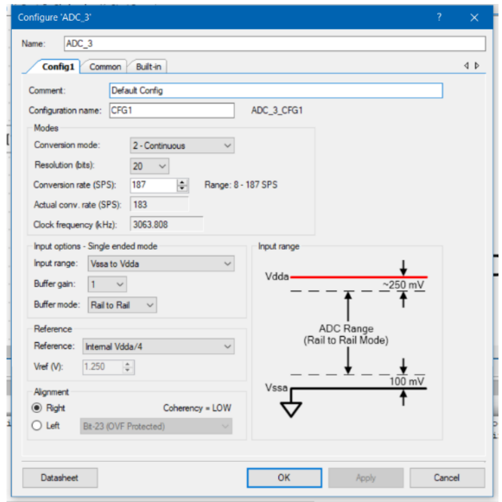
-ADC_2 (SAR ADC).

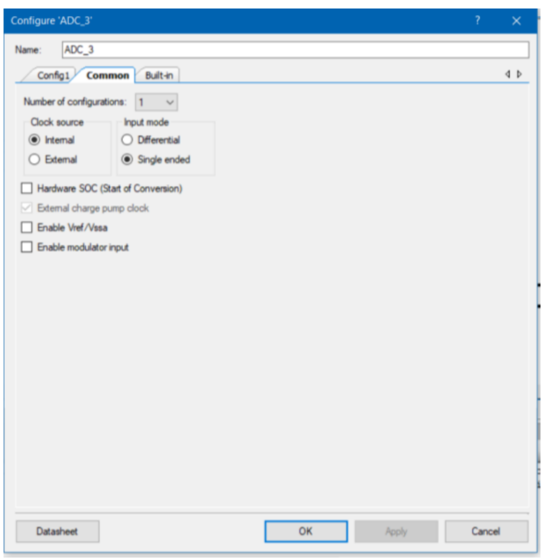




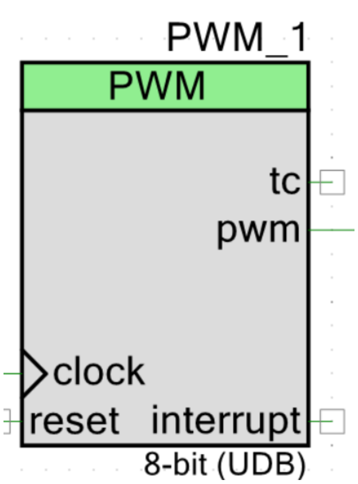
-ADC_3(Delta Sigma ADC).

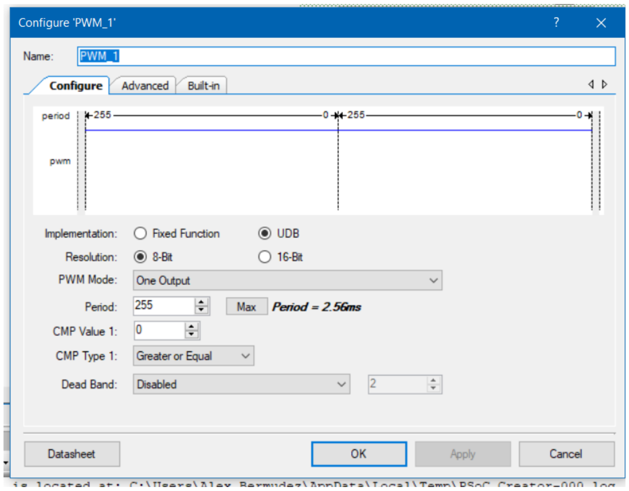


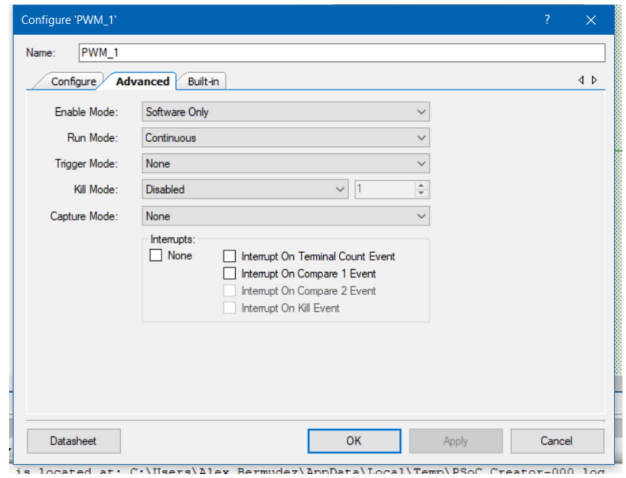




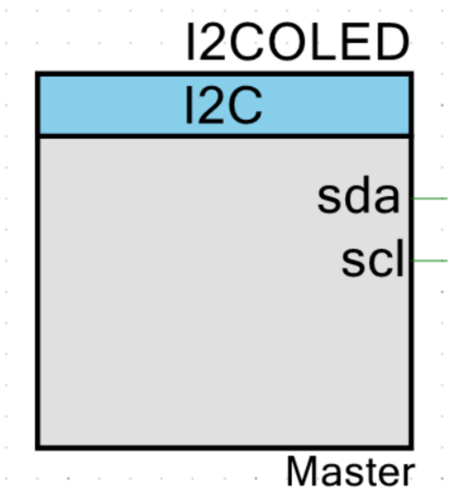
-PWM_1(PWM).

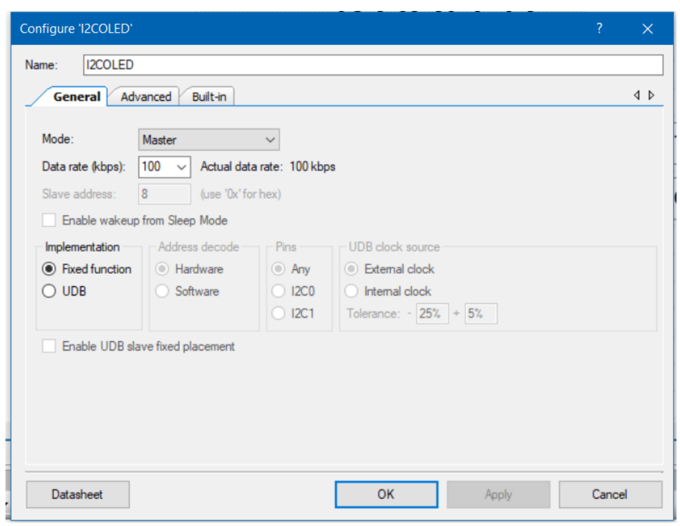


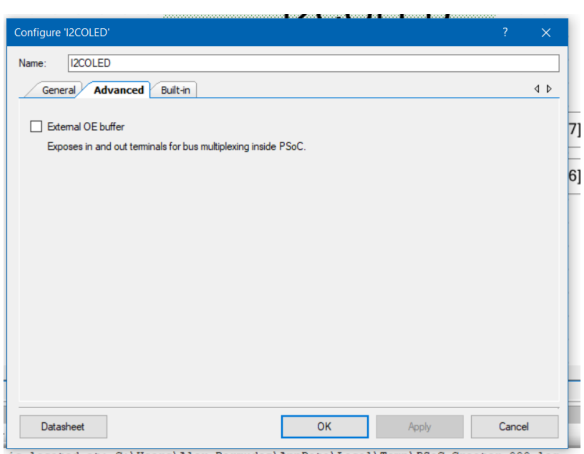




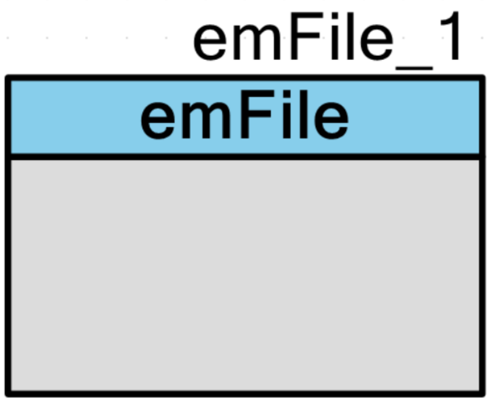
-I2COLED (I2C Master (Fixed Function)).

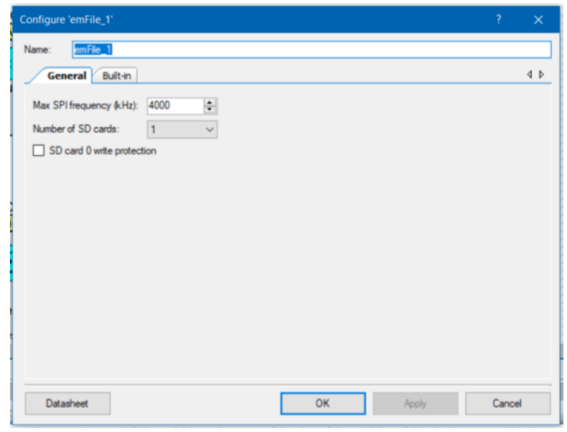






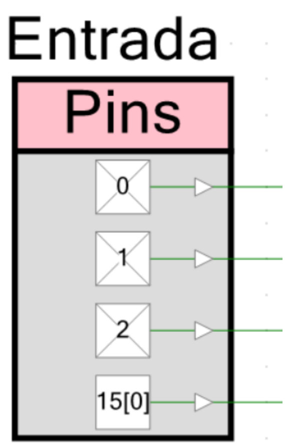
-emFile_1(emFile SPI Mode).

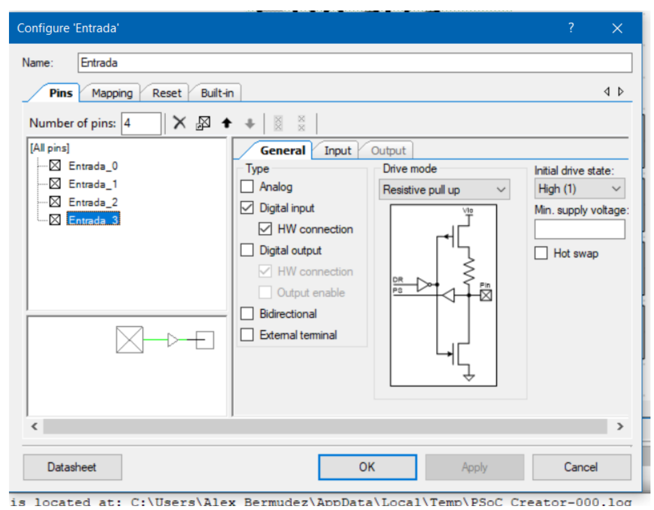


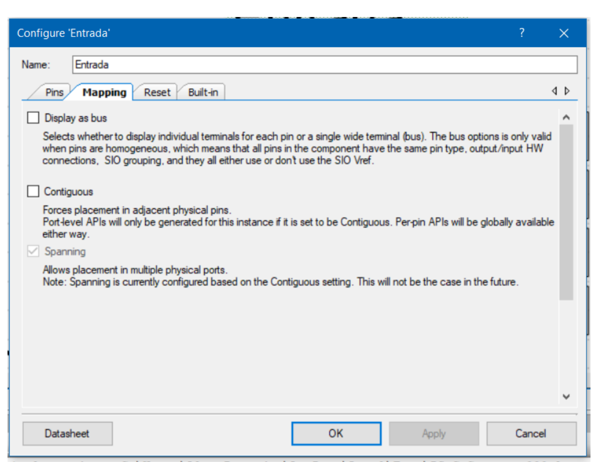


-Entrada (Digital Input Pin).

En este caso es algo diferente, ya que se agrego una entrada digital, pero al momento de configurarla en la parte de numero de pines se cambio de 1 a 4 y posteriormente, adopto esta forma.

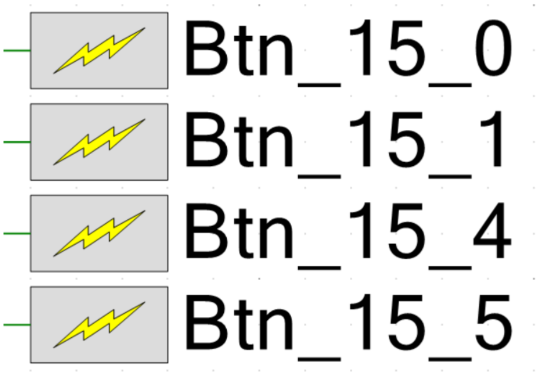


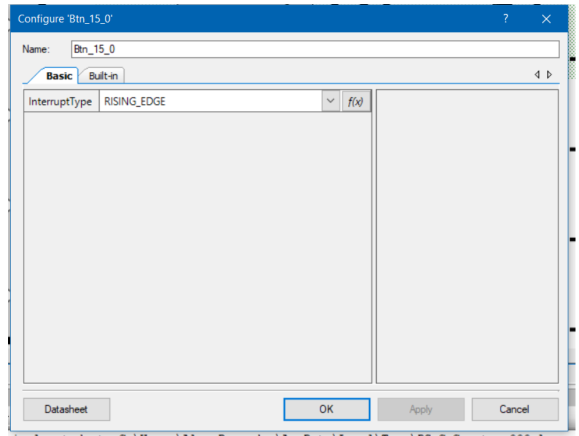




-Btn_15_0, Btn_15_0, Btn_15_0 y Btn_15_0 (Interrupt).

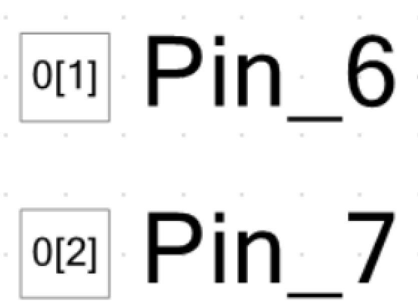
En este caso estos cuatro componentes están configurados de la misma manera, así que solamente se tomara la configuración de 1 como ejemplo.

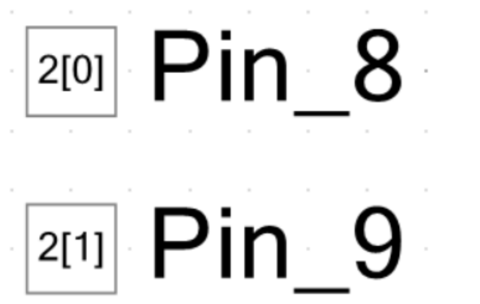


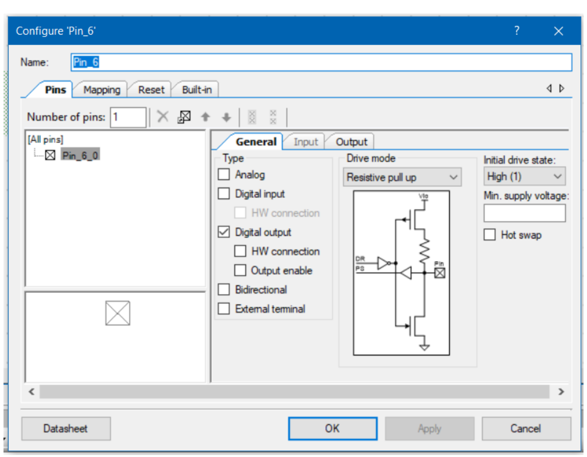


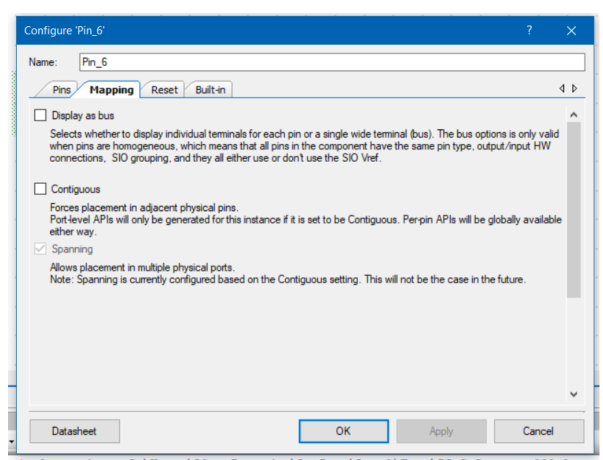
-Pin_6, Pin_7, Pin_8 y Pin_9 (Digital Input Pin).

En este caso son dos pines digitales por separado, pero al estar configurados de igual manera solo se tomará la configuración de uno como ejemplo.



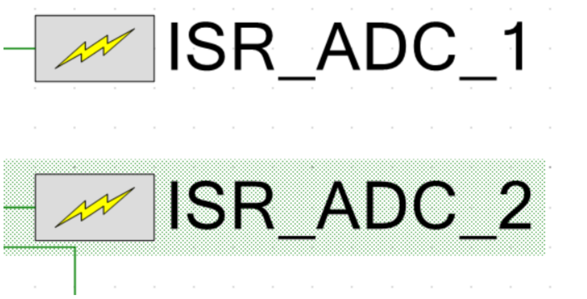


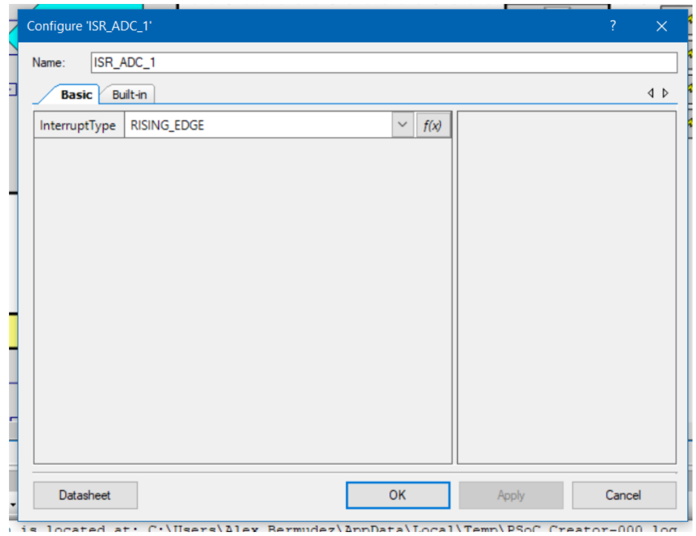




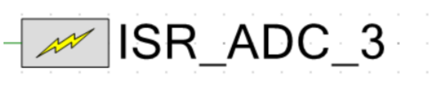
-ISR_ADC_1 y ISR_ADC_2 (Interrupt).

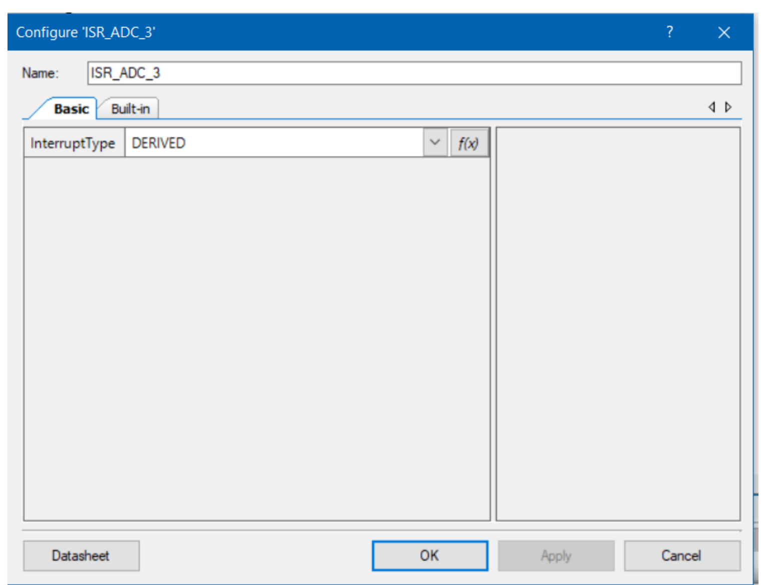
Son las dos interrupciones de los ADC, las cuales son exactamente iguales a diferencia de sus nombres, por lo cual se tomará solo una para el ejemplo de configuración.



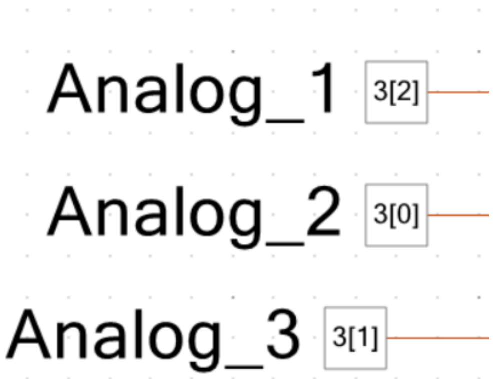


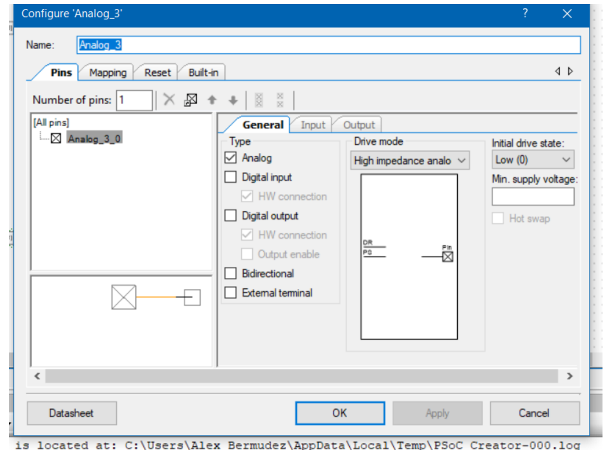
-ISR_ADC_3 (Interrupt).

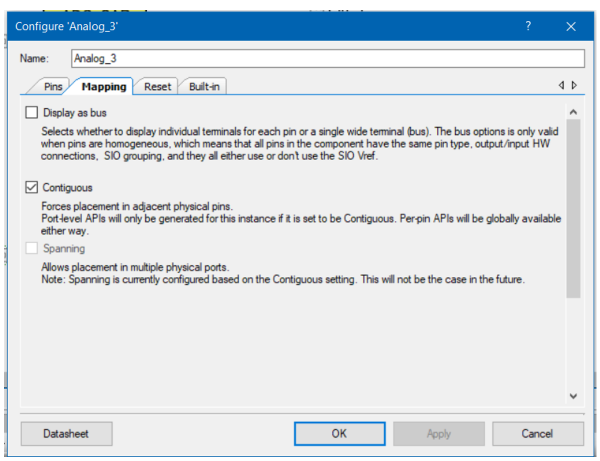




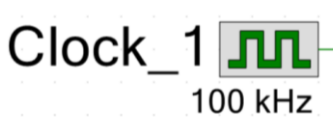
-Analog_1, Analog_2 y Analog_3 (Analog Pin).

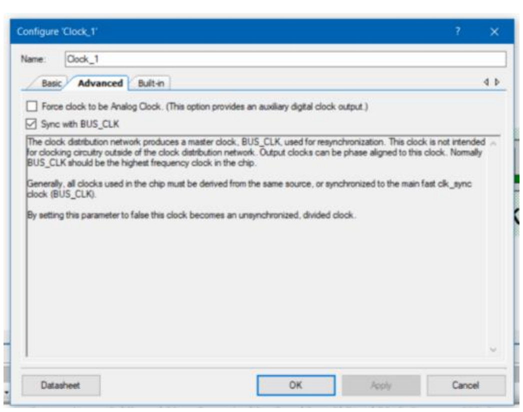


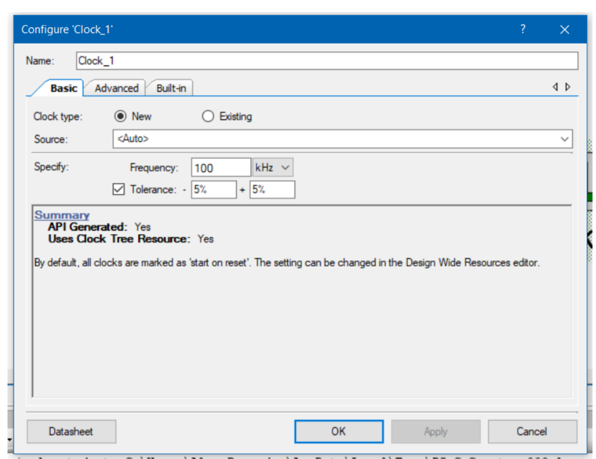




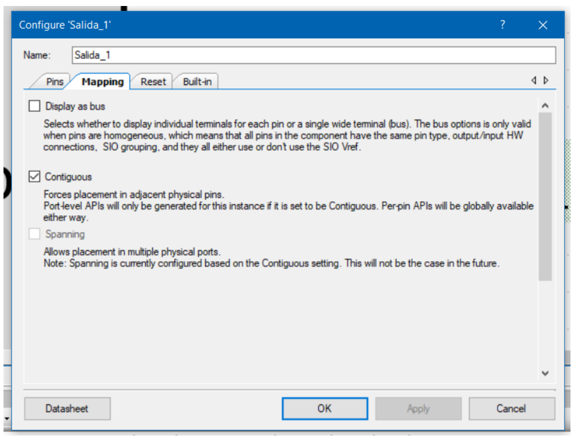
-Clock_1 (Clock).

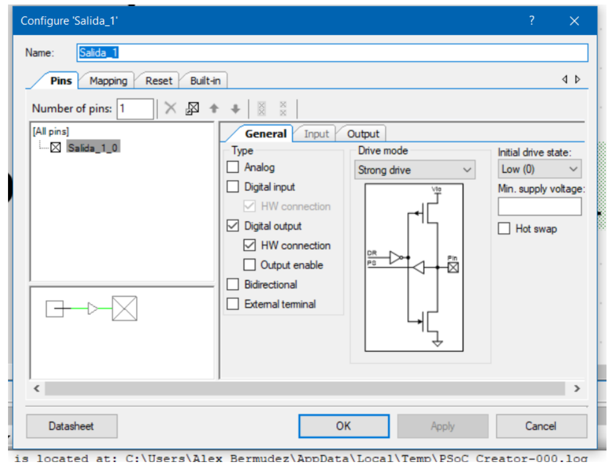




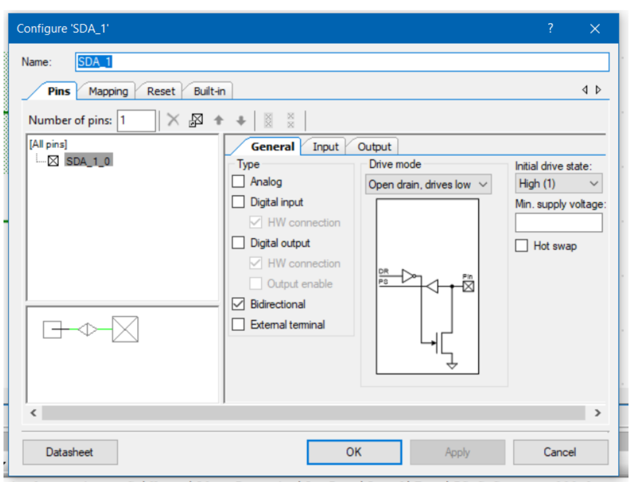


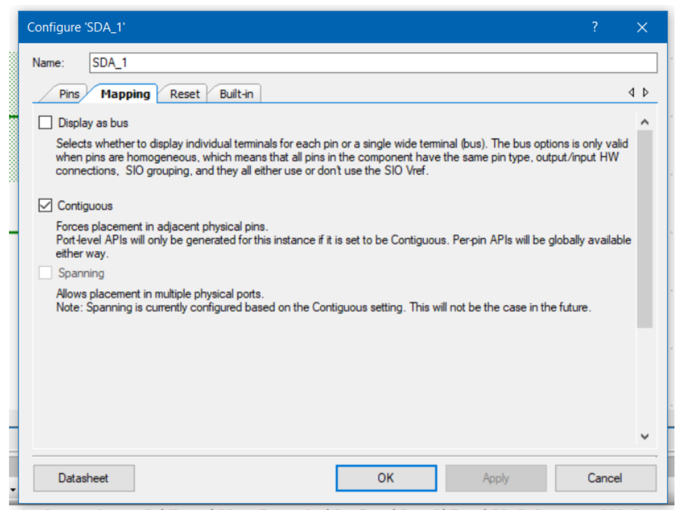
-Salida_1 (Digital Output Pin).





-SDA_1 y SCL_1 (Digital Output Pin).





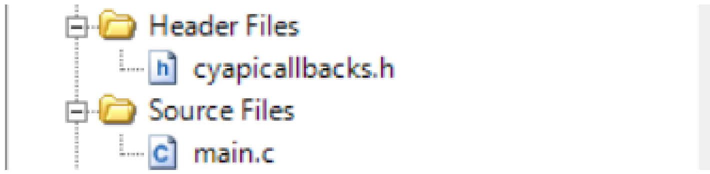
Asignación de Pines y Código de Probador de motores

Posteriormente de agregar los componentes anteriores en la parte de Top Design es necesario asignarle un Pin en salida en la parte de PINS

	Name	Port	Pin	Lock
	\emFile_1:miso0\	P12[2]	46	✓
	\emFile_1:mosi0\	P12[3]	47	✓
	\emFile_1:sclk0\	P12[4]	3	✓
	\emFile_1:SPI0_CS\	P12[0]	38	✓
	Analog_1	P0[6]	55	✓
	Analog_2	P0[7]	56	✓
	Analog_3	P2[2]	64	✓
	Entrada_0	P15[0]	27	✓
	Entrada_1	P15[1]	28	✓
	Entrada_2	P15[4]	60	✓
	Entrada_3	P15[5]	61	✓
	Pin_6	P0[1]	49	✓
	Pin_7	P0[2]	50	✓
	Pin_8	P2[0]	62	✓
	Pin_9	P2[1]	63	✓
	Salida_1	P0[0]	48	✓
	SCL_1	P3[0]	29	✓
	SDA_1	P3[1]	30	✓

Codigo

Al crear el proyecto se crearán las siguientes carpetas y documentos en donde solamente agregaremos el siguiente código en el main.c



Código de main.c

```
/*
Probador de motor V1.0
Realizado por: Alejandro Bermudez Cardenas
Empresa: Mectel Acotron
*/

/*Librerias*/
#include <project.h>
#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <ssd1306.h>
#include <FS.h>
#include <Global.h>

/*Variables*/
unsigned char ADC1; //Variables para almacenar el valor obtenido del ADC
unsigned char ADC2;
unsigned char ADC3;
int valor_ADC1;
int valor_ADC11;
int valor_ADC12;
int valor_PWM;
int valorBAT;

int pwm;
int valorU;
int valorD;
int maquina;
char unit[1];
char dece[1];
char total[3];
char cadena[3];
char str[12];
char str1[12];
int modo;
int memoria;
int a;
float sensibilidad;
float current;
float currentf;
```

```
int   current_mA;
/*Banderas*/
int paro;
int menu;
int motor;
int tipo;
int flag;
int opti;
int posicion;

int update;
int time;

int32 entrada[3];
float32 VoltsADC[3];

char sdFile[9] = "File.csv"; //Nombre del archivo

/*Prototipado*/
int map(long x, long in_min, long in_max, long out_min, long out_max);
//Funcion para escalar los valores obtenidos por el ADC

/*Interrupciones*/
CY_ISR(ADC_POT_ISR){ //Interrupcion ADC_1
    ISR_ADC_1_ClearPending(); //Limpia la interrupcion
    ADC1=ADC_1_GetResult8(); //Se obtiene el valor del ADC
    valor_ADC1=map(ADC1,0,255,0,50); //Se escala el valor del ADC
    valor_ADC11=map(ADC1,0,255,55,17); //Se escala el valor del ADC
    valor_ADC12=map(ADC1,0,255,0,5000);
}
CY_ISR(ADC_POT_ISR_1){//Interrupcion ADC_2
    ISR_ADC_2_ClearPending();
    ADC2=ADC_2_GetResult8();
    valorBAT=map(ADC2,0,255,0,255);
}
CY_ISR(ADC_POT_ISR_2){//Interrupcion ADC_3
    ISR_ADC_2_ClearPending();
    entrada[0]=ADC_3_GetResult32();
    VoltsADC[0] = ADC_3_CountsTo_Volts(entrada[0]);//Convierte el valor
del ADC en voltaje
}

CY_ISR(Interrupcion_15_0) //Interrupcion Boton 1
{
    Btn_15_0_ClearPending(); //Limpia la interrupcion

    flag=1;

    CyDelay(100); //Delay para la accion mecanica del boton
}
CY_ISR(Interrupcion_15_1) //Interrupcion Boton 2
{
    Btn_15_1_ClearPending(); //Limpia la interrupcion

    flag=2;
    //maquina=0;
```

```c
    CyDelay(50); //Delay para la accion mecanica del boton
}
CY_ISR(Interrupcion_15_4) //Interrupcion Boton 3
{
    Btn_15_4_ClearPending(); //Limpia la interrupcion
    if(maquina==0)
    {
        tipo = 0;
    }


    CyDelay(50); //Delay para la accion mecanica del boton
}
CY_ISR(Interrupcion_15_5) //Interrupcion Boton 4
{
    Btn_15_5_ClearPending(); //Limpia la interrupcion
    if(maquina==0)
    {
        tipo = 1;
    }


   CyDelay(50); //Delay para la accion mecanica del boton
}

#define DISPLAY_ADDRESS 0x3C

int main(void)
{
    FS_FILE * pFile; //Define el tipo de archivo de la memoria SD
    #define FS_SEEK_END 2 //Dicta que se escriba al final del documento

    CyGlobalIntEnable;

    FS_Init(); //Inicializa la memoria SD

    I2COLED_Start(); //Inicializa la comunicacion con la pantalla OLED
    CyDelay(100);    //Retardo necesario para la inicializacion
    display_init(DISPLAY_ADDRESS);  //Inicializa la pantalla OLED

    menu=1;  //Declaramos valores por defecto
    motor=0;
    pwm=70;
    tipo=0;
    modo=1;
    maquina=0;
    flag=0;
    time=15;
    PWM_1_Start(); //Inicializa el pwm
    PWM_1_WriteCompare(0); //Dejamos su valor en 0

    Btn_15_0_ClearPending(); ///Limpia las interrupciones
    Btn_15_1_ClearPending();
    Btn_15_4_ClearPending();
    Btn_15_5_ClearPending();
```

```
    Btn_15_0_StartEx(Interrupcion_15_0); //Inicializa las interrupciones
de los botones
    Btn_15_1_StartEx(Interrupcion_15_1);
    Btn_15_4_StartEx(Interrupcion_15_4);
    Btn_15_5_StartEx(Interrupcion_15_5);

    ISR_ADC_1_StartEx(ADC_POT_ISR);//Inicializa las interrupciones del
ADC
    ADC_1_Start();//Inicializa el ADC
    ADC_1_StartConvert();//Empieza a convertir el ADC

    ISR_ADC_2_StartEx(ADC_POT_ISR_1);
    ADC_2_Start();
    ADC_2_StartConvert();

    ISR_ADC_3_StartEx(ADC_POT_ISR_2);
    ADC_3_Start();
    ADC_3_StartConvert();

    //Mensaje de Bienvenida
    display_clear(); //Limpia la pantalla
    display_update(); //Actualiza la pantalla
    gfx_setTextSize(2); //Define el tamaño del texto
    gfx_setTextColor(1); //Define el color del texto
    gfx_setCursor(5,24); //Define la posicion del cursor
    gfx_drawRect(0,0,128,64,1); //Dibuja un rectangulo el cual sera el
marco de la pantalla
    gfx_println("Bienvenido"); //Escribe en la pantalla
    display_update();
    CyDelay(100); //Delay para mostrar el mensaje


    pFile = FS_FOpen(sdFile, "ab"); //Abre el archivo y en caso de no
existir lo crea
    CyDelay(100);
    if(pFile) //Confirma si fue creado o abierto con exito
    {

       gfx_fillRect(1,11,126,52,0); //Dibuja un rectangulo relleno en la
pantalla
       gfx_setTextSize(1);
       gfx_setTextColor(1);
       gfx_setCursor(40,20);
       gfx_println("Memoria SD");
       gfx_setCursor(50,30);
       gfx_println("Correcto");
       memoria = 1;
       display_update();

       CyDelay(200);
    }
    else //Indica que hay un error con la memoria SD
    {
       gfx_fillRect(1,11,126,52,0); //Dibuja un rectangulo relleno oscuro
en la pantalla para borrar solo una parte de la pantalla
       gfx_setTextSize(1);
       gfx_setTextColor(1);
```

```
        gfx_setCursor(40,20);
        gfx_println("Memoria SD");
        gfx_setCursor(50,30);
        gfx_println("Error");
        memoria = 0;
        display_update();
        CyDelay(200);
    }

        gfx_fillRect(1,11,126,52,0); //Dibuja un rectangulo relleno oscuro
en la pantalla para borrar solo una parte de la pantalla
        gfx_setCursor(25,20);
        gfx_println("Modo Manual");
        display_update();
        CyDelay(200);


    while(1) //Comienzo de ciclo for y programa
    {
        if(flag==2 && maquina==0)
        {
            modo=modo+1;
            flag=0;
            if(modo>=2)
            {
            modo=0;
            }
            if(modo==0)
            {
               gfx_fillRect(1,11,126,52,0); //Dibuja un rectangulo
relleno oscuro en la pantalla para borrar solo una parte de la pantalla
               gfx_setCursor(25,20);
               gfx_println("Modo Automatico");
               display_update();
               Pin_6_Write(0); //Cambia el estado de la salida digital a
               Pin_7_Write(0);
               CyDelay(200);
            }
            if(modo==1)
            {
               gfx_fillRect(1,11,126,52,0); //Dibuja un rectangulo
relleno oscuro en la pantalla para borrar solo una parte de la pantalla
               gfx_setCursor(25,20);
               gfx_println("Modo Manual");
               Pin_6_Write(0); //Cambia el estado de la salida digital a
               Pin_7_Write(0);
               display_update();

               CyDelay(200);
            }


            maquina=0;


        }
        if(flag==2 && maquina!=0)
```

```
        {
            maquina=0;
            FS_Write(pFile, " , Secuencia Abortada \n", 24u);
            flag=0;
            Pin_6_Write(0); //Cambia el estado de la salida digital a
            Pin_7_Write(0);

        }
        if(maquina==0)
            {
                gfx_fillRect(2,2,60,10,0);
                Btn_15_4_StartEx(Interrupcion_15_4);
                Btn_15_5_StartEx(Interrupcion_15_5);
                ADC_2_StartConvert();//Para algunas interrupciones no
necesarias para el motor a pasos
                ADC_3_StartConvert();
                PWM_1_Start();
                if(valorBAT<166) //Compara el valor del ADC si es mayor
al 75% del valor total
                {
                    gfx_drawRect(106,3,19,8,1); //Dibuja el simbolo de la
bateria dependiendo de su porcentaje
                    gfx_fillRect(103,5,3,5,1);
                    gfx_fillRect(108,5,3,5,0);
                    gfx_fillRect(112,5,3,5,0);
                    gfx_fillRect(116,5,3,5,0);
                    gfx_fillRect(120,5,3,5,1);

                }
                if(valorBAT>166 && valorBAT <182) //Compara el valor del
ADC si es mayor al 50% y menor al 75% del valor total
                {
                    gfx_drawRect(106,3,19,8,1); //Dibuja el simbolo de la
bateria dependiendo de su porcentaje
                    gfx_fillRect(103,5,3,5,1);
                    gfx_fillRect(108,5,3,5,0);
                    gfx_fillRect(112,5,3,5,0);
                    gfx_fillRect(116,5,3,5,1);
                    gfx_fillRect(120,5,3,5,1);


                }
                if(valorBAT>182 && valorBAT <199)//Compara el valor del
ADC si es mayor al 25% y menor al 50% del valor total
                {
                    gfx_drawRect(106,3,19,8,1); //Dibuja el simbolo de la
bateria dependiendo de su porcentaje
                    gfx_fillRect(103,5,3,5,1);
                    gfx_fillRect(108,5,3,5,0);
                    gfx_fillRect(112,5,3,5,1);
                    gfx_fillRect(116,5,3,5,1);
                    gfx_fillRect(120,5,3,5,1);

                }
                if(valorBAT>199) //Compara el valor del ADC si es menor
al 25%
                {
```

```
                    gfx_drawRect(106,3,19,8,1); //Dibuja el simbolo de la
bateria dependiendo de su porcentaje
                    gfx_fillRect(103,5,3,5,1);
                    gfx_fillRect(108,5,3,5,1);
                    gfx_fillRect(112,5,3,5,1);
                    gfx_fillRect(116,5,3,5,1);
                    gfx_fillRect(120,5,3,5,1);
                }
                gfx_fillRect(1,11,126,52,0); //Limpia una parte de la
pantalla
                gfx_setTextSize(1);
                gfx_setTextColor(1);
                gfx_setCursor(17,18);
                gfx_println("Seleccione Tipo");
                gfx_setCursor(40,28);
                gfx_println("de Motor");
                gfx_setCursor(20,48);
                gfx_println("Pasos");
                gfx_setCursor(90,48);
                gfx_println("Iman");

                    if(tipo ==0)
                    {
                    gfx_fillRect(8,48,7,7,1);
                    gfx_fillRect(78,48,7,7,0);
                    }
                    if(tipo ==1)
                    {
                    gfx_fillRect(8,48,7,7,0);
                    gfx_fillRect(78,48,7,7,1);
                    }
                display_update();
                if(flag==1)  ///Banderas para unicamente cumplir un ciclo
de la accion especificada
                {
                    maquina = maquina +1;
                    flag=0;
                }

            }
        if(modo==0)
        {

            if(maquina==1)
            {
                if(tipo ==0)
                {
                gfx_fillRect(1,11,126,52,0); //Limpia una parte de la
pantalla
                gfx_setCursor(17,18);
                gfx_println("Probando motor");
                gfx_setCursor(37,28);
                gfx_println("a pasos");
                display_update();
                if(memoria==1)
                {
```

```
                FS_Write(pFile, "Motor a pasos, Modo Automatico \n",
33u);
                FS_Write(pFile, "Voltaje, Unidad \n", 18u);
                }
                }
                if(tipo ==1)
                {
                gfx_fillRect(1,11,126,52,0); //Limpia una parte de la
pantalla
                gfx_setCursor(17,18);
                gfx_println("Probando motor");
                gfx_setCursor(37,28);
                gfx_println("de iman");
                display_update();
                if(memoria==1)
                {
                FS_Write(pFile, "Motor de iman, Modo Automatico \n",
33u);
                FS_Write(pFile, "Corriente, Unidad, Voltaje, Unidad \n",
37u);
                }

                }
            CyDelay(100);
            maquina=maquina+1;
            ADC_2_StopConvert();//Para algunas interrupciones no
necesarias para el motor a pasos
            ADC_3_StopConvert();

            }

            if(maquina ==2)
            {

                if(tipo ==0)
                {
                    PWM_1_Stop();
                    Pin_9_Write(1);//Determina la direccion del motor

                    Pin_8_Write(0);//Pulsos para poder mover el motor a
pasos
                    CyDelay(3);
                    Pin_8_Write(1);
                    CyDelay(3);
                }
                if(tipo ==1)
                {
                    PWM_1_Start();
                    Pin_6_Write(1); //Cambia el estado de la salida
digital a
                    Pin_7_Write(0);  //Cambia el estado de la salida
digital a 1
                    PWM_1_WriteCompare(0);
                }
            if(valor_ADC1>=47)//Compara el valor con el del potenciometro
por si llego a el tope y lo manda a stop
               {
```

```
                maquina=maquina+1;
                time=15;
               }
        }

        if(maquina==3)
        {
        gfx_fillRect(1,11,126,52,0);
        gfx_drawLine(15,16,15,55,1);
        gfx_drawLine(15,55,120,55,1);
        gfx_setCursor(3,17);
        gfx_println("5v");
        gfx_setCursor(3,50);
        gfx_println("0v");
        display_update();
        maquina=maquina+1;
            if(tipo ==0)
            {
            Pin_9_Write(0);//Determina la direccion del motor
            CyDelay(10);
            }
            if(tipo ==1)
            {
            Pin_6_Write(0); //Cambia el estado de la salida digital a
            Pin_7_Write(0);
            CyDelay(10);
            ADC_3_StartConvert();
            }
        }

        if(maquina==4)
        {
            if(tipo ==0)
            {
                Pin_8_Write(0);//Pulsos para poder mover el motor a
pasos
                CyDelay(3);
                Pin_8_Write(1);
                CyDelay(3);

                update++;
                if(time==120)
                {
                    time=15;
                    gfx_fillRect(16,16,105,39,0);
                }

                if(update >=20)
                {
                    time++;
                    gfx_drawPixel(time,valor_ADC11,1);
                    display_update();
                        if(memoria==1)
                        {

                        sprintf(str1,"%i ",valor_ADC12);
                        FS_Write(pFile, str1, 4u);
```

```
                    FS_Write(pFile, ", mv \n", 7u);
                    }
                update=0;
            }
        }
        if(tipo ==1)
        {

            current=VoltsADC[0]-2.522; //Calibrado del sensor de
corriente
            currentf=current/0.2034; //Escalamiento del sensor de
corriente
            current_mA=(currentf*1000); //Convertir a mA el valor
del sensor de corriente
            sprintf(str,"%i ",current_mA);
            sprintf(str1,"%i ",valor_ADC12);

            Pin_6_Write(0); //Cambia el estado de la salida
digital a
            Pin_7_Write(1);

            gfx_fillRect(1,1,60,10,0);
            gfx_setCursor(2,2);
            gfx_println(str); //Imprime el valor del sensor de
corriente
            gfx_setCursor(40,2);
            gfx_println("mA");
            CyDelay(100);
            time++;
            gfx_drawPixel(time,valor_ADC11,1);
            display_update();
            if(memoria==1)
            {
            FS_Write(pFile, str, 5u);
            FS_Write(pFile, ", mA, ", 6u);
            FS_Write(pFile, str1, 4u);
            FS_Write(pFile, ", mV, \n", 8u);
            }
            if(time==120)
            {
                time=15;
                gfx_fillRect(16,16,105,39,0);
            }
        }

    if(valor_ADC1<=2)//Compara el valor con el del potenciometro
por si llego a el tope y lo manda a stop
       {
        maquina=maquina+1;
        gfx_fillRect(16,16,105,39,0);
        Pin_9_Write(1);
        Pin_6_Write(0); //Cambia el estado de la salida digital a
        Pin_7_Write(0);
        FS_Write(pFile, " , Cambio de sentido \n", 23u);
        display_update();
        update=0;
        time=15;
```

```
            }
        }



        if(maquina==5)
        {
            if(tipo ==0)
            {
                Pin_8_Write(0);//Pulsos para poder mover el motor a
pasos
                CyDelay(3);
                Pin_8_Write(1);
                CyDelay(3);

                update++;
                if(time==120)
                {
                    time=15;
                    gfx_fillRect(16,16,105,39,0);
                    display_update();
                }
                if(update >=20)
                {
                time++;
                gfx_drawPixel(time,valor_ADC11,1);
                display_update();
                if(memoria==1)
                    {

                    sprintf(str1,"%i ",valor_ADC12);
                    FS_Write(pFile, str1, 4u);
                    FS_Write(pFile, ", mv \n", 7u);
                    }
                update=0;
                }
            }
            if(tipo ==1)
            {
                current=VoltsADC[0]-2.522; //Calibrado del sensor de
corriente
                currentf=current/0.2034; //Escalamiento del sensor de
corriente
                current_mA=(currentf*1000); //Convertir a mA el valor
del sensor de corriente
                sprintf(str,"%i ",current_mA);
                sprintf(str1,"%i ",valor_ADC12);

                Pin_6_Write(1); //Cambia el estado de la salida
digital a
                Pin_7_Write(0);

                gfx_fillRect(1,1,60,10,0);
                gfx_setCursor(2,2);
                gfx_println(str); //Imprime el valor del sensor de
corriente
                gfx_setCursor(40,2);
```

```
                    gfx_println("mA");
                    CyDelay(100);
                    time++;
                    gfx_drawPixel(time,valor_ADC11,1);
                    if(memoria==1)
                    {
                    FS_Write(pFile, str, 5u);
                    FS_Write(pFile, ", mA, ", 6u);
                    FS_Write(pFile, str1, 4u);
                    FS_Write(pFile, ", mV, \n", 8u);
                    }
                    display_update();
                    if(time==120)
                    {
                        time=15;
                        gfx_fillRect(16,16,105,39,0);
                    }
                }

            if(valor_ADC1>=47)//Compara el valor con el del potenciometro
por si llego a el tope y lo manda a stop
               {
                maquina=maquina+1;
                Pin_9_Write(0);
                Pin_6_Write(0); //Cambia el estado de la salida digital a
                Pin_7_Write(0);


                update=0;
                time=15;
               }
            }
            if(maquina==6)
            {
            gfx_fillRect(1,1,30,10,0);
            gfx_fillRect(1,11,126,52,0);
            gfx_setCursor(30,20);
            gfx_println("Secuencia");
            gfx_setCursor(30,30);
            gfx_println("Finalizada");
            FS_Write(pFile, " , Secuencia Finalizada \n", 26u);
            display_update();
            CyDelay(2000);
            maquina=0;
            }
        }

        if(modo==1)
        {
            if(tipo == 0)
            {
                if(maquina==1)
                {
                gfx_fillRect(1,11,126,52,0);
                gfx_drawLine(15,16,15,55,1);
                gfx_drawLine(15,55,120,55,1);
                gfx_setCursor(3,17);
```

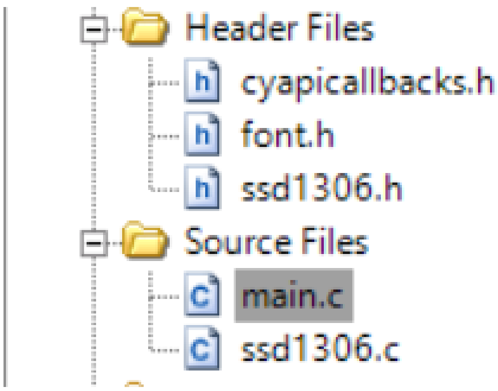
```
                gfx_println("5v");
                gfx_setCursor(3,50);
                gfx_println("0v");
                display_update();
                maquina=maquina+1;
                Btn_15_4_Stop();
                Btn_15_5_Stop();
                ADC_3_Stop();
                ADC_2_Stop();
                PWM_1_Stop();
                time=15;
                }
                if(maquina==2)
                {

                    if(Entrada_2_Read()==1 && Entrada_3_Read()==1)
                    {

                    }

                    if(Entrada_3_Read()==0  && valor_ADC1<46 &&
posicion==0)
                    {
                            Pin_9_Write(1);
                            Pin_8_Write(0);//Pulsos para poder mover el
motor a pasos
                            CyDelay(2);
                            Pin_8_Write(1);
                            CyDelay(2);
                            a=0;

                    }

                    if(Entrada_2_Read()==0 && valor_ADC1>2 && posicion==0
)
                    {
                            Pin_9_Write(0);
                            Pin_8_Write(0);//Pulsos para poder mover el
motor a pasos
                            CyDelay(2);
                            Pin_8_Write(1);
                            CyDelay(2);
                            a=0;

                    }

                   if(valor_ADC1>2 && valor_ADC1<47 )//Compara el valor
con el del potenciometro por si llego a el tope y lo manda a stop
                   {
                        posicion=0;
                   }

                    CyDelay(a);
                    update++;
                    if(time==120)
                    {
                        time=15;
```

```
                        gfx_fillRect(16,16,105,39,0);
                    }

                    if(update >=20)
                    {
                        time++;
                        gfx_drawPixel(time,valor_ADC11,1);
                        display_update();
                        update=0;
                    }
                    a=4;
                }

            }
            if(tipo == 1)
            {
                if(maquina==1)
                    {
                    gfx_fillRect(1,11,126,52,0);
                    gfx_drawLine(15,16,15,55,1);
                    gfx_drawLine(15,55,120,55,1);
                    gfx_setCursor(3,17);
                    gfx_println("5v");
                    gfx_setCursor(3,50);
                    gfx_println("0v");
                    display_update();
                    maquina=maquina+1;
                    Btn_15_4_Stop();
                    Btn_15_5_Stop();
                    PWM_1_Start();
                    PWM_1_WriteCompare(0);
                    ADC_3_StartConvert();
                    time=15;
                    }
                    if(maquina==2)
                    {


                        if(Entrada_2_Read()==1 && Entrada_3_Read()==1)
                        {
                            Pin_6_Write(0); //Cambia el estado de la salida
digital a
                            Pin_7_Write(0);
                        }

                        if(Entrada_3_Read()==0  && valor_ADC1<46 &&
posicion==0)
                        {
                        posicion=0;
                        Pin_6_Write(1); //Cambia el estado de la salida
digital a
                        Pin_7_Write(0);
                            if(valor_ADC1>46)
                            {
                            Pin_6_Write(0); //Cambia el estado de la salida
digital a
                            Pin_7_Write(0);
```

```
                        posicion=1;
                        }
                    }

                    if(Entrada_2_Read()==0 && valor_ADC1>2 && posicion==0
)
                    {
                        posicion=0;
                    Pin_6_Write(0); //Cambia el estado de la salida
digital a
                    Pin_7_Write(1);
                        if(valor_ADC1<2)
                        {
                        Pin_6_Write(0); //Cambia el estado de la salida
digital a
                        Pin_7_Write(0);
                        posicion=1;
                        }
                    }

                   if(valor_ADC1>2 && valor_ADC1<47 )//Compara el valor
con el del potenciometro por si llego a el tope y lo manda a stop
                   {
                        posicion=0;

                   }

                    gfx_fillRect(1,1,30,10,0);
                    current=VoltsADC[0]-2.522; //Calibrado del sensor de
corriente
                    currentf=current/0.2034; //Escalamiento del sensor de
corriente
                    current_mA=(currentf*1000); //Convertir a mA el valor
del sensor de corriente
                        sprintf(str,"%i ",current_mA);
                        gfx_setCursor(2,2);
                        gfx_println(str); //Imprime el valor del sensor
de corriente
                        gfx_setCursor(40,2);
                        gfx_println("mA");
                        CyDelay(100);
                        time++;
                        gfx_drawPixel(time,valor_ADC11,1);
                        display_update();
                        if(time==120)
                        {
                            time=15;
                            gfx_fillRect(16,16,105,39,0);
                        }
            }
        }

        }

    }
}
/*Funciones*/
```

```
int map(long x, long in_min, long in_max, long out_min, long out_max){
    return (x - in_min)*(out_max - out_min) / (in_max - in_min) + 
out_min; //Funcion para escalar los valores obtenidos por el ADC
}
```

- Posteriormente de agregar el código será necesario crear nuevos documentos en las carpetas de Headers Files y Source Files, agrega los documentos necesarios para que así se vea esa parte de tu programa, deberán ser guardados con el mismo nombre como se muestra en la siguiente imagen



- Una vez agregados dichos documentos será necesario agregar el siguiente código a dichos archivos.

- ssd1306.c

```
/*
SSD1306 OLED - I2C driver
Derk Steggewentz, 3/2015
This is a I2C driver for SSD1306 OLED displays including graphics 
library.
The graphics library part (gfx_ functions) is based on the Adafruit 
graphics library.
No license restrictions on my part, do whatever you want as long as you 
follow the inherited
license requirements (applying to the Adafruit graphics library part).
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met:
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this list of conditions and the following disclaimer.
```

```
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AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE
IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR
PURPOSE
ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE
LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR
CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF
SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS
INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN
CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF
THE
POSSIBILITY OF SUCH DAMAGE.
*/


#include <project.h>
#include <stdlib.h>

#include "font.h"
#include "ssd1306.h"


#define DISPLAYWIDTH 128
#define DISPLAYHEIGHT 64

#define SSD1306_SETCONTRAST 0x81
#define SSD1306_DISPLAYALLON_RESUME 0xA4
#define SSD1306_DISPLAYALLON 0xA5
#define SSD1306_NORMALDISPLAY 0xA6
#define SSD1306_INVERTDISPLAY 0xA7
#define SSD1306_DISPLAYOFF 0xAE
#define SSD1306_DISPLAYON 0xAF
#define SSD1306_SETDISPLAYOFFSET 0xD3
#define SSD1306_SETCOMPINS 0xDA
#define SSD1306_SETVCOMDETECT 0xDB
#define SSD1306_SETDISPLAYCLOCKDIV 0xD5
#define SSD1306_SETPRECHARGE 0xD9
#define SSD1306_SETMULTIPLEX 0xA8
#define SSD1306_SETLOWCOLUMN 0x00
#define SSD1306_SETHIGHCOLUMN 0x10
#define SSD1306_SETSTARTLINE 0x40
#define SSD1306_MEMORYMODE 0x20
#define SSD1306_COLUMNADDR 0x21
#define SSD1306_PAGEADDR 0x22
#define SSD1306_COMSCANINC 0xC0
#define SSD1306_COMSCANDEC 0xC8
#define SSD1306_SEGREMAP 0xA0
#define SSD1306_CHARGEPUMP 0x8D
#define SSD1306_EXTERNALVCC 0x1
#define SSD1306_SWITCHCAPVCC 0x2
#define SSD1306_ACTIVATE_SCROLL 0x2F
```

```
#define SSD1306_DEACTIVATE_SCROLL 0x2E


// I2C result status
#define TRANSFER_CMPLT    (0x00u)
#define TRANSFER_ERROR    (0xFFu)


static uint32 display_write_buf( uint8* buf, uint16_t size );

void gfx_init( int16_t width, int16_t height );

static uint8 _i2caddr;

// display memory buffer ( === MUST INCLUDE === the preceding I2C 0x40
control byte for the display)
static uint8_t SSD1306_buffer[DISPLAYHEIGHT * DISPLAYWIDTH / 8 + 1] = {
0x40 };
// pointer to actual display memory buffer
static uint8_t* _displaybuf = SSD1306_buffer+1;
static uint16_t _displaybuf_size = sizeof(SSD1306_buffer) - 1;

// see data sheet page 25 for Graphic Display Data RAM organization
// 8 pages, each page a row of DISPLAYWIDTH bytes
// start address of of row: y/8*DISPLAYWIDTH
// x pos in row: == x
#define GDDRAM_ADDRESS(X,Y) ((_displaybuf)+((Y)/8)*(DISPLAYWIDTH)+(X))

// lower 3 bit of y determine vertical pixel position (pos 0...7) in
GDDRAM byte
// (y&0x07) == position of pixel on row (page). LSB is top, MSB bottom
#define GDDRAM_PIXMASK(Y) (1 << ((Y)&0x07))

#define PIXEL_ON(X,Y) (*GDDRAM_ADDRESS(x,y) |= GDDRAM_PIXMASK(y))
#define PIXEL_OFF(X,Y) (*GDDRAM_ADDRESS(x,y) &= ~GDDRAM_PIXMASK(y))
#define PIXEL_TOGGLE(X,Y) (*GDDRAM_ADDRESS(x,y) ^= GDDRAM_PIXMASK(y))



// call before first use of other functions
void display_init( uint8 i2caddr ){

    _i2caddr = i2caddr;
    gfx_init( DISPLAYWIDTH, DISPLAYHEIGHT );

    uint8 cmdbuf[] = {
        0x00,
        SSD1306_DISPLAYOFF,
        SSD1306_SETDISPLAYCLOCKDIV,
        0x80,
        SSD1306_SETMULTIPLEX,
        0x3f,
        SSD1306_SETDISPLAYOFFSET,
        0x00,
        SSD1306_SETSTARTLINE | 0x0,
        SSD1306_CHARGEPUMP,
        0x14,
```

```
        SSD1306_MEMORYMODE,
        0x00,
        SSD1306_SEGREMAP | 0x1,
        SSD1306_COMSCANDEC,
        SSD1306_SETCOMPINS,
        0x12,
        SSD1306_SETCONTRAST,
        0xcf,
        SSD1306_SETPRECHARGE,
        0xf1,
        SSD1306_SETVCOMDETECT,
        0x40,
        SSD1306_DISPLAYALLON_RESUME,
        SSD1306_NORMALDISPLAY,
        SSD1306_DISPLAYON
    };

    display_write_buf( cmdbuf, sizeof(cmdbuf) );
}


// for submitting command sequences:
//  buf[0] must be 0x00
// for submitting bulk data (writing to display RAM):
//  buf[0] must be 0x40
static uint32 display_write_buf( uint8* buf, uint16_t size ){

    uint32 status = TRANSFER_ERROR;
    I2COLED_MasterSendStart(_i2caddr,I2COLED_WRITE_XFER_MODE);

    for(int i=0; i<size; i++){
        status=I2COLED_MasterWriteByte(buf[i]);
    }
    I2COLED_MasterSendStop();
    return status;
}


// used by gfx_ functions. Needs to be implemented by display_
static void display_setPixel( int16_t x, int16_t y, uint16_t color ){

    if( (x < 0) || (x >= DISPLAYWIDTH) || (y < 0) || (y >= DISPLAYHEIGHT)
)
        return;

    switch( color ){
        case WHITE:
            PIXEL_ON(x,y);
            break;
        case BLACK:
            PIXEL_OFF(x,y);
            break;
        case INVERSE:
            PIXEL_TOGGLE(x,y);
            break;
    }
}
```

```
void display_clear(void){
    memset( _displaybuf, 0, _displaybuf_size );
    SSD1306_buffer[0] = 0x40; // to be sure its there
}


// contrast: 0 ...255
void display_contrast( uint8_t contrast ){

    uint8 cmdbuf[] = {
        0x00,
        SSD1306_SETCONTRAST,
        contrast
    };
    display_write_buf( cmdbuf, sizeof(cmdbuf) );
}


// invert <> 0 for inverse display, invert == 0 for normal display
void display_invert( uint8_t invert ){

    uint8 cmdbuf[] = {
        0x00,
        0
    };
    cmdbuf[1] = invert ? SSD1306_INVERTDISPLAY : SSD1306_NORMALDISPLAY;
    display_write_buf( cmdbuf, sizeof(cmdbuf) );
}


void display_update(void) {

    uint8 cmdbuf[] = {
        0x00,
        SSD1306_COLUMNADDR,
        0,                      // start
        DISPLAYWIDTH-1, // end
        SSD1306_PAGEADDR,
        0,                      // start
        7                       // end
    };
    display_write_buf( cmdbuf, sizeof(cmdbuf) );
    display_write_buf( SSD1306_buffer, sizeof(SSD1306_buffer) );
}


// draws horizontal or vertical line
// Note: no check for valid coords, this needs to be done by caller
// should only be called from gfx_hvline which is doing all validity
checking
static void display_line( int16_t x1, int16_t y1, int16_t x2, int16_t y2,
uint16_t color ){

    if( x1 == x2 ){
        // vertical
```

```
        uint8_t* pstart = GDDRAM_ADDRESS(x1,y1);
        uint8_t* pend = GDDRAM_ADDRESS(x2,y2);
        uint8_t* ptr = pstart;

        while( ptr <= pend ){

            uint8_t mask;
            if( ptr == pstart ){
                // top
                uint8_t lbit = y1 % 8;
                // bottom (line can be very short, all inside this one
byte)
                uint8_t ubit = lbit + y2 - y1;
                if( ubit >= 7 )
                    ubit = 7;
                mask = ((1 << (ubit-lbit+1)) - 1) << lbit;
            }else if( ptr == pend ){
                // top is always bit 0, that makes it easy
                // bottom
                mask = (1 << (y2 % 8)) - 1;
            }

            if( ptr == pstart || ptr == pend ){
                switch( color ){
                    case WHITE:     *ptr |= mask; break;
                    case BLACK:     *ptr &= ~mask; break;
                    case INVERSE:   *ptr ^= mask; break;
                };
            }else{
                switch( color ){
                    case WHITE:     *ptr = 0xff; break;
                    case BLACK:     *ptr = 0x00; break;
                    case INVERSE:   *ptr ^= 0xff; break;
                };
            }

            ptr += DISPLAYWIDTH;
        }
    }else{
        // horizontal
        uint8_t* pstart = GDDRAM_ADDRESS(x1,y1);
        uint8_t* pend = pstart + x2 - x1;
        uint8_t pixmask = GDDRAM_PIXMASK(y1);

        uint8_t* ptr = pstart;
        while( ptr <= pend ){
            switch( color ){
                case WHITE:     *ptr |= pixmask; break;
                case BLACK:     *ptr &= ~pixmask; break;
                case INVERSE:   *ptr ^= pixmask; break;
            };
            ptr++;
        }
    }
}
```

```
void display_stopscroll(void){

    uint8 cmdbuf[] = {
        0x00,
        SSD1306_DEACTIVATE_SCROLL
    };
    display_write_buf( cmdbuf, sizeof(cmdbuf) );
}

void display_scroll( SCROLL_AREA start, SCROLL_AREA end, SCROLL_DIR dir,
SCROLL_SPEED speed ){

    uint8 cmdbuf[] = {
        0x00,
        dir,                    // 0x26 or 0x2a
        0x00,                   // dummy byte
        start,                  // start page
        speed,                  // scroll step interval in terms of frame
frequency
        end,                    // end page
        0x00,                   // dummy byte
        0xFF,                   // dummy byte
        SSD1306_ACTIVATE_SCROLL // 0x2F
    };
    display_write_buf( cmdbuf, sizeof(cmdbuf) );
}



// ============================================================
// graphics library stuff

int16_t WIDTH, HEIGHT; // This is the 'raw' display w/h - never changes
static int16_t _width, _height; // Display w/h as modified by current
rotation
static int16_t cursor_x, cursor_y;
static uint16_t textcolor, textbgcolor;
static uint8_t textsize;
uint8_t rotation;
uint8_t wrap; // If set, 'wrap' text at right edge of display



void gfx_init( int16_t width, int16_t height ){
    WIDTH = width;
    HEIGHT = height;
    _width = WIDTH;
    _height = HEIGHT;

    rotation = 0;
    cursor_y = cursor_x = 0;
    textsize = 1;
    textcolor = textbgcolor = 0xFFFF;
    wrap = 1;
}
```

```
// Return the size of the display (per current rotation)
int16_t gfx_width(void){
    return _width;
}

int16_t gfx_height(void){
    return _height;
}

uint8_t gfx_rotation(void){
    return rotation;
}

void gfx_setCursor( int16_t x, int16_t y ){
    cursor_x = x;
    cursor_y = y;
}

void gfx_setTextSize( uint8_t size ){
    textsize = (size > 0) ? size : 1;
}

void gfx_setTextColor( uint16_t color ){
    // For 'transparent' background, we'll set the bg
    // to the same as fg instead of using a flag
    textcolor = textbgcolor = color;
}

void gfx_setTextBg( uint16_t color ){
    textbgcolor = color;
}

void gfx_setTextWrap( uint8 w ){
    wrap = w;
}

void gfx_setRotation( uint8_t x ){

    rotation = (x & 3);
    switch( rotation ){
        case 0:
        case 2:
            _width = WIDTH;
            _height = HEIGHT;
            break;
        case 1:
        case 3:
            _width = HEIGHT;
            _height = WIDTH;
        break;
    }
}

static void gfx_rotation_adjust( int16_t* px, int16_t* py ){

    int16_t y0 = *py;
```

```c
    switch( rotation ){
        case 1:
            *py = *px;
            *px = WIDTH - y0 - 1;
            break;
        case 2:
            *px = WIDTH - *px - 1;
            *py = HEIGHT - *py - 1;
            break;
        case 3:
            *py = HEIGHT - *px - 1;
            *px = y0;
            break;
    }
}

void gfx_drawPixel( int16_t x, int16_t y, uint16_t color ){

    if( (x < 0) || (x >= _width) || (y < 0) || (y >= _height) )
        return;

    gfx_rotation_adjust( &x, &y );

    display_setPixel(x,y,color);
}

// helper function for gfx_drawLine, handles special cases of horizontal
and vertical lines
static void gfx_hvLine( int16_t x1, int16_t y1, int16_t x2, int16_t y2,
uint16_t color ){

    if( x1 != x2 && y1 != y2 ){
        // neither vertical nor horizontal
        return;
    }

    // bounds check
    if( rotation == 1 || rotation == 3 ){
        if( x1 < 0 || x1 >= HEIGHT || x2 < 0 || x2 >= HEIGHT )
            return;
        if( y1 < 0 || y1 >= WIDTH || y2 < 0 || y2 >= WIDTH )
            return;
    }else{
        if( y1 < 0 || y1 >= HEIGHT || y2 < 0 || y2 >= HEIGHT )
            return;
        if( x1 < 0 || x1 >= WIDTH || x2 < 0 || x2 >= WIDTH )
            return;
    }

    gfx_rotation_adjust( &x1, &y1 );
    gfx_rotation_adjust( &x2, &y2 );

    // ensure coords are from left to right and top to bottom
    if( (x1 == x2 && y2 < y1) || (y1 == y2 && x2 < x1) ){
        // swap as needed
        int16_t t = x1; x1 = x2; x2 = t;
        t = y1; y1 = y2; y2 = t;
```

```
    }

    display_line( x1, y1, x2, y2, color );
}

// always use this function for line drawing
void gfx_drawLine( int16_t x0, int16_t y0, int16_t x1, int16_t y1,
uint16_t color ){

    if( x0 == x1 || y0 == y1 ){
        // vertical and horizontal lines can be drawn faster
        gfx_hvLine( x0, y0, x1, y1, color );
        return;
    }

    int16_t t;

    int16_t steep = abs(y1 - y0) > abs(x1 - x0);
    if( steep ){
        t = x0; x0 = y0; y0 = t;
        t = x1; x1 = y1; y1 = t;
    }
    if( x0 > x1 ){
        t = x0; x0 = x1; x1 = t;
        t = y0; y0 = y1; y1 = t;
    }
    int16_t dx, dy;
    dx = x1 - x0;
    dy = abs(y1 - y0);
    int16_t err = dx / 2;
    int16_t ystep;
    if( y0 < y1 ){
        ystep = 1;
    }else{
        ystep = -1;
    }
    for( ; x0<=x1; x0++ ){
        if( steep ){
            gfx_drawPixel( y0, x0, color );
        }else{
            gfx_drawPixel( x0, y0, color );
        }
        err -= dy;
        if( err < 0 ){
            y0 += ystep;
            err += dx;
        }
    }
}

void gfx_drawRect( int16_t x, int16_t y, int16_t w, int16_t h, uint16_t
color ){

    gfx_drawLine( x, y, x+w-1, y, color );
    gfx_drawLine( x, y+h-1, x+w-1, y+h-1, color );
    gfx_drawLine( x, y, x, y+h-1, color );
    gfx_drawLine( x+w-1, y, x+w-1, y+h-1, color );
```

```
}

void gfx_fillRect( int16_t x, int16_t y, int16_t w, int16_t h, uint16_t
color ){
    int16_t i = 0;
    if( h > w ){
        for( i = x ; i < x+w ; i++ ){
            gfx_drawLine( i, y, i, y+h-1, color );
        }
    }else{
        for( i = y ; i < y+h ; i++ ){
            gfx_drawLine( x, i, x+w-1, i, color );
        }
    }
}


// circle outline
void gfx_drawCircle( int16_t x0, int16_t y0, int16_t r,uint16_t color ){

    int16_t f = 1 - r;
    int16_t ddF_x = 1;
    int16_t ddF_y = -2 * r;
    int16_t x = 0;
    int16_t y = r;
    gfx_drawPixel( x0 , y0+r, color );
    gfx_drawPixel( x0 , y0-r, color );
    gfx_drawPixel( x0+r, y0 , color );
    gfx_drawPixel( x0-r, y0 , color );
    while( x < y ){
        if( f >= 0 ){
            y--;
            ddF_y += 2;
            f += ddF_y;
        }
        x++;
        ddF_x += 2;
        f += ddF_x;
        gfx_drawPixel( x0 + x, y0 + y, color );
        gfx_drawPixel( x0 - x, y0 + y, color );
        gfx_drawPixel( x0 + x, y0 - y, color );
        gfx_drawPixel( x0 - x, y0 - y, color );
        gfx_drawPixel( x0 + y, y0 + x, color );
        gfx_drawPixel( x0 - y, y0 + x, color );
        gfx_drawPixel( x0 + y, y0 - x, color );
        gfx_drawPixel( x0 - y, y0 - x, color );
    }
}

void gfx_drawTriangle( int16_t x0, int16_t y0,int16_t x1, int16_t y1,
int16_t x2, int16_t y2, uint16_t color ){

    gfx_drawLine( x0, y0, x1, y1, color );
    gfx_drawLine( x1, y1, x2, y2, color );
    gfx_drawLine( x2, y2, x0, y0, color );
}
```

```
// Draw a character
void gfx_drawChar( int16_t x, int16_t y, unsigned char c,uint16_t color,
uint16_t bg, uint8_t size) {
    if( (x >= _width) || // Clip right
        (y >= _height) || // Clip bottom
        ((x + 6 * size - 1) < 0) || // Clip left
        ((y + 8 * size - 1) < 0)) // Clip top
        return;

    int8_t i = 0;
    for( i = 0 ; i < 6 ; i++ ){
        uint8_t line;
        if( i == 5 )
            line = 0x0;
        else
           line = font[(c*5)+i];
        int8_t j = 0;
        for( j = 0; j < 8 ; j++ ){
            if( line & 0x1 ){
                if( size == 1 ) // default size
                    gfx_drawPixel( x+i, y+j, color );
                else { // big size
                    gfx_fillRect( x+(i*size), y+(j*size), size, size,
color );
                }
            } else if( bg != color ){
                if( size == 1 ) // default size
                    gfx_drawPixel( x+i, y+j, bg );
                else { // big size
                    gfx_fillRect( x+i*size, y+j*size, size, size, bg );
                }
            }
            line >>= 1;
        }
    }
}

void gfx_write( uint8_t ch ){
    if( ch == '\n' ){
        cursor_y += textsize*8;
        cursor_x = 0;
    }else if( ch == '\r' ){
        // skip em
    }else{
        gfx_drawChar(cursor_x, cursor_y, ch, textcolor, textbgcolor,
textsize);
        cursor_x += textsize*6;
        if( wrap && (cursor_x > (_width - textsize*6)) ){
            cursor_y += textsize*8;
            cursor_x = 0;
        }
    }
}

void gfx_print( const char* s ){
```

```c
    unsigned int len = strlen( s );
    unsigned int i = 0;
    for( i = 0 ; i < len ; i++ ){
        gfx_write( s[i] );
    }
}

void gfx_println( const char* s ){
    gfx_print( s );
    gfx_write( '\n' );
}
/* [] END OF FILE */
```

- ssd1306.h

```c
/* ========================================
 *
 * Copyright YOUR COMPANY, THE YEAR
 * All Rights Reserved
 * UNPUBLISHED, LICENSED SOFTWARE.
 *
 * CONFIDENTIAL AND PROPRIETARY INFORMATION
 * WHICH IS THE PROPERTY OF your company.
 *
 * ========================================
*/


#ifndef _SSD1306_H
#define _SSD1306_H




#define BLACK 0
#define WHITE 1
#define INVERSE 2

typedef enum{
    SCROLL_RIGHT = 0x26,
    SCROLL_LEFT = 0x2A
}SCROLL_DIR;

typedef enum{
    SCROLL_SPEED_0 = 0x03,  // slowest
    SCROLL_SPEED_1 = 0x02,
    SCROLL_SPEED_2 = 0x01,
    SCROLL_SPEED_3 = 0x06,
    SCROLL_SPEED_4 = 0x00,
    SCROLL_SPEED_5 = 0x05,
    SCROLL_SPEED_6 = 0x04,
    SCROLL_SPEED_7 = 0x07   // fastest
}SCROLL_SPEED;

typedef enum{
    SCROLL_PAGE_0 = 0,
```

```
    SCROLL_PAGE_1,
    SCROLL_PAGE_2,
    SCROLL_PAGE_3,
    SCROLL_PAGE_4,
    SCROLL_PAGE_5,
    SCROLL_PAGE_6,
    SCROLL_PAGE_7
}SCROLL_AREA;

void display_init( uint8 i2caddr );
void display_update(void);
void display_clear(void);
void display_stopscroll(void);
void display_scroll( SCROLL_AREA start, SCROLL_AREA end, SCROLL_DIR dir,
SCROLL_SPEED speed );
void display_contrast( uint8_t contrast );
void display_invert( uint8_t invert );




void gfx_drawPixel(int16_t x, int16_t y, uint16_t color);
void gfx_drawLine( int16_t x0, int16_t y0, int16_t x1, int16_t y1,
uint16_t color );
void gfx_setCursor( int16_t x, int16_t y );
void gfx_setTextSize( uint8_t size );
void gfx_setTextColor( uint16_t color );
void gfx_setTextBg( uint16_t background );
void gfx_write( uint8_t ch );
int16_t gfx_width(void);
int16_t gfx_height(void);
void gfx_print( const char* s );
void gfx_println( const char* s );
void gfx_drawRect( int16_t x, int16_t y, int16_t w, int16_t h, uint16_t
color );
void gfx_fillRect( int16_t x, int16_t y, int16_t w, int16_t h, uint16_t
color );
void gfx_drawCircle( int16_t x0, int16_t y0, int16_t r,uint16_t color );
void gfx_drawTriangle( int16_t x0, int16_t y0,int16_t x1, int16_t y1,
int16_t x2, int16_t y2, uint16_t color );
void gfx_setRotation( uint8_t x );

#endif      // _SSD1306_H



/* [] END OF FILE */
```

- font.h

```
#ifndef FONT5X7_H
#define FONT5X7_H

// Standard ASCII 5x7 font
static const unsigned char font[] = {
0x00, 0x00, 0x00, 0x00, 0x00,
0x3E, 0x5B, 0x4F, 0x5B, 0x3E,
```

```
0x3E, 0x6B, 0x4F, 0x6B, 0x3E,
0x1C, 0x3E, 0x7C, 0x3E, 0x1C,
0x18, 0x3C, 0x7E, 0x3C, 0x18,
0x1C, 0x57, 0x7D, 0x57, 0x1C,
0x1C, 0x5E, 0x7F, 0x5E, 0x1C,
0x00, 0x18, 0x3C, 0x18, 0x00,
0xFF, 0xE7, 0xC3, 0xE7, 0xFF,
0x00, 0x18, 0x24, 0x18, 0x00,
0xFF, 0xE7, 0xDB, 0xE7, 0xFF,
0x30, 0x48, 0x3A, 0x06, 0x0E,
0x26, 0x29, 0x79, 0x29, 0x26,
0x40, 0x7F, 0x05, 0x05, 0x07,
0x40, 0x7F, 0x05, 0x25, 0x3F,
0x5A, 0x3C, 0xE7, 0x3C, 0x5A,
0x7F, 0x3E, 0x1C, 0x1C, 0x08,
0x08, 0x1C, 0x1C, 0x3E, 0x7F,
0x14, 0x22, 0x7F, 0x22, 0x14,
0x5F, 0x5F, 0x00, 0x5F, 0x5F,
0x06, 0x09, 0x7F, 0x01, 0x7F,
0x00, 0x66, 0x89, 0x95, 0x6A,
0x60, 0x60, 0x60, 0x60, 0x60,
0x94, 0xA2, 0xFF, 0xA2, 0x94,
0x08, 0x04, 0x7E, 0x04, 0x08,
0x10, 0x20, 0x7E, 0x20, 0x10,
0x08, 0x08, 0x2A, 0x1C, 0x08,
0x08, 0x1C, 0x2A, 0x08, 0x08,
0x1E, 0x10, 0x10, 0x10, 0x10,
0x0C, 0x1E, 0x0C, 0x1E, 0x0C,
0x30, 0x38, 0x3E, 0x38, 0x30,
0x06, 0x0E, 0x3E, 0x0E, 0x06,
0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x5F, 0x00, 0x00,
0x00, 0x07, 0x00, 0x07, 0x00,
0x14, 0x7F, 0x14, 0x7F, 0x14,
0x24, 0x2A, 0x7F, 0x2A, 0x12,
0x23, 0x13, 0x08, 0x64, 0x62,
0x36, 0x49, 0x56, 0x20, 0x50,
0x00, 0x08, 0x07, 0x03, 0x00,
0x00, 0x1C, 0x22, 0x41, 0x00,
0x00, 0x41, 0x22, 0x1C, 0x00,
0x2A, 0x1C, 0x7F, 0x1C, 0x2A,
0x08, 0x08, 0x3E, 0x08, 0x08,
0x00, 0x80, 0x70, 0x30, 0x00,
0x08, 0x08, 0x08, 0x08, 0x08,
0x00, 0x00, 0x60, 0x60, 0x00,
0x20, 0x10, 0x08, 0x04, 0x02,
0x3E, 0x51, 0x49, 0x45, 0x3E,
0x00, 0x42, 0x7F, 0x40, 0x00,
0x72, 0x49, 0x49, 0x49, 0x46,
0x21, 0x41, 0x49, 0x4D, 0x33,
0x18, 0x14, 0x12, 0x7F, 0x10,
0x27, 0x45, 0x45, 0x45, 0x39,
0x3C, 0x4A, 0x49, 0x49, 0x31,
0x41, 0x21, 0x11, 0x09, 0x07,
0x36, 0x49, 0x49, 0x49, 0x36,
0x46, 0x49, 0x49, 0x29, 0x1E,
0x00, 0x00, 0x14, 0x00, 0x00,
```

```
0x00, 0x40, 0x34, 0x00, 0x00,
0x00, 0x08, 0x14, 0x22, 0x41,
0x14, 0x14, 0x14, 0x14, 0x14,
0x00, 0x41, 0x22, 0x14, 0x08,
0x02, 0x01, 0x59, 0x09, 0x06,
0x3E, 0x41, 0x5D, 0x59, 0x4E,
0x7C, 0x12, 0x11, 0x12, 0x7C,
0x7F, 0x49, 0x49, 0x49, 0x36,
0x3E, 0x41, 0x41, 0x41, 0x22,
0x7F, 0x41, 0x41, 0x41, 0x3E,
0x7F, 0x49, 0x49, 0x49, 0x41,
0x7F, 0x09, 0x09, 0x09, 0x01,
0x3E, 0x41, 0x41, 0x51, 0x73,
0x7F, 0x08, 0x08, 0x08, 0x7F,
0x00, 0x41, 0x7F, 0x41, 0x00,
0x20, 0x40, 0x41, 0x3F, 0x01,
0x7F, 0x08, 0x14, 0x22, 0x41,
0x7F, 0x40, 0x40, 0x40, 0x40,
0x7F, 0x02, 0x1C, 0x02, 0x7F,
0x7F, 0x04, 0x08, 0x10, 0x7F,
0x3E, 0x41, 0x41, 0x41, 0x3E,
0x7F, 0x09, 0x09, 0x09, 0x06,
0x3E, 0x41, 0x51, 0x21, 0x5E,
0x7F, 0x09, 0x19, 0x29, 0x46,
0x26, 0x49, 0x49, 0x49, 0x32,
0x03, 0x01, 0x7F, 0x01, 0x03,
0x3F, 0x40, 0x40, 0x40, 0x3F,
0x1F, 0x20, 0x40, 0x20, 0x1F,
0x3F, 0x40, 0x38, 0x40, 0x3F,
0x63, 0x14, 0x08, 0x14, 0x63,
0x03, 0x04, 0x78, 0x04, 0x03,
0x61, 0x59, 0x49, 0x4D, 0x43,
0x00, 0x7F, 0x41, 0x41, 0x41,
0x02, 0x04, 0x08, 0x10, 0x20,
0x00, 0x41, 0x41, 0x41, 0x7F,
0x04, 0x02, 0x01, 0x02, 0x04,
0x40, 0x40, 0x40, 0x40, 0x40,
0x00, 0x03, 0x07, 0x08, 0x00,
0x20, 0x54, 0x54, 0x78, 0x40,
0x7F, 0x28, 0x44, 0x44, 0x38,
0x38, 0x44, 0x44, 0x44, 0x28,
0x38, 0x44, 0x44, 0x28, 0x7F,
0x38, 0x54, 0x54, 0x54, 0x18,
0x00, 0x08, 0x7E, 0x09, 0x02,
0x18, 0xA4, 0xA4, 0x9C, 0x78,
0x7F, 0x08, 0x04, 0x04, 0x78,
0x00, 0x44, 0x7D, 0x40, 0x00,
0x20, 0x40, 0x40, 0x3D, 0x00,
0x7F, 0x10, 0x28, 0x44, 0x00,
0x00, 0x41, 0x7F, 0x40, 0x00,
0x7C, 0x04, 0x78, 0x04, 0x78,
0x7C, 0x08, 0x04, 0x04, 0x78,
0x38, 0x44, 0x44, 0x44, 0x38,
0xFC, 0x18, 0x24, 0x24, 0x18,
0x18, 0x24, 0x24, 0x18, 0xFC,
0x7C, 0x08, 0x04, 0x04, 0x08,
0x48, 0x54, 0x54, 0x54, 0x24,
```

```
0x04, 0x04, 0x3F, 0x44, 0x24,
0x3C, 0x40, 0x40, 0x20, 0x7C,
0x1C, 0x20, 0x40, 0x20, 0x1C,
0x3C, 0x40, 0x30, 0x40, 0x3C,
0x44, 0x28, 0x10, 0x28, 0x44,
0x4C, 0x90, 0x90, 0x90, 0x7C,
0x44, 0x64, 0x54, 0x4C, 0x44,
0x00, 0x08, 0x36, 0x41, 0x00,
0x00, 0x00, 0x77, 0x00, 0x00,
0x00, 0x41, 0x36, 0x08, 0x00,
0x02, 0x01, 0x02, 0x04, 0x02,
0x3C, 0x26, 0x23, 0x26, 0x3C,
0x1E, 0xA1, 0xA1, 0x61, 0x12,
0x3A, 0x40, 0x40, 0x20, 0x7A,
0x38, 0x54, 0x54, 0x55, 0x59,
0x21, 0x55, 0x55, 0x79, 0x41,
0x22, 0x54, 0x54, 0x78, 0x42, // a-umlaut
0x21, 0x55, 0x54, 0x78, 0x40,
0x20, 0x54, 0x55, 0x79, 0x40,
0x0C, 0x1E, 0x52, 0x72, 0x12,
0x39, 0x55, 0x55, 0x55, 0x59,
0x39, 0x54, 0x54, 0x54, 0x59,
0x39, 0x55, 0x54, 0x54, 0x58,
0x00, 0x00, 0x45, 0x7C, 0x41,
0x00, 0x02, 0x45, 0x7D, 0x42,
0x00, 0x01, 0x45, 0x7C, 0x40,
0x7D, 0x12, 0x11, 0x12, 0x7D, // A-umlaut
0xF0, 0x28, 0x25, 0x28, 0xF0,
0x7C, 0x54, 0x55, 0x45, 0x00,
0x20, 0x54, 0x54, 0x7C, 0x54,
0x7C, 0x0A, 0x09, 0x7F, 0x49,
0x32, 0x49, 0x49, 0x49, 0x32,
0x3A, 0x44, 0x44, 0x44, 0x3A, // o-umlaut
0x32, 0x4A, 0x48, 0x48, 0x30,
0x3A, 0x41, 0x41, 0x21, 0x7A,
0x3A, 0x42, 0x40, 0x20, 0x78,
0x00, 0x9D, 0xA0, 0xA0, 0x7D,
0x3D, 0x42, 0x42, 0x42, 0x3D, // O-umlaut
0x3D, 0x40, 0x40, 0x40, 0x3D,
0x3C, 0x24, 0xFF, 0x24, 0x24,
0x48, 0x7E, 0x49, 0x43, 0x66,
0x2B, 0x2F, 0xFC, 0x2F, 0x2B,
0xFF, 0x09, 0x29, 0xF6, 0x20,
0xC0, 0x88, 0x7E, 0x09, 0x03,
0x20, 0x54, 0x54, 0x79, 0x41,
0x00, 0x00, 0x44, 0x7D, 0x41,
0x30, 0x48, 0x48, 0x4A, 0x32,
0x38, 0x40, 0x40, 0x22, 0x7A,
0x00, 0x7A, 0x0A, 0x0A, 0x72,
0x7D, 0x0D, 0x19, 0x31, 0x7D,
0x26, 0x29, 0x29, 0x2F, 0x28,
0x26, 0x29, 0x29, 0x29, 0x26,
0x30, 0x48, 0x4D, 0x40, 0x20,
0x38, 0x08, 0x08, 0x08, 0x08,
0x08, 0x08, 0x08, 0x08, 0x38,
0x2F, 0x10, 0xC8, 0xAC, 0xBA,
0x2F, 0x10, 0x28, 0x34, 0xFA,
```

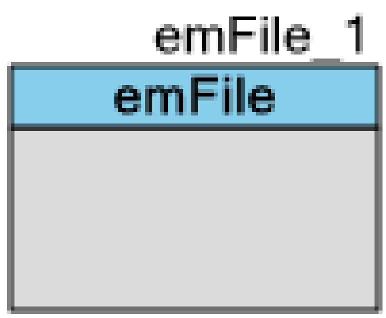
```
0x00, 0x00, 0x7B, 0x00, 0x00,
0x08, 0x14, 0x2A, 0x14, 0x22,
0x22, 0x14, 0x2A, 0x14, 0x08,
0xAA, 0x00, 0x55, 0x00, 0xAA,
0xAA, 0x55, 0xAA, 0x55, 0xAA,
0x00, 0x00, 0x00, 0xFF, 0x00,
0x10, 0x10, 0x10, 0xFF, 0x00,
0x14, 0x14, 0x14, 0xFF, 0x00,
0x10, 0x10, 0xFF, 0x00, 0xFF,
0x10, 0x10, 0xF0, 0x10, 0xF0,
0x14, 0x14, 0x14, 0xFC, 0x00,
0x14, 0x14, 0xF7, 0x00, 0xFF,
0x00, 0x00, 0xFF, 0x00, 0xFF,
0x14, 0x14, 0xF4, 0x04, 0xFC,
0x14, 0x14, 0x17, 0x10, 0x1F,
0x10, 0x10, 0x1F, 0x10, 0x1F,
0x14, 0x14, 0x14, 0x1F, 0x00,
0x10, 0x10, 0x10, 0xF0, 0x00,
0x00, 0x00, 0x00, 0x1F, 0x10,
0x10, 0x10, 0x10, 0x1F, 0x10,
0x10, 0x10, 0x10, 0xF0, 0x10,
0x00, 0x00, 0x00, 0xFF, 0x10,
0x10, 0x10, 0x10, 0x10, 0x10,
0x10, 0x10, 0x10, 0xFF, 0x10,
0x00, 0x00, 0x00, 0xFF, 0x14,
0x00, 0x00, 0xFF, 0x00, 0xFF,
0x00, 0x00, 0x1F, 0x10, 0x17,
0x00, 0x00, 0xFC, 0x04, 0xF4,
0x14, 0x14, 0x17, 0x10, 0x17,
0x14, 0x14, 0xF4, 0x04, 0xF4,
0x00, 0x00, 0xFF, 0x00, 0xF7,
0x14, 0x14, 0x14, 0x14, 0x14,
0x14, 0x14, 0xF7, 0x00, 0xF7,
0x14, 0x14, 0x14, 0x17, 0x14,
0x10, 0x10, 0x1F, 0x10, 0x1F,
0x14, 0x14, 0x14, 0xF4, 0x14,
0x10, 0x10, 0xF0, 0x10, 0xF0,
0x00, 0x00, 0x1F, 0x10, 0x1F,
0x00, 0x00, 0x00, 0x1F, 0x14,
0x00, 0x00, 0x00, 0xFC, 0x14,
0x00, 0x00, 0xF0, 0x10, 0xF0,
0x10, 0x10, 0xFF, 0x10, 0xFF,
0x14, 0x14, 0x14, 0xFF, 0x14,
0x10, 0x10, 0x10, 0x1F, 0x00,
0x00, 0x00, 0x00, 0xF0, 0x10,
0xFF, 0xFF, 0xFF, 0xFF, 0xFF,
0xF0, 0xF0, 0xF0, 0xF0, 0xF0,
0xFF, 0xFF, 0xFF, 0x00, 0x00,
0x00, 0x00, 0x00, 0xFF, 0xFF,
0x0F, 0x0F, 0x0F, 0x0F, 0x0F,
0x38, 0x44, 0x44, 0x38, 0x44,
0xFC, 0x4A, 0x4A, 0x4A, 0x34, // sharp-s or beta
0x7E, 0x02, 0x02, 0x06, 0x06,
0x02, 0x7E, 0x02, 0x7E, 0x02,
0x63, 0x55, 0x49, 0x41, 0x63,
0x38, 0x44, 0x44, 0x3C, 0x04,
0x40, 0x7E, 0x20, 0x1E, 0x20,
```

```
0x06, 0x02, 0x7E, 0x02, 0x02,
0x99, 0xA5, 0xE7, 0xA5, 0x99,
0x1C, 0x2A, 0x49, 0x2A, 0x1C,
0x4C, 0x72, 0x01, 0x72, 0x4C,
0x30, 0x4A, 0x4D, 0x4D, 0x30,
0x30, 0x48, 0x78, 0x48, 0x30,
0xBC, 0x62, 0x5A, 0x46, 0x3D,
0x3E, 0x49, 0x49, 0x49, 0x00,
0x7E, 0x01, 0x01, 0x01, 0x7E,
0x2A, 0x2A, 0x2A, 0x2A, 0x2A,
0x44, 0x44, 0x5F, 0x44, 0x44,
0x40, 0x51, 0x4A, 0x44, 0x40,
0x40, 0x44, 0x4A, 0x51, 0x40,
0x00, 0x00, 0xFF, 0x01, 0x03,
0xE0, 0x80, 0xFF, 0x00, 0x00,
0x08, 0x08, 0x6B, 0x6B, 0x08,
0x36, 0x12, 0x36, 0x24, 0x36,
0x06, 0x0F, 0x09, 0x0F, 0x06,
0x00, 0x00, 0x18, 0x18, 0x00,
0x00, 0x00, 0x10, 0x10, 0x00,
0x30, 0x40, 0xFF, 0x01, 0x01,
0x00, 0x1F, 0x01, 0x01, 0x1E,
0x00, 0x19, 0x1D, 0x17, 0x12,
0x00, 0x3C, 0x3C, 0x3C, 0x3C,
0x00, 0x00, 0x00, 0x00, 0x00
};
#endif // FONT5X7_H

/* [] END OF FILE */
```

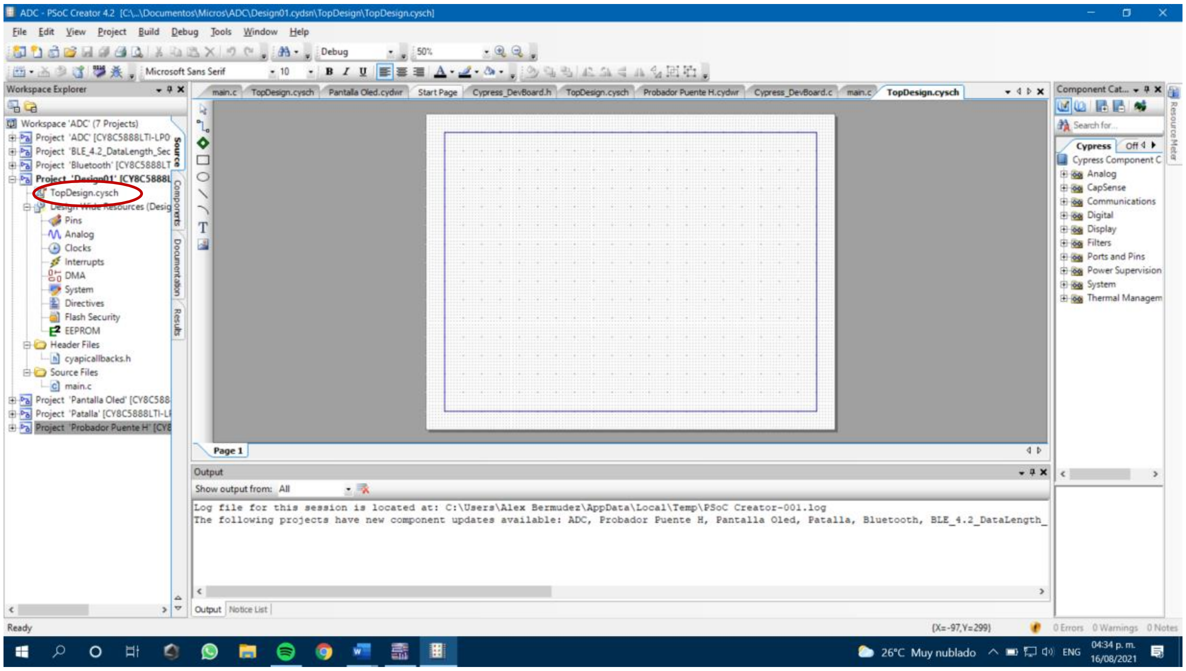
Sección 3: Agregado de librerías necesarias.

Manual para agregar Librería emFile en PSOC Creator (Manejo de memoria SD)

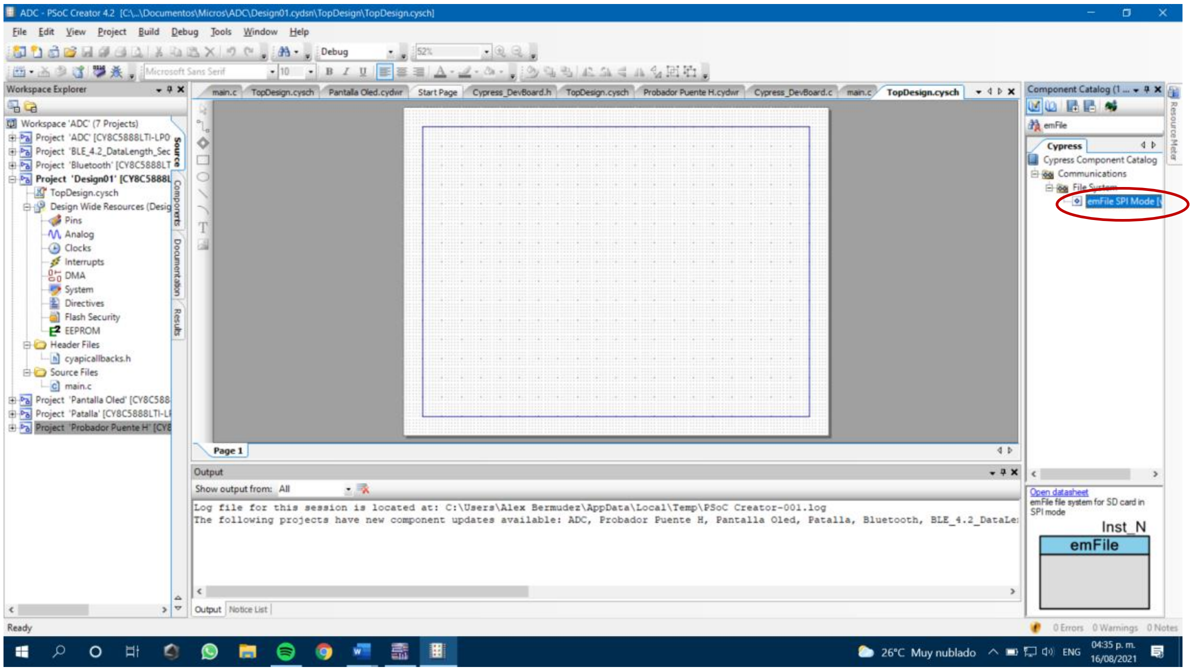


Manual para agregar Librería emFile en PSOC Creator (Manejo de memoria SD)

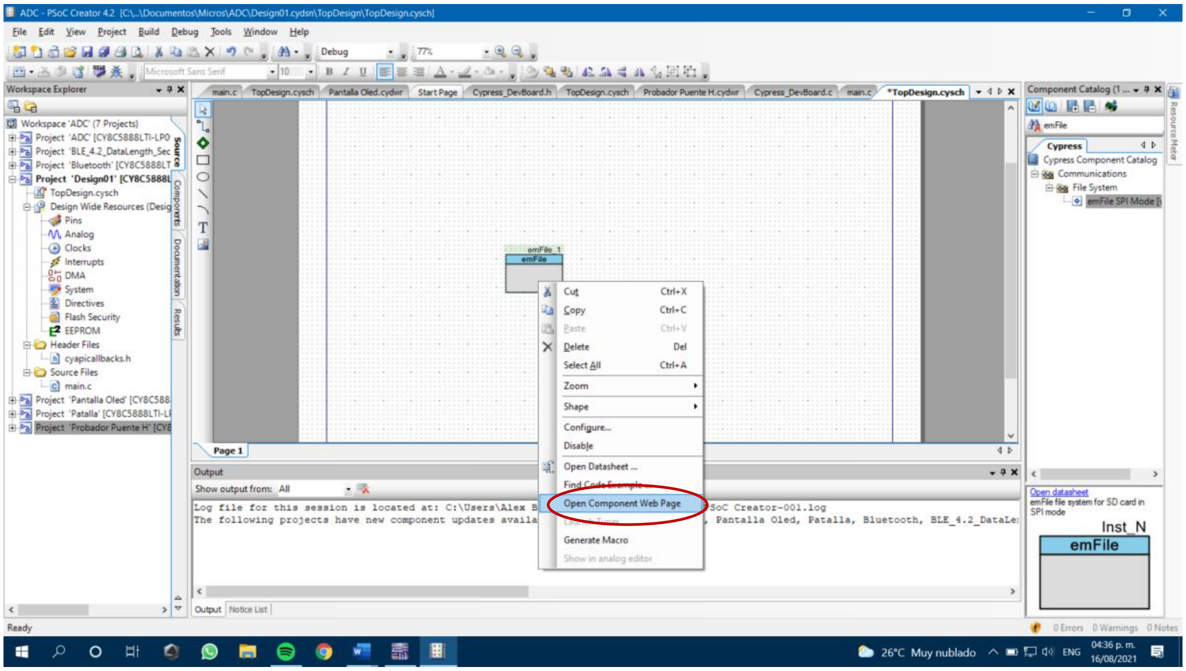
1.Una vez creador el proyecto dirigirse a la parte de TopDesign de su proyecto.



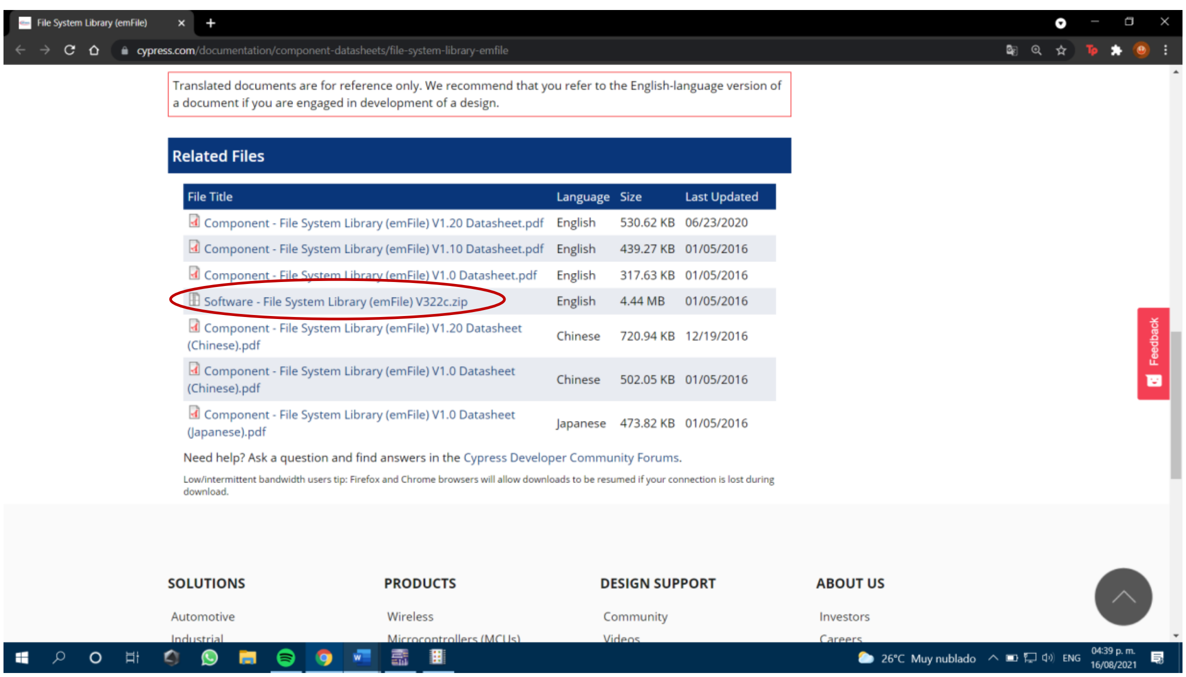
2.Una vez ahí agregue un componente de emFile desde el catálogo de componentes.



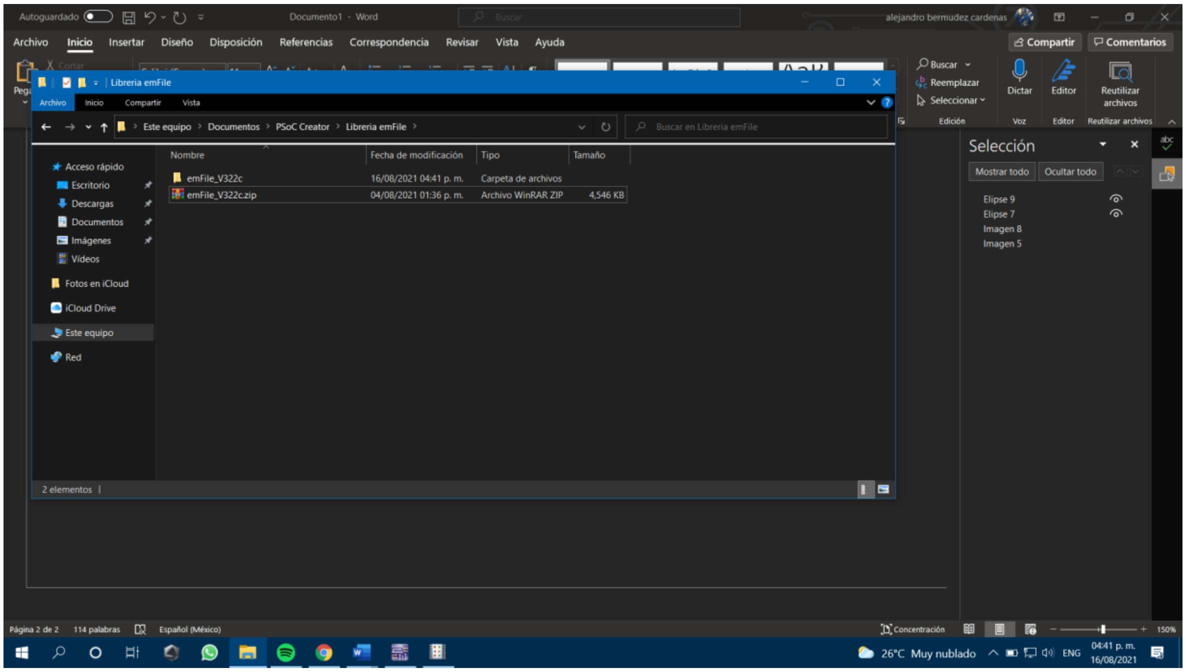
3. Ya agregado el componente dar click derecho en el y dar click en Abrir la página web del componente.



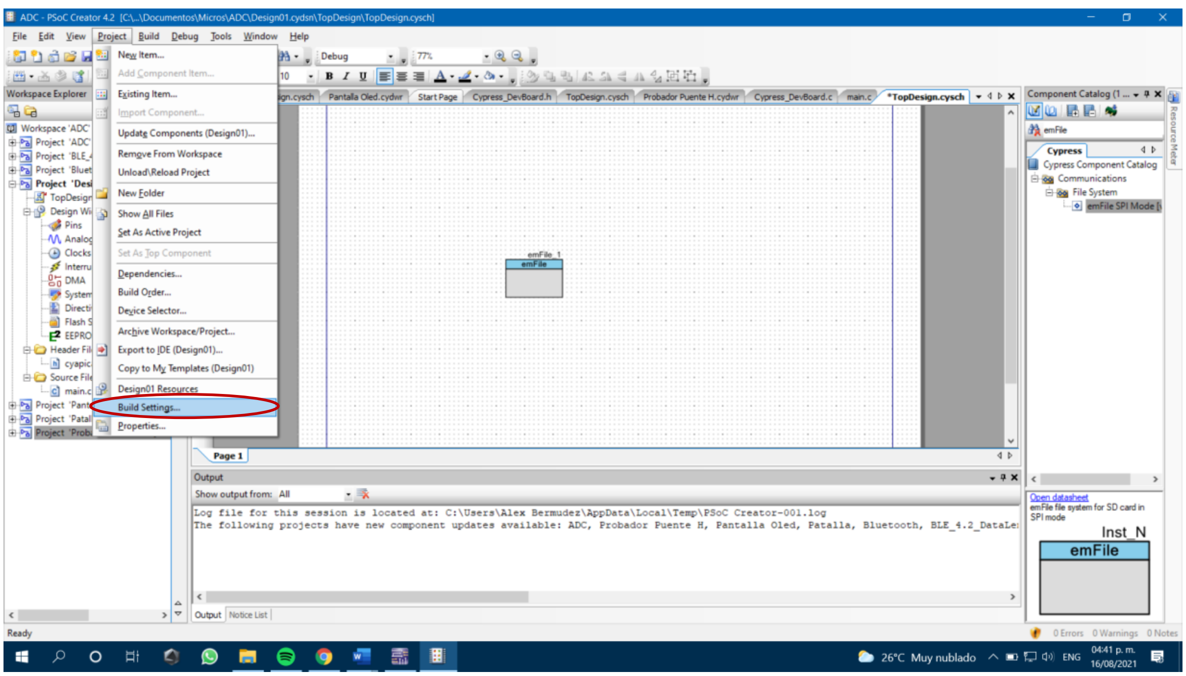
4. En la pagina web bajar hasta donde encuentres los archivos de descarga y descargar el archivo: [Software - File System Library (emFile) V322c.zip]



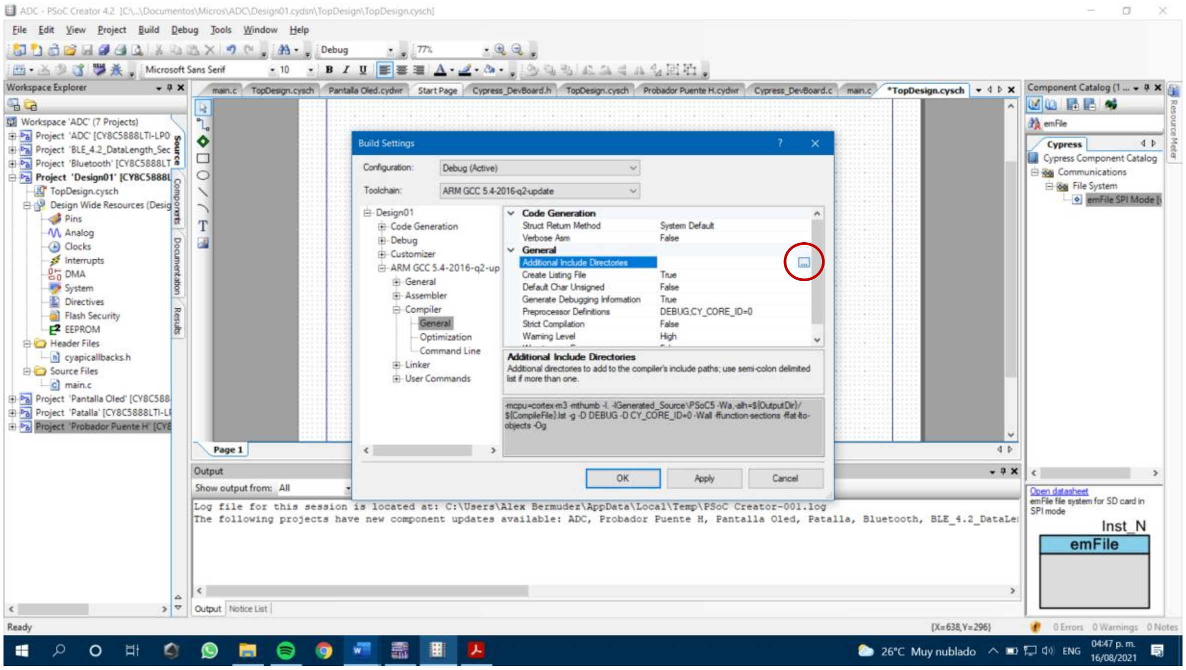
5. Descomprimir el archivo descargado en la ubicación de su elección, de preferencia que sea una ruta de fácil acceso, como consejo personal elegiría la carpeta de proyectos de Psoc Creator.



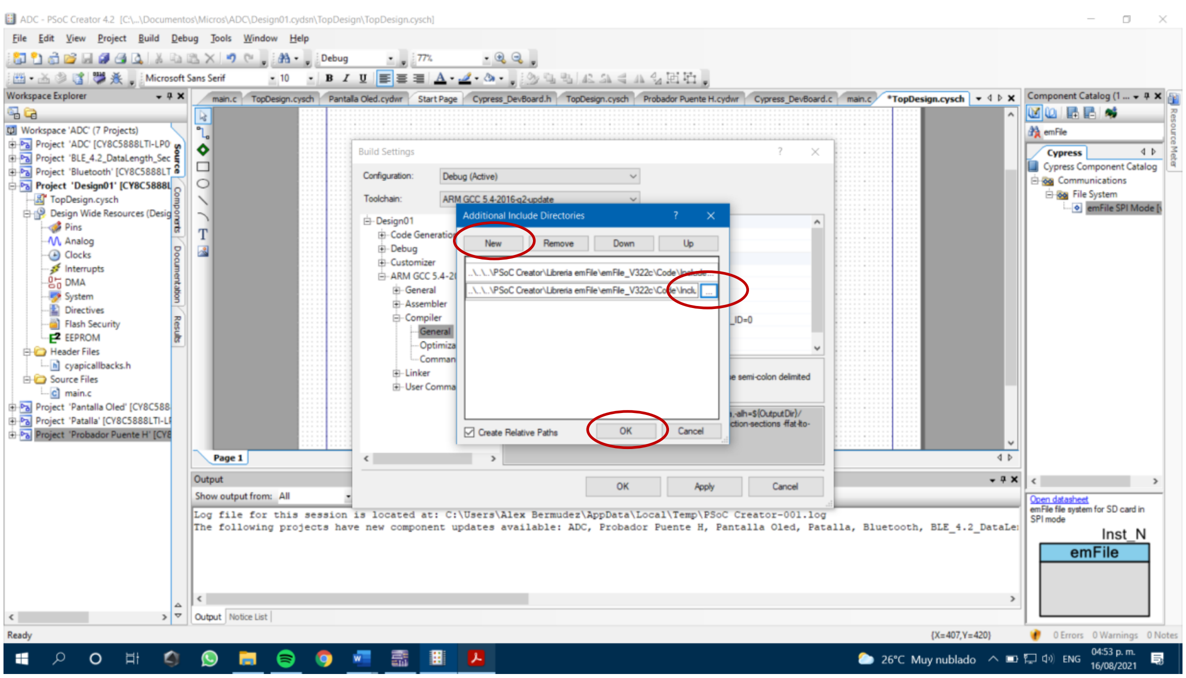
6. De vuelta en Psoc Creator iremos a la parte superior izquierda en la pestaña de Project>Build Settings.



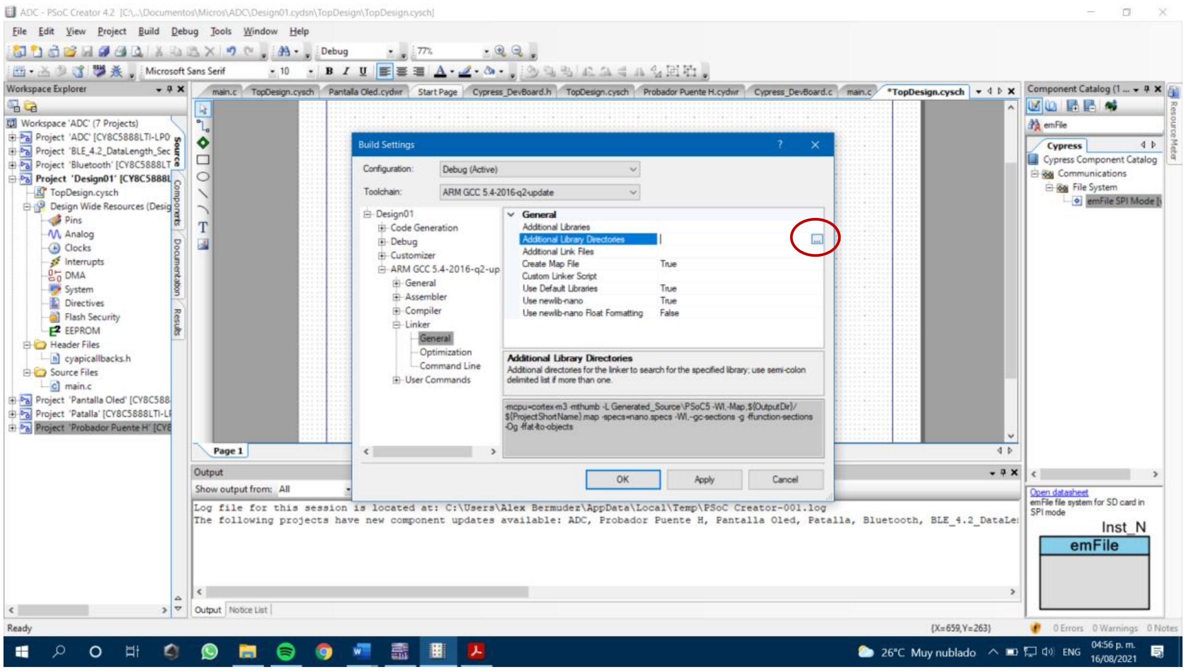
7.Ahi dentro verificar que el compilador que estas usando sea el mismo que estas modificando, en nuestro caso usaremos el ARM-GCC 5.4-2016. Ir a ARM GCC 4.8.4 > Compiler > General. Y dar click en los tres puntos de la parte de agregar Additional Include Directories.



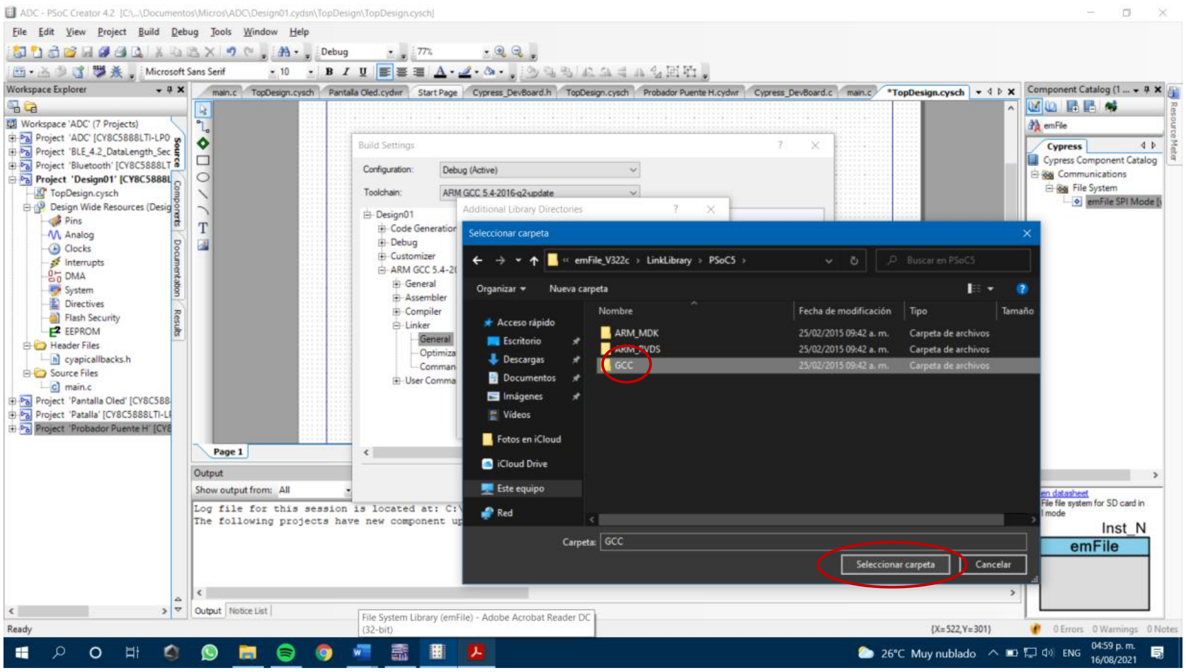
8.Despues de dar click ahí se abrirá una pantalla en la cual te da varias opciones, ahí seleccionar la opción de nuevo y agregar la Carpeta que se encuentra en emFile_V322c\Code\Include\PSoC5, posteriormente volver a agregar un nuevo y agregar la carpeta dependiendo del tipo de memoria que se vaya a utilizar, en nuestro caso seria una emf32nOS, esa carpeta se encuentra en emFile_V322c\Code\Include\PSoC5\emf32nOS.



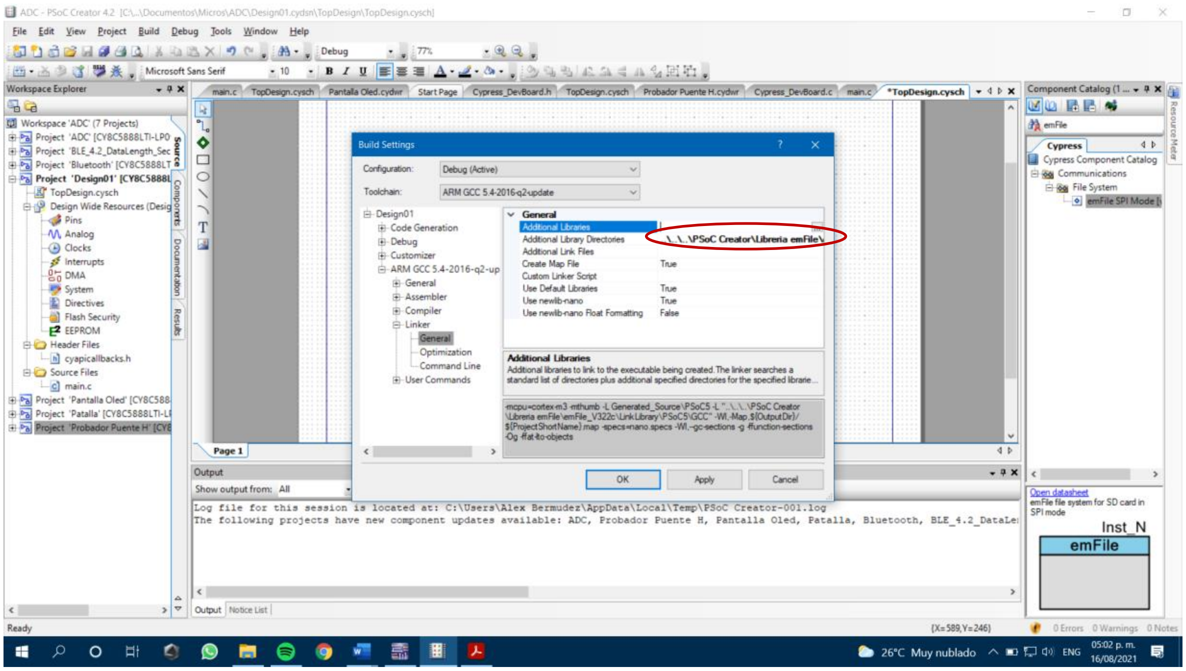
9. Después de darle en OK nos regresara a la pantalla de Build Settings, ahí nos iremos a la siguiente dirección ARM GCC 4.8.4 > Linker > General > Additional Library Directories.



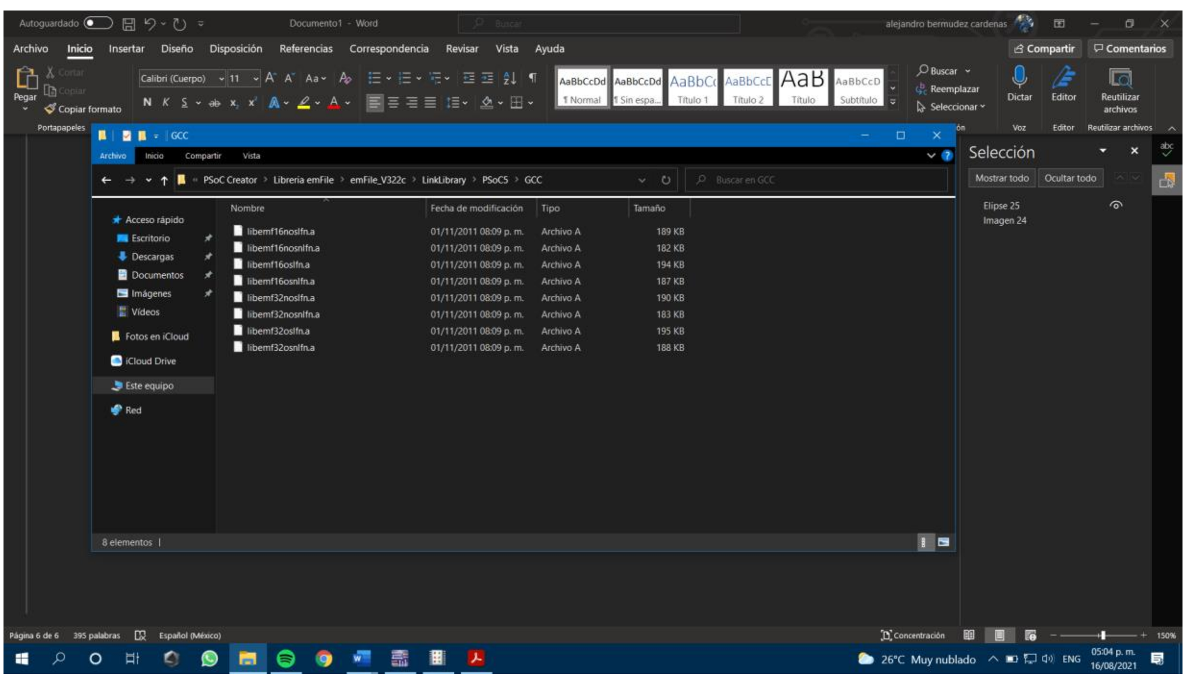
10. Se abrirá una pantalla igual a la anterior, en donde tendrás que repetir el proceso anterior de agregar una nueva y seleccionar su dirección, sin embargo, esta vez agregaras la carpeta en la dirección emFile_V322c\LinkLibrary\PSoC5\GCC.



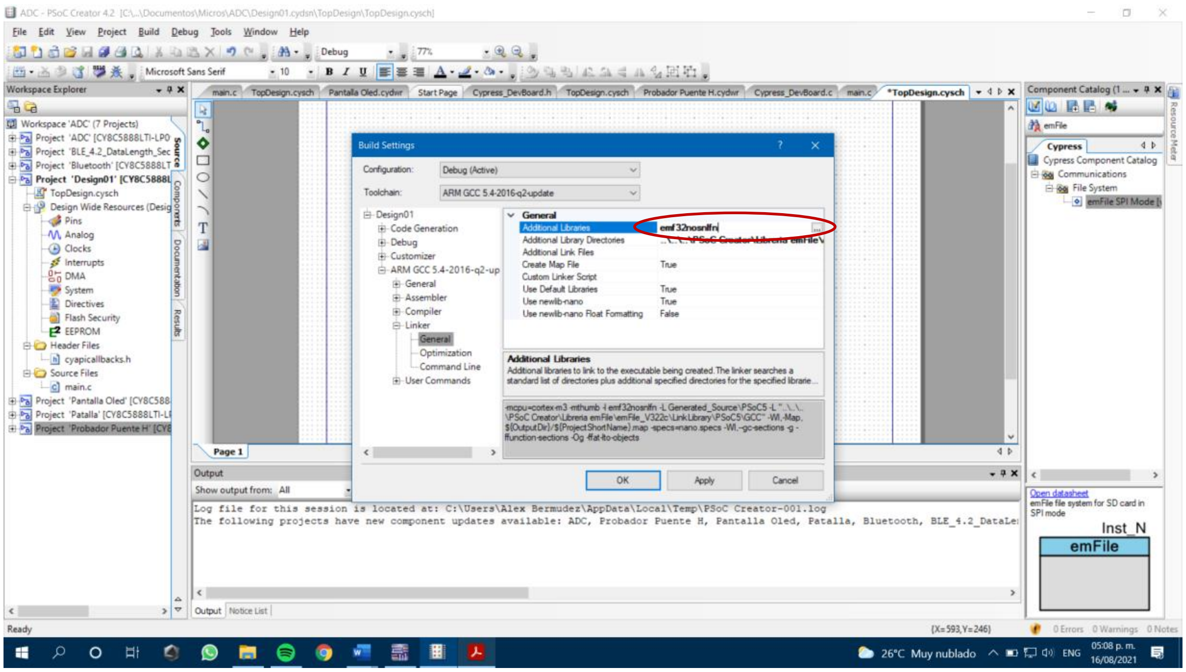
11.Despues de agregar la carpeta y seleccionar OK en la pantalla, regresaras a la pantalla de Build Settings en donde te dirigiras a la dirección ARM GCC 4.8.4 > Linker > General > Additional Libraries.



12. Esta parte es diferente a las demás, ya que no seleccionaras la opción de 3 puntos en la parte de Additional Libraries, si no que abrirás la carpeta de GCC desde el explorador de archivos la cual se encuentra en la ruta emFile_V322c\LinkLibrary\PSoC5\GCC de los archivos que descargaste y descomprimiste.

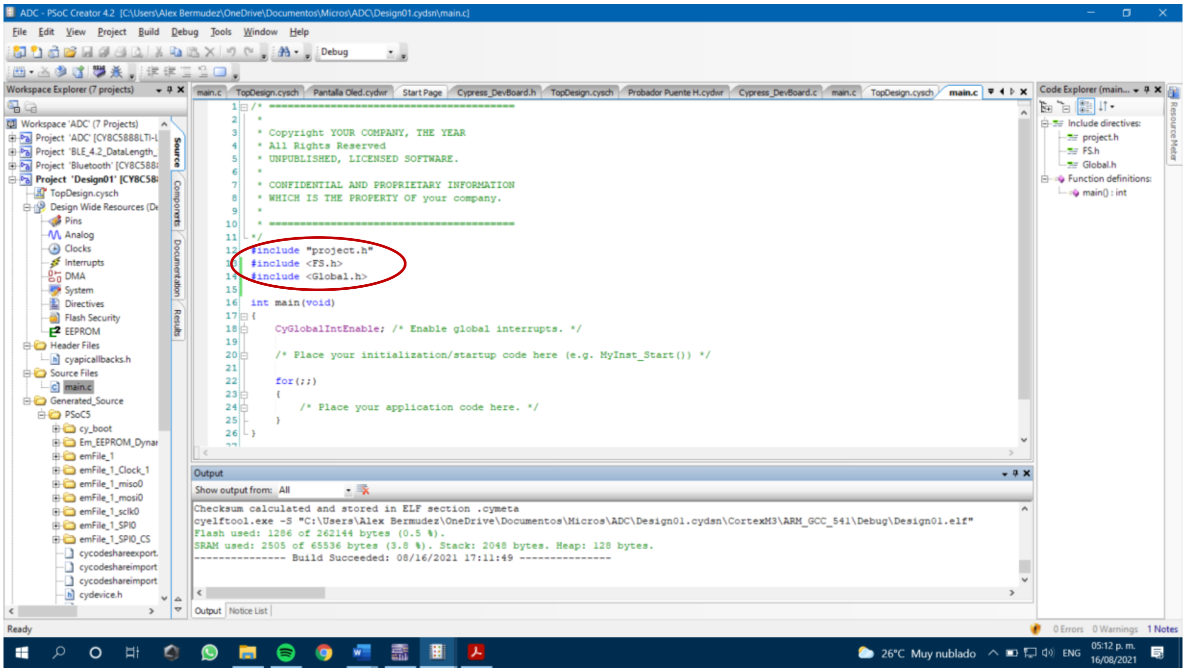


13. Ahí en la carpeta seleccionaras el archivo que corresponda a el tipo de memoria que utilizaste como recordaras en nuestro caso estamos utilizando una 32nosnlfn, así que de regreso en la pantalla de Build Project escribirás el nombre del archivo que seleccionaste en la parte de Additional Libraries, solamente que sin el prefijo “lib” y sin el sufijo “.a”, por ejemplo "libemf32nosnlfn.a" seria "emf32nosnlfn". Esto es porque el compilador automáticamente agrega los prefijos y sufijos.

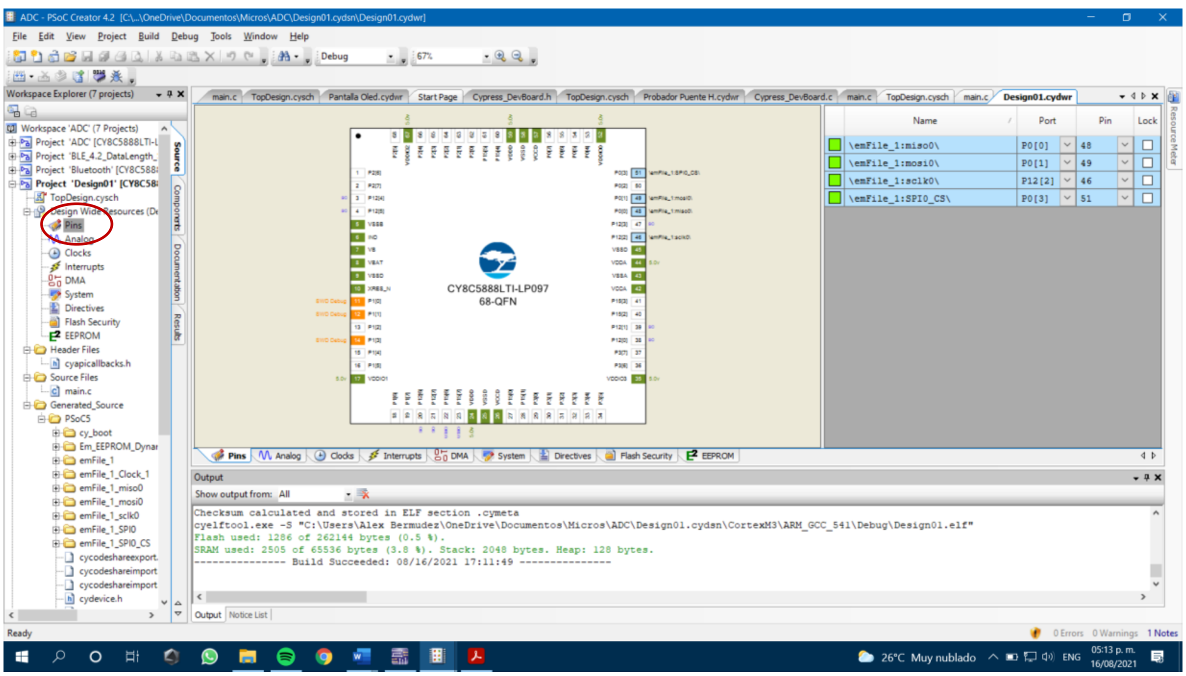


14. Dar click en el botón de OK y en el main agregar las librerías de #include <FS.h> y

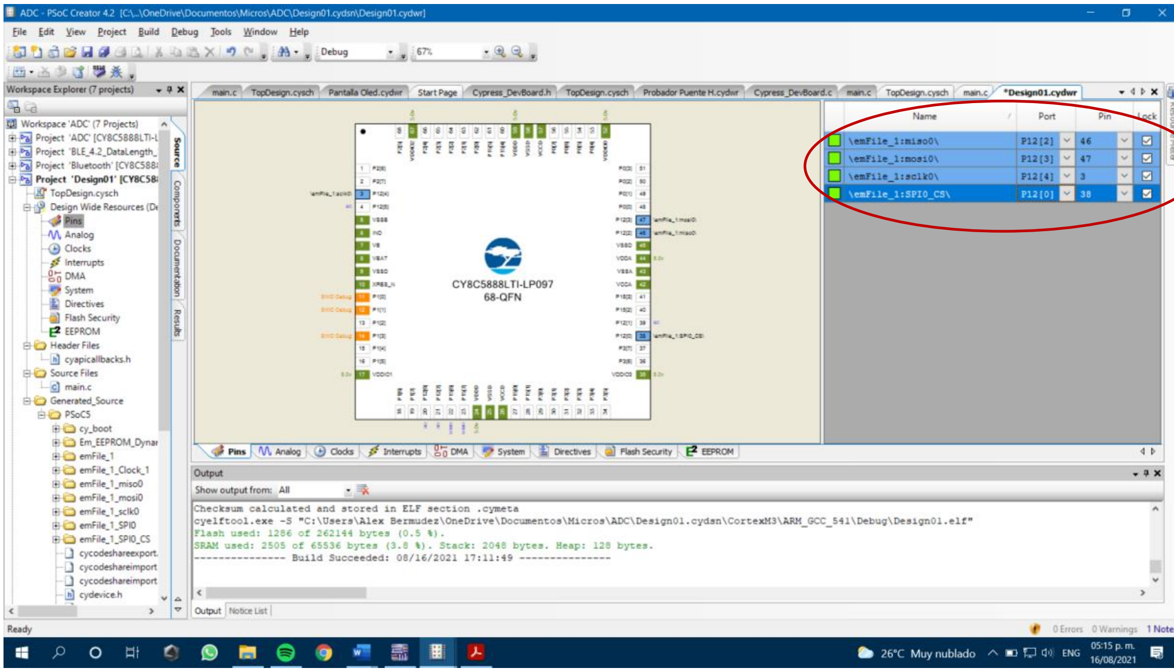
#include <Global.h>.



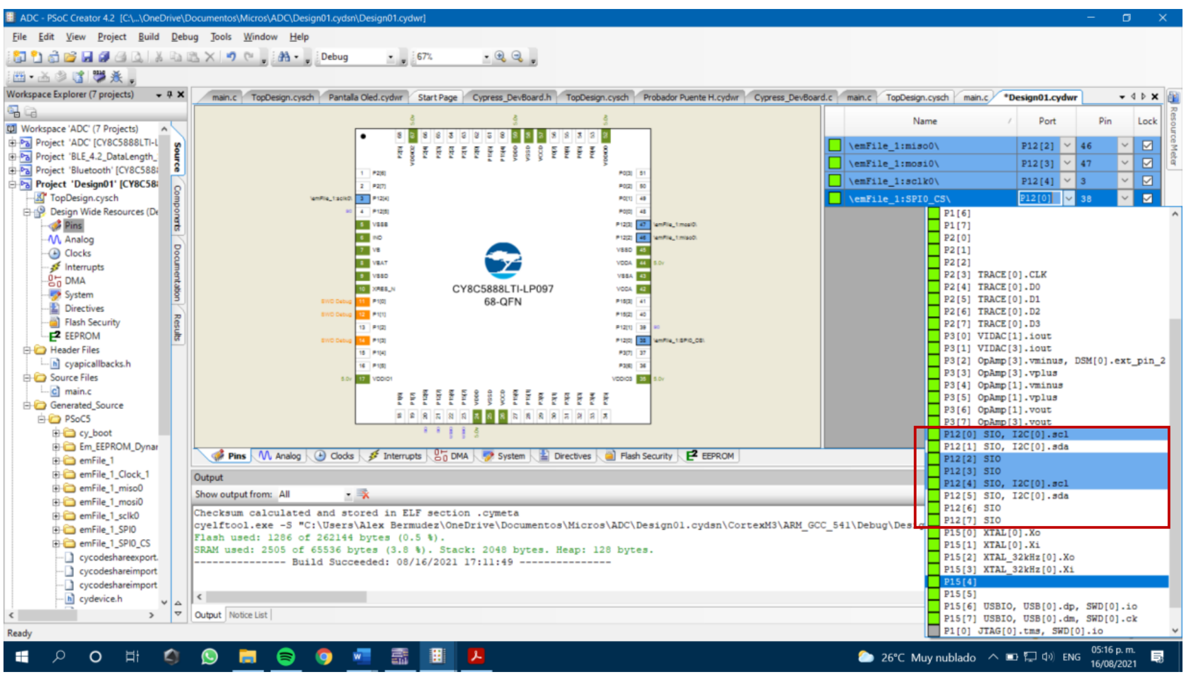
15. Dirigirse a la parte de Pins del proyecto.



16. Por último Cambiar los pines de salida del componente emFile.



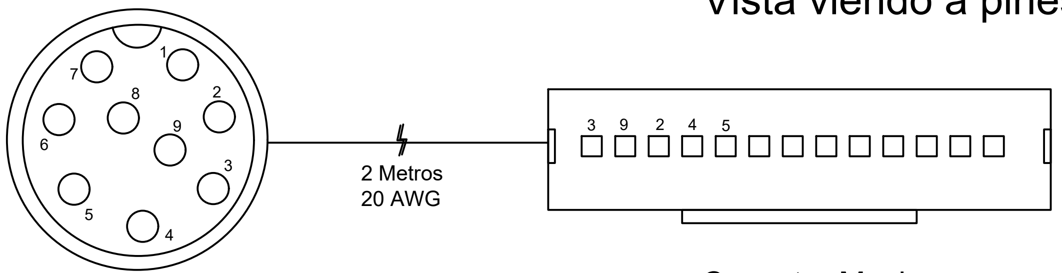
17. Nosotros utilizamos los pines mostrados en la imagen anterior, sin embargo, puede elegir cualquier que tenga la etiqueta de SIO, tal como se muestra en la siguiente imagen.



18. Disfrutar su librería y programar lo necesario, además de leer el manual para la utilización de la librería para un Óptimo funcionamiento.

Sección 4: Creación de Cables con Conectores para los Motores.

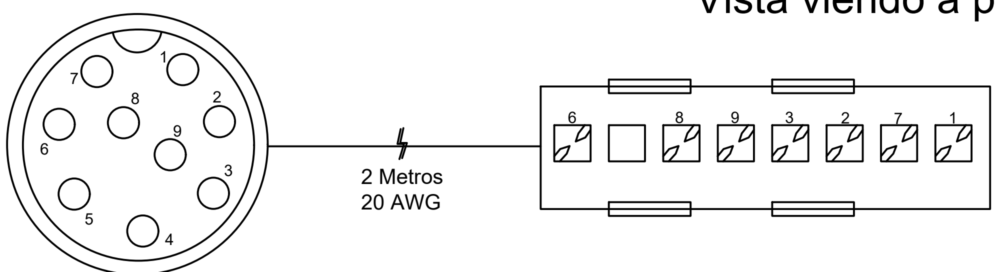
Vista viendo a pines



Conector Hembra

Conector Macho
Motor Iman

Vista viendo a pines



Conector Hembra

Conector Macho
Motor a Pasos

Fecha de inicio: 22/09/2021	Fecha de modificacíon: 22/09/2021	MECTEL	Cliente: Mectel	Archivo: Conectores
Edición: Alejandro Bermudez Cardenas	Revisó: Ing. Armando Melchor Garcia			Página: 1 / 1
Aprobado: Ing. Armando Melchor Garcia	Revición Tec. Cliente: Mectel			
Comentarios:		Referencia:	Equipo: Probador de Motores	

Sección 5: Hojas de Datos.

CY8CKIT-059

PSoC® 5LP Prototyping Kit Guide

Doc. #: 001-96498 Rev. *G

Cypress Semiconductor
198 Champion Court
San Jose, CA 95134-1709
www.cypress.com

Copyrights

Contents

Safety Information

Regulatory Compliance

The CY8CKIT-059 PSoC® 5LP Prototyping Kit is intended for use as a development platform for hardware or software in a laboratory environment. The board is an open system design, which does not include a shielded enclosure. This may cause interference to other electrical or electronic devices in close proximity. In a domestic environment, this product may cause radio interference. In such cases, you may be required to take adequate preventive measures. In addition, this board should not be used near any medical equipment or RF devices.

Attaching additional wiring to this product or modifying the product operation from the factory default may affect its performance and cause interference with other apparatus in the immediate vicinity. If such interference is detected, suitable mitigating measures should be taken.

The PSoC 5LP Prototyping Kit, as shipped from the factory, has been verified to meet with requirements of CE as a Class A product.

The PSoC 5LP Prototyping Kit contains electrostatic discharge (ESD) sensitive devices. Electrostatic charges readily accumulate on the human body and any equipment, and can discharge without detection. Permanent damage may occur on devices subjected to high-energy discharges. Proper ESD precautions are recommended to avoid performance degradation or loss of functionality. Store unused PSoC 5LP Prototyping Kit boards in the protective shipping package.

End-of-Life/Product Recycling

This kit has an end-of life five years from the date of manufacture mentioned on the back of the box. Contact your nearest recycler for discarding the kit.

General Safety Instructions

ESD Protection

ESD can damage boards and associated components. Cypress recommends that you perform procedures only at an ESD workstation. If such a workstation is not available, use appropriate ESD protection by wearing an antistatic wrist strap attached to the chassis ground (any unpainted metal surface) on your board when handling parts.

Handling Boards

PSoC 5LP Prototyping Kit boards are sensitive to ESD. Hold the board only by its edges. After removing the board from its box, place it on a grounded, static-free surface. Use a conductive foam pad if available. Do not slide board over any surface.

1. Introduction

Thank you for your interest in the CY8CKIT-059 PSoC 5LP Prototyping Kit. This kit is designed as an easy-to-use and inexpensive prototyping platform. The PSoC 5LP Prototyping Kit supports the PSoC 5LP device family, delivering a complete system solution for a wide range of embedded applications at a very low cost. The PSoC 5LP is the industry's most integrated SoC with an Arm® Cortex™-M3 CPU. It combines programmable and reconfigurable high-precision analog and digital blocks with flexible automatic routing. The unique flexibility of the PSoC 5LP architecture will help those who want to rapidly develop products using the PSoC 5LP device family.

The PSoC 5LP Prototyping Kit offers an open footprint breakout board to maximize the end-utility of the PSoC 5LP device. This kit provides a low-cost alternative to device samples while providing a platform to easily develop and integrate the PSoC 5LP device into your end-system. In addition, the board includes the following features:

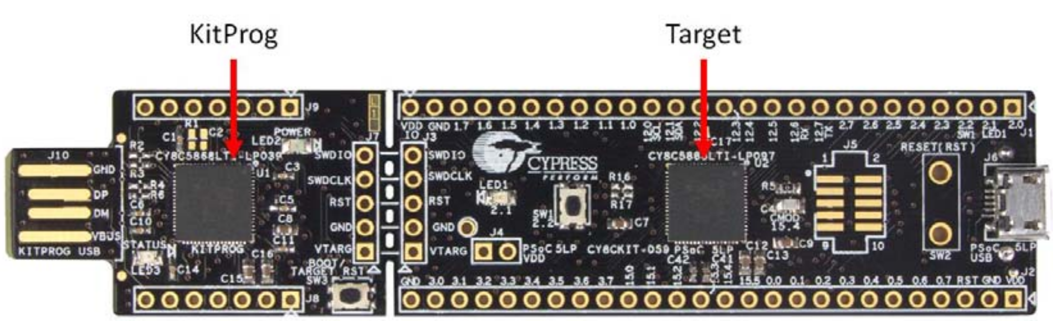
- Micro-USB connector to enable USB application development
- Onboard CMOD capacitors to enable CapSense® development
- Bypass capacitors to ensure the high-quality ADC conversions
- An LED to provide feedback
- A push button to provide a simple user input
- Load capacitors to connect 32-kHz external crystal oscillator
- 3.3-V to 5.5-V operation

The PSoC 5LP prototyping kit also integrates the Cypress KitProg that enables onboard programming, debugging, and bridging functionality, such as USB-UART and USB-I2C. The KitProg is used to program and debug the target PSoC 5LP device (see Figure 1-1). The prototyping kit allows you to separate the KitProg board from the PSoC 5LP target board.

1.1 Kit Contents

This kit contains only the PSoC 5LP Prototyping Kit board.

Figure 1-1. CY8CKIT-059 PSoC 5LP Prototyping Kit

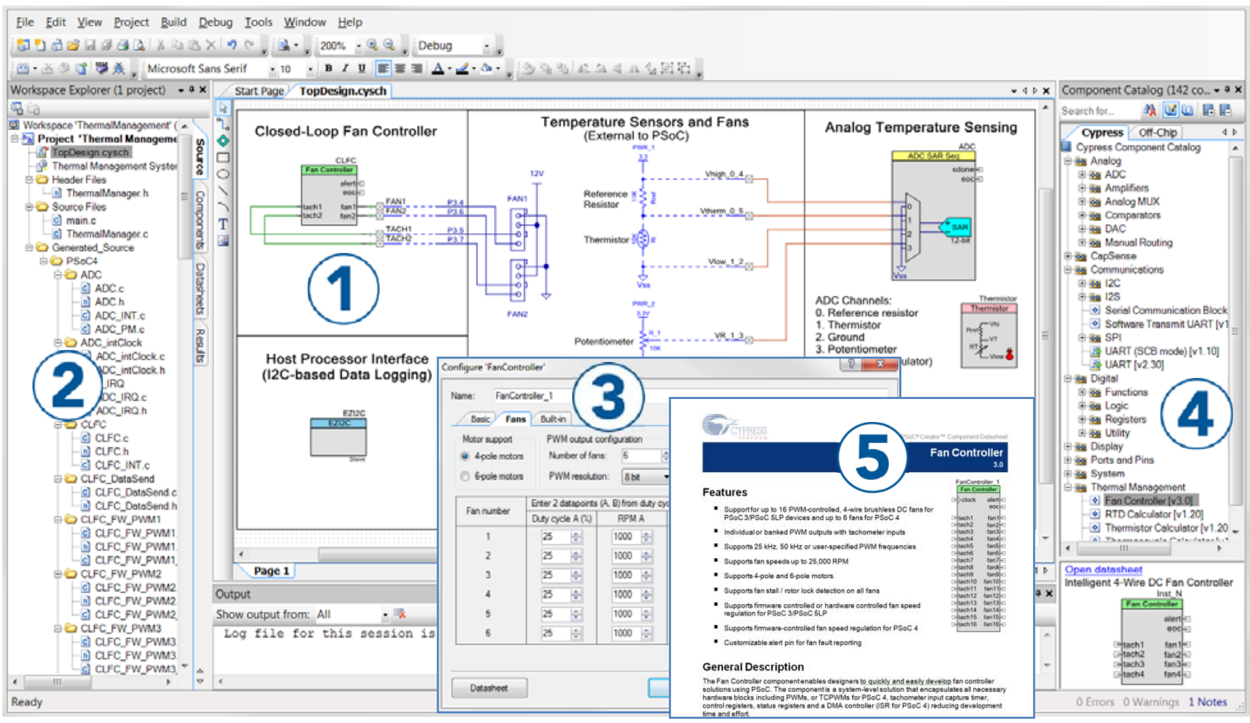


1.2 PSoC Creator

PSoC Creator™ is a state-of-the-art, easy-to-use integrated design environment (IDE). It introduces revolutionary hardware and software co-design, powered by a library of pre-verified and pre-characterized PSoC Components. With PSoC Creator, you can:

1. Drag and drop Components to build your hardware system design in the main design workspace
2. Codesign your application firmware with the PSoC hardware
3. Configure Components using configuration tools
4. Explore the library of 100+ Components
5. Review Component datasheets

Figure 1-2. PSoC Creator Features



PSoC Creator also enables you to tap into an entire tool ecosystem with integrated compiler chains and production programming programmers for PSoC devices.

For more information, visit www.cypress.com/psoccreator.

1.2.1 PSoC Creator Code Examples

PSoC Creator includes a large number of code examples. These examples are available from the PSoC Creator Start Page, as Figure 1-3 on page 9 shows.

Code examples can speed up your design process by starting you off with a complete design, instead of a blank page. They also show how PSoC Creator Components can be used for various applications. Code examples and documentation are included, as shown in Figure 1-4 on page 10.

In the **Find Example Project** dialog shown in Figure 1-4, you have several options:

- Filter for examples based on architecture or device family, that is, PSoC 3, PSoC 4, or PSoC 5LP; project name; or keyword.
- Select from the menu of examples offered based on the **Filter Options**.
- Review the example project's description (on the **Documentation** tab).
- Review the code from the **Sample Code** tab. You can copy the code from this window and paste to your project, which can help speed up code development.
- Create a new project (and a new workspace if needed) based on the selection. This can speed up your design process by starting you off with a complete, basic design. You can then adapt that design to your application.

Figure 1-3. Code Examples in PSoC Creator

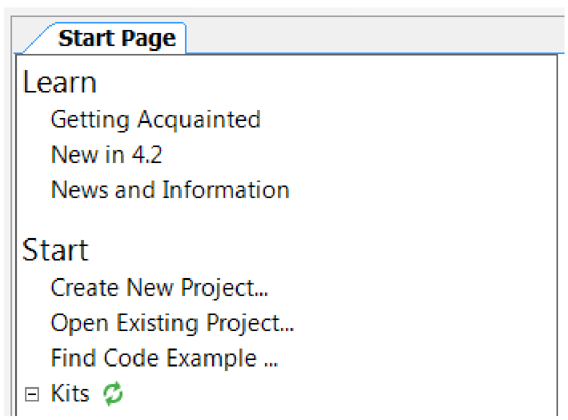
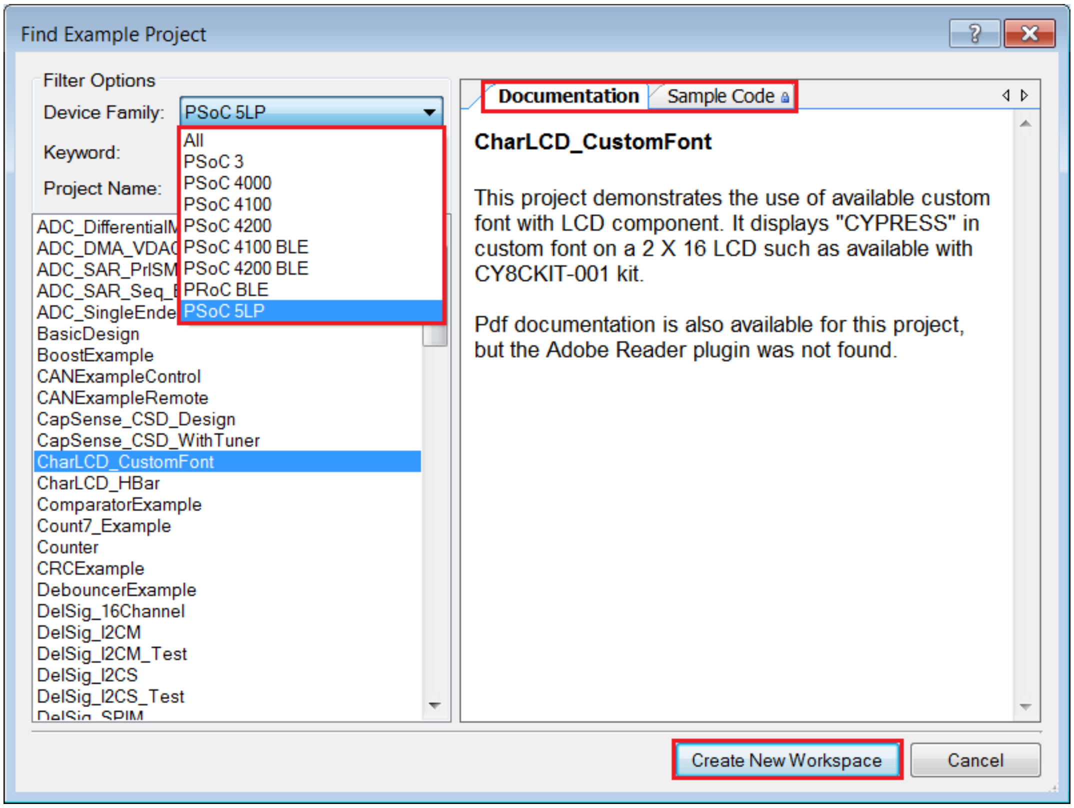


Figure 1-4. Code Example Projects with Sample Code



1.2.2 Kit Code Examples

This kit includes a number of code examples, which can be used to quickly evaluate the functionality of this kit. These examples are described in the Code Examples chapter on page 31.

1.2.3 PSoC Creator Help

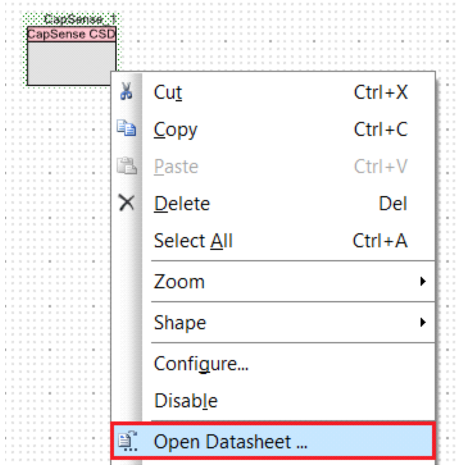
Visit the PSoC Creator home page to download the latest version of PSoC Creator. Then, launch PSoC Creator and navigate to the following items:

- **Quick Start Guide**: Choose **Help** > **Documentation** > **Quick Start Guide**. This guide gives you the basics for developing PSoC Creator projects.
- **Simple Component example projects**: Choose **File** > **Open** > **Example projects**. These example projects demonstrate how to configure and use PSoC Creator Components.
- **Starter designs**: Choose **File** > **New** > **Project** > **PSoC 5LP Starter Designs**. These starter designs demonstrate the unique features of PSoC 5LP.
- **System Reference Guide**: Choose **Help** > **System Reference** > **System Reference Guide**. This guide lists and describes the system functions provided by PSoC Creator.
- **Component datasheets**: Right-click a Component and select **Open Datasheet**, as shown in Figure 1-5. Visit the PSoC 5LP Component Datasheets page for a list of all PSoC 5LP Components datasheets.
- **Document Manager**: PSoC Creator provides a document manager to help you to easily find and review document resources. To open the document manager, choose the menu item **Help** > **Document Manager**.

1.2.4 Component Datasheets

Right-click a Component and select **Open Datasheet** (see Figure 1-5).

Figure 1-5. Opening Component Datasheet



1.3 Getting Started

This guide will help you get acquainted with the PSoC 5LP Prototyping Kit:

- The Software Installation chapter on page 13 describes the installation of the kit software. This includes installation of PSoC Creator IDE for development and debugging the applications, and PSoC Programmer for programming hex files.
- The Kit Operation chapter on page 16 describes the major features of the PSoC 5LP Pioneer Kit and functionalities such as programming, debugging, and the USB-UART and USB-I2C bridges.
- The Hardware chapter on page 20 details the hardware content of the kit and the hardware operation.
- The Code Examples chapter on page 31 describes multiple PSoC 5LP code examples that will help you understand how to create your own PSoC 5LP projects.
- The Appendix on page 39 provides schematics, details about programming the kit using MiniProg3, and the bill of materials (BOM).

1.4 Additional Learning Resources

Cypress provides a wealth of information at www.cypress.com to help you to select the right PSoC device for your design, and to help you to quickly and effectively integrate the device into your design. For a comprehensive list of resources, see KBA86521, How to Design with PSoC 3, PSoC 4, and PSoC 5LP. The following is an abbreviated list for PSoC 5LP:

- Overview: PSoC Portfolio, PSoC Roadmap
- Product Selectors: PSoC 1, PSoC 3, PSoC 4, or PSoC 5LP. In addition, PSoC Creator includes a device selection tool.
- Datasheets: Describe and provide electrical specifications for the PSoC 5LP device family
- CapSense Design Guide: Learn how to design capacitive touch-sensing applications with the PSoC 5LP family of devices.
- Application Notes and Code Examples: Cover a broad range of topics, from basic to advanced level. Many of the application notes include code examples. Visit the PSoC 3/4/5 Code Examples

webpage for a list of all available PSoC Creator code examples. For accessing code examples from within PSoC Creator - see PSoC Creator Code Examples.

- Technical Reference Manuals (TRM): Provide detailed descriptions of the architecture and registers in each PSoC 5LP device family.
- Development Kits:
  - CY8CKIT-050 PSoC 5LP Development Kit enables you to evaluate, develop, and prototype high-precision analog, low-power, and low-voltage applications designed using the PSoC 5LP device family.
  - CY8CKIT-001 is a common development platform for all PSoC family devices.
  - PSoC 5LP Expansion Boards are the expansion modules designed to implement a target application.
- The MiniProg3 device provides an interface for flash programming and debug.
- Knowledge Base Articles (KBA): Provide design and application tips from experts on using the device.
- PSoC Creator Training: Visit the link www.cypress.com/go/creatorstart/creatortraining for a comprehensive list of video trainings on PSoC Creator.
- Learning From Peers: Visit www.cypress.com/forums to meet enthusiastic PSoC developers discussing the next generation embedded systems on Cypress Developer Community Forums.

1.5 Technical Support

If you have any questions, our technical support team is happy to assist you. You can create a support request on the Cypress Technical Support page.

If you are in the United States, you can talk to our technical support team by calling our toll-free number: +1-800-541-4736. Select option 3 at the prompt.

You can also use the following support resources if you need quick assistance.

- Self-help
- Local Sales Office Locations

1.6 Document Conventions

Table 1-1. Document Conventions for Guides

Convention	Usage
Courier New	Displays file locations, user entered text, and source code: `C:\...cd\icc\`
Italics	Displays file names and reference documentation: Read about the *sourcefile.hex* file in the *PSoC Creator User Guide*.
[**Bracketed, Bold**]	Displays keyboard commands in procedures: [**Enter**] or [**Ctrl**] [**C**]
File > Open	Represents menu paths: **File** > **Open** > **New Project**
Bold	Displays commands, menu paths, and icon names in procedures: Click the **File** icon and then click **Open**.
Times New Roman	Displays an equation: $2 + 2 = 4$
Text in gray boxes	Describes Cautions or unique functionality of the product.

2. Software Installation

This chapter describes the steps to install the software tools and packages on a PC for using the PSoC 5LP Prototyping Kit. This includes the IDE on which the projects will be built and used for programming.

2.1 Before You Begin

All Cypress software installations require administrator privileges, but these are not required to run the software after it is installed. Close any other Cypress software that is currently running before installing the kit software.

Note: By default, the kit contents are installed in the `C:\Program Files\Cypress` folder, for a 32-bit machine and `C:\Program Files (x86)\Cypress`, for a 64-bit machine. This directory will contain the kit code examples. To open these code examples, it is recommended to use the procedure described in the Code Examples chapter on page 31. This procedure will create an editable copy of the code example in a path that you chose so that the original installed code examples will not be modified.

2.2 Install Software

Follow these steps to install the PSoC 5LP Prototyping Kit software:

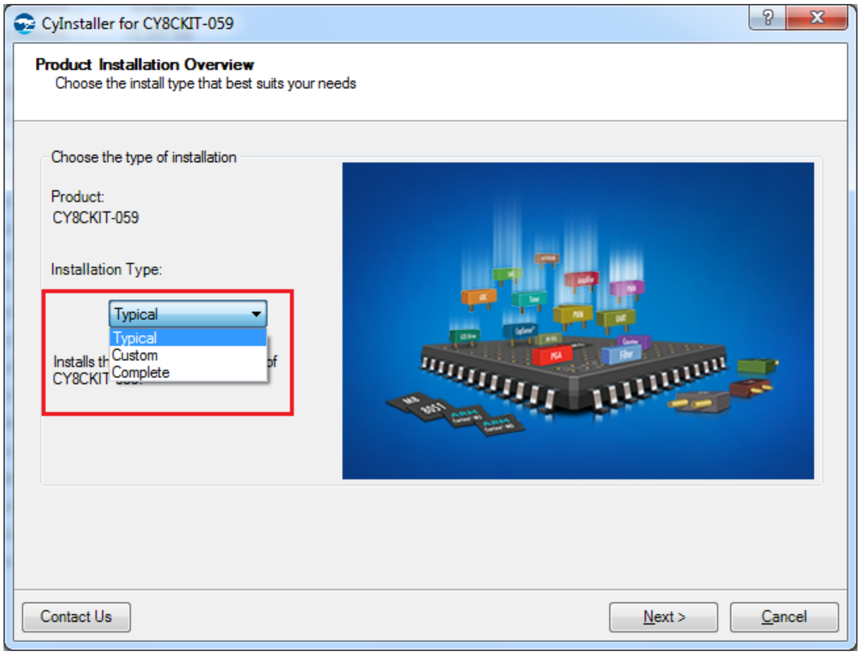
1. Download the PSoC 5LP Prototyping Kit software from www.cypress.com/CY8CKIT-059. The kit software is available in three formats for download.
   a. CY8CKIT-059 Kit Setup: This installation package contains the files related to the kit including PSoC Creator, PSoC Programmer, and PDL. However, it does not include the Windows Installer or Microsoft .NET framework packages. If these packages are not on your computer, the installer will direct you to download and install them from the Internet.
   b. CY8CKIT-059 Kit Only: This executable file installs only the kit contents, which include kit code examples, hardware files, and user documents. This package can be used if all the software prerequisites (listed in step 5) are installed on your PC.
   c. CY8CKIT-059 DVD ISO: This file is a complete package, stored in a DVD-ROM image format, that you can use to create a DVD or extract using an ISO extraction program such as WinZip or WinRAR. The file can also be mounted like a virtual CD/DVD using virtual drive programs such as Virtual CloneDrive and MagicISO. This file includes all the required software, utilities, drivers, hardware files, and user documents.
2. If you have downloaded the ISO file, mount it in a virtual drive. Extract the ISO contents if you do not have a virtual drive to mount. Double-click *cyautorun.exe* in the root directory of the extracted content or mounted ISO if "Autorun from CD/DVD" is not enabled on the PC. The installation window will appear automatically. **Note:** If you are using the "Kit Setup" or "Kit Only" file, then go to step 4 for installation.

3. Click **Install CY8CKIT-059 Kit** to start the kit installation, as shown in Figure 2-1.

Figure 2-1. Kit Installer Screen

4. Select the directory in which you want to install the PSoC 5LP Prototyping Kit-related files. Choose the directory and click **Next**.
5. When you click **Next**, the PSoC 5LP Prototyping Kit installer automatically installs the required software, if it is not present on your computer. Following is the required software:
   a. PSoC Creator 4.2: This software is available for download separately from the kit at www.cypress.com/psoccreator. PSoC Creator 4.2 installer automatically installs the following additional software:
      – PSoC Programmer 3.27.1
      – Peripheral Driver Library 3.0.1.
6. Choose the **Typical/Custom/Complete** installation type in the Product Installation Overview window, as shown in Figure 2-2. Click **Next** after you select the installation type.

Figure 2-2. Product Installation Overview



7. Read the License agreement and select 'I accept the terms in the license agreement' to continue with installation. Click **Next.**
8. When the installation begins, a list of packages appears on the installation page. A green check mark appears next to each package after successful installation.
9. Enter your contact information or select the **Continue Without Contact Information** check box. Click **Finish** to complete the PSoC 5LP Prototyping Kit installation.
10. After the installation is complete, the kit contents are available at the following location: <Install_Directory>\CY8CKIT-059

Default location:

Windows OS (64-bit):

`C:\Program Files (x86)\Cypress\CY8CKIT-059`

Windows OS (32-bit):

`C:\Program Files\Cypress\CY8CKIT-059`

Note: For Windows 7/8/8.1/10 users, the installed files and the folder are read-only. To use the installed code examples, follow the steps outlined in the Code Examples chapter on page 31. These steps will create an editable copy of the example in a path that you choose, so the original installed example is not modified.

2.3 Uninstall Software

The software can be uninstalled using one of the following methods:

1. Go to **Start** > **All Programs** > **Cypress** > **Cypress Update Manager** and select the **Uninstall** button.
2. Go to **Start** > **Control Panel** > **Programs and Features for Windows 7** or **Add/Remove Programs for Windows XP**; select the **Uninstall/Change** button.

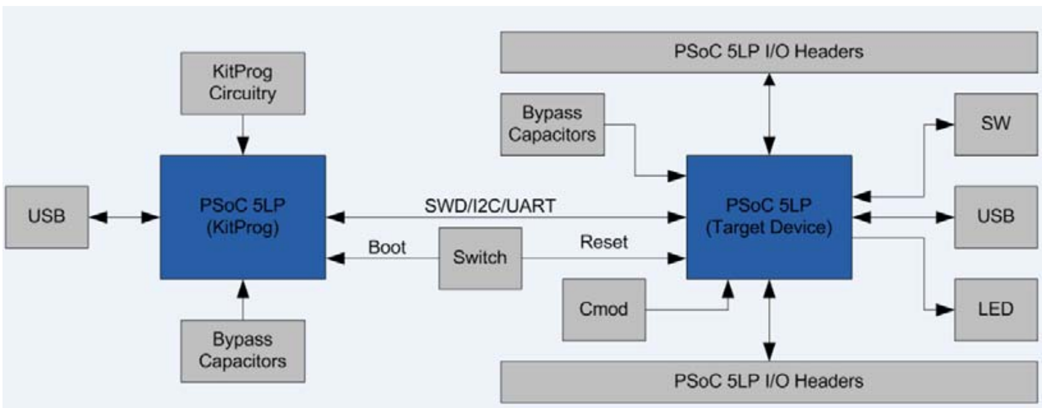
3. Kit Operation

This chapter introduces you to the different features of the PSoC 5LP Prototyping Kit. This primarily includes the programming/debugging functionality, KitProg USB-UART and USB-I2C bridges, and the method to update the KitProg firmware.

3.1 Theory of Operation

Figure 3-1 shows the block diagram for the PSoC 5LP Prototyping Kit.

Figure 3-1. Block Diagram of PSoC 5LP Prototyping Kit



The PSoC 5LP Prototyping Kit is simplistic in design and focuses on providing you with complete access to develop applications using the PSoC 5LP device family. This kit supports the following features:

- KitProg: It is an onboard programmer/debugger, which enables programming and debugging the target PSoC 5LP device. It can also act as a USB-UART and UART-I2C bridge.
  When used as a standalone module, it can be used to program devices of the PSoC 3, PSoC 4, or PSoC 5LP families through the SWD interface. For more details on the KitProg functionality, refer to the *KitProg User Guide* in the kit installation directory:
  <Install_Directory>\CY8CKIT-059\<version>\Documentation\KitProg_User_Guide.pdf
- Expansion Headers: The PSoC 5LP Prototyping Kit brings all I/Os of the device to the two expansion headers, allowing you to have maximum access to the capabilities of the PSoC 5LP device.
- Micro-USB Connector: The onboard micro-USB connector provides access to the USB block of the PSoC 5LP device. This connector enables you to develop USB applications.
- User LED: The onboard LED can be used to display outputs from the PSoC 5LP device. This includes modulating the brightness of the LED to notify different states of the device.

- Push Button (SW): This kit has a push button, which can be used to provide input to the PSoC 5LP.

  Note: The switch connects the PSoC 5LP pin to ground when pressed. Therefore, you need to configure the PSoC 5LP pin as resistive pull-up to detect the switch press.
- Reset Button: This button is used for the following purposes:
  - Reset the PSoC 5LP device: When pressed, it connects the XRES line of the PSoC 5LP to ground and resets the PSoC 5LP device.
  - Bootload the KitProg: When pressed while connecting the kit's PCB USB connector to the USB port of the PC, this button puts the KitProg into the bootloader mode. For more details on the KitProg functionality, refer to the *KitProg User Guide*.

Note: When the two boards are separated, you can mount the SW2 button on the target board to reset the PSoC 5LP device using a switch.

3.2 KitProg

The KitProg is a multi-functional system, which includes a programmer, debugger, USB-I2C bridge, and a USB-UART bridge. The Cypress PSoC 5LP device is used to implement KitProg functionality. The KitProg is integrated in most PSoC development kits. For more details on the KitProg functionality, refer to the KitProg User Guide in the kit installation directory: <Install_Directory>\CY8CKIT-059\<version>\Documentation\KitProg_User_Guide.pdf.

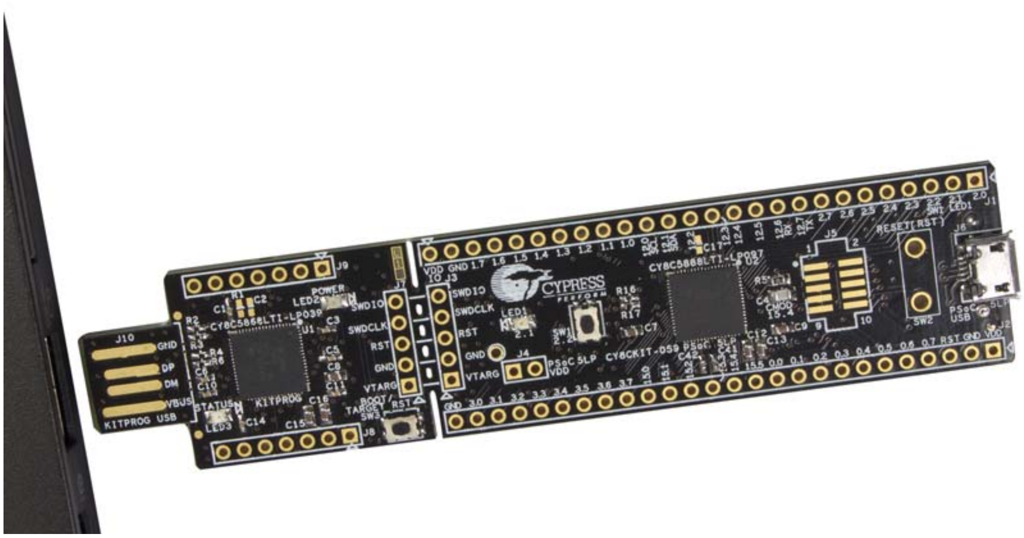
3.3 Programming and Debugging the PSoC 5LP Target Device

The target PSoC 5LP device can be programmed and debugged using the KitProg. Before programming the device, ensure that PSoC Creator and PSoC Programmer software are installed on the PC. See Install Software on page 13 for more information.

3.3.1 Programming using PSoC Creator

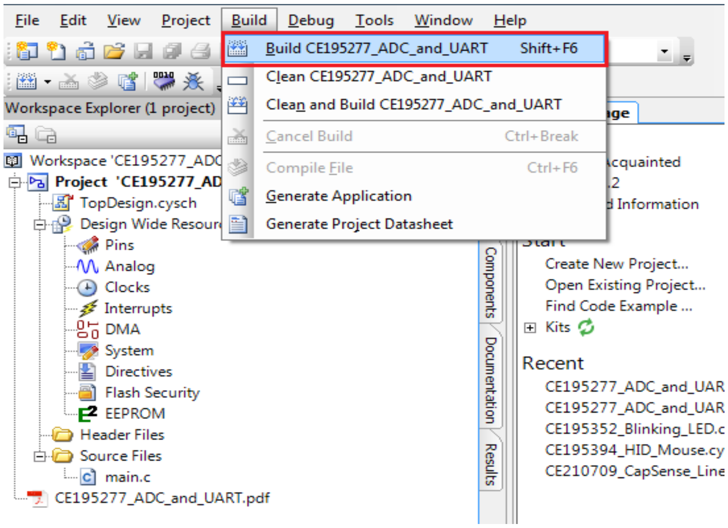
1. Connect the kit to the computer through the PCB USB connector, J10, as shown in Figure 3-2. The kit will enumerate as a composite device, if you are plugging in the PSoC 5LP Prototyping Kit to your PC for the first time.

Figure 3-2. Connecting the PSoC 5LP Prototyping Kit to a Computer



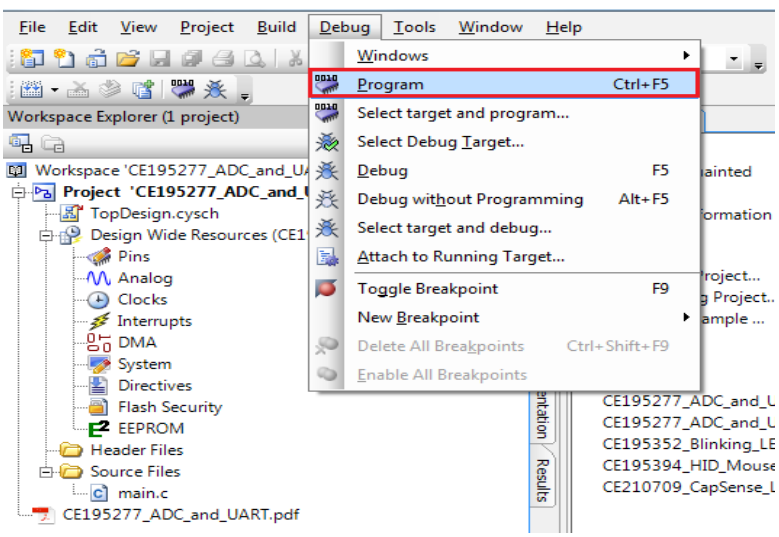
2. Open the desired project in PSoC Creator by selecting **File** > **Open** > **Project/Workspace**. This provides the option to browse to and open a previously saved project. If you want to open one of the code examples provided with the kit, follow the instructions in the Code Examples chapter on page 31.
3. Select the option **Build** > **Build Project** or press **[Shift] [F6]** to build the project as shown in Figure 3-3.

Figure 3-3. Build a Code Example



4. If there are no errors during build, program the firmware into the kit by choosing **Debug** > **Program** or press **[Ctrl] [F5]**, as shown in Figure 3-4. This programs the target PSoC 5LP device on the PSoC 5LP Prototyping Kit, and the kit is ready to use.

Figure 3-4. Programming Device From PSoC Creator



3.3.2 Debugging using PSoC Creator

To debug the project using PSoC Creator, follow steps 1 to 3 from Programming using PSoC Creator on page 17 followed by:

1. Click the **Debug** icon or press **[F5]**. Alternatively, you can use the option **Debug** > **Debug**.
2. When the PSoC Creator opens in Debug mode, use the buttons on the toolbar to debug your application.

For more details on using the debug features, refer to section 3.2 of the *KitProg User Guide*.

3.3.3 Programming using PSoC Programmer

PSoC Programmer (3.27.1 or later) can be used to program existing `.hex` files into the PSoC 5LP Prototyping Kit. Refer to section 3.3 of the *KitProg User Guide* for a detailed explanation on how to program using PSoC Programmer.

3.4 USB-UART Bridge

The KitProg on the PSoC 5LP Pioneer Kit can act as a USB-UART bridge. The UART lines between the KitProg and the target are hardwired on the board, through the snappable area, with UART_RX assigned to **P12_6** and UART_TX assigned to **P12_7** on PSoC 5LP (target). For more details on the KitProg USB-UART functionality, refer to the *KitProg User Guide*.

3.5 USB-I2C Bridge

The KitProg can function as a USB-I2C bridge and communicate with the Bridge Control Panel (BCP) software utility. The I2C lines on the PSoC 5LP (target) device are **P12_1 (SDA)** and **P12_0 (SCL)**, which are hardwired on the board to the I2C lines of the KitProg. The USB-I2C supports I2C speeds of 50 kHz, 100 kHz, 400 kHz, and 1 MHz. For more details on the KitProg USB-I2C functionality, refer to the *KitProg User Guide*.

3.6 Updating KitProg Firmware

The KitProg firmware normally does not require any update. You can use the PSoC Programmer software to update the firmware. Refer to the *KitProg Use Guide* for a detailed explanation on how to update the KitProg firmware.

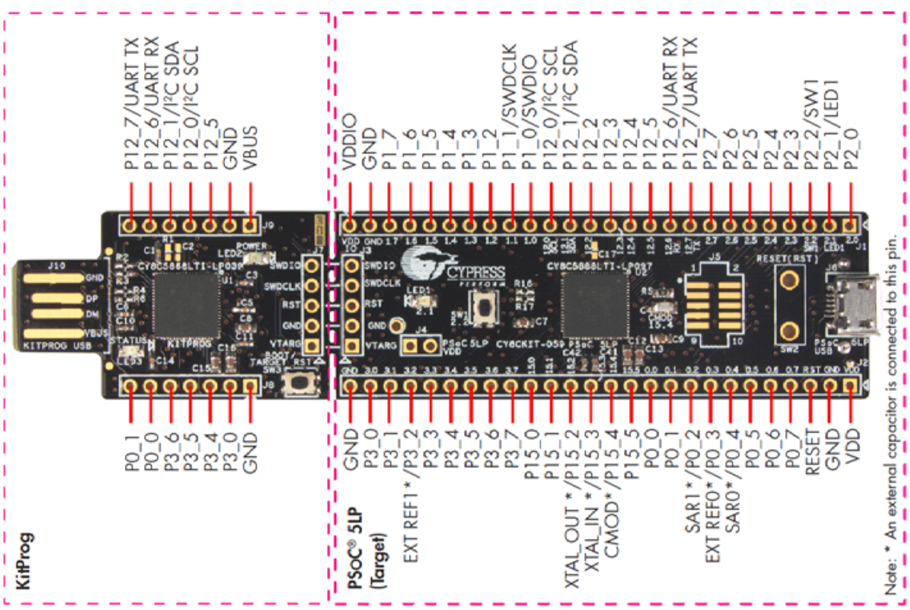
4. Hardware

4.1 Board Details

The PSoC 5LP Prototyping Kit consists of the following blocks:

- PSoC 5LP device
- PSoC 5LP header ports J1 and J2
- Micro-USB connector, J6
- PSoC 5LP program/debug JTAG header, J5
- KitProg (PSoC 5LP) device
- KitProg ports J8 and J9 (GPIO)
- SWD connection J3 and J7
- PCB USB connector
- One amber LED (Power)
- One green LED (Status)
- One blue LED (User)
- User push button and reset button
- External reference capacitors (ADC Bypass)
- CapSense capacitor (CMOD)
- Programming connector, J3
- Perforated 'snappable' board design

Figure 4-1. PSoC 5LP Prototyping Kit Pin Details

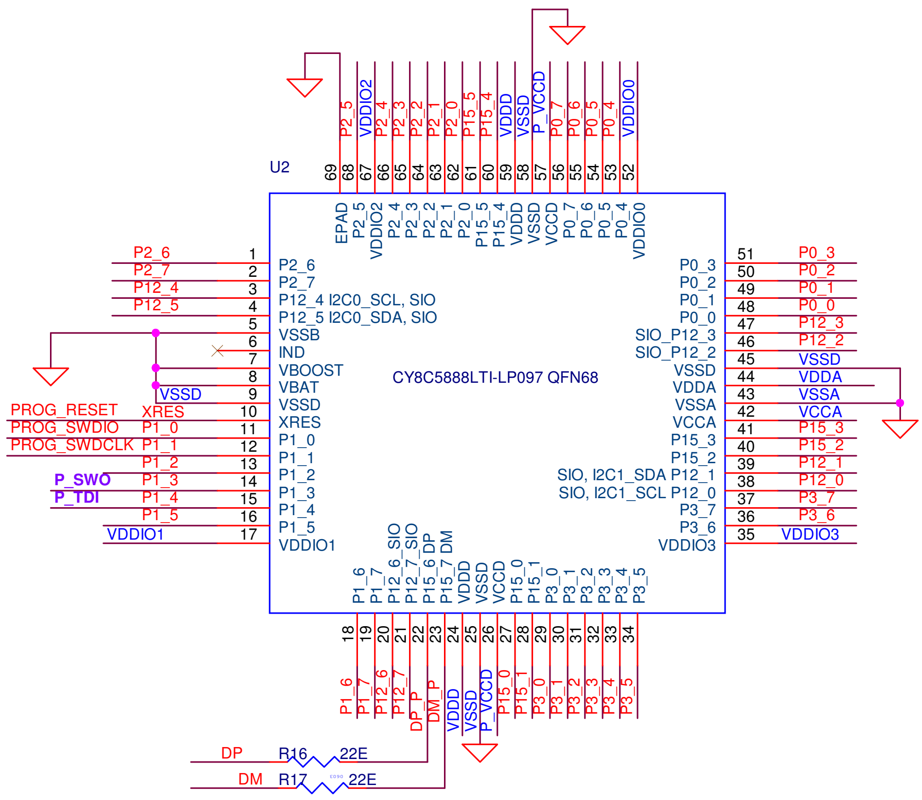


4.2 Hardware Details

4.2.1 Target Board

The target board uses the PSoC 5LP family device. PSoC 5LP is the industry's most integrated programmable SoC, integrating high-precision and programmable analog and digital peripherals, and an Arm® Cortex™-M3 CPU. The PSoC 5LP features a high-precision analog-to-digital converter (ADC), programmable amplifiers, flexible digital subsystem, unmatched parallel co-processing digital filter block (DFB), high-throughput peripherals such as DMA, CAN, and USB, and standard communication and timing peripherals. The programmable analog and digital subsystems allow flexibility and in-field tuning of the design. For more information, refer to the PSoC 5LP family datasheet in the PSoC 5LP web page.

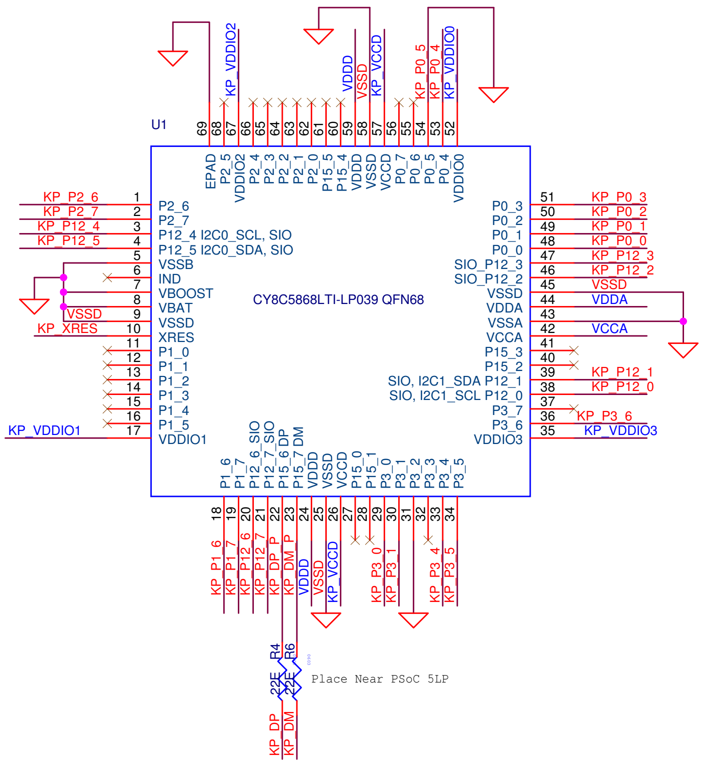
Figure 4-2. Schematic of PSoC 5LP (Target)



4.2.2 KitProg Board

PSoC 5LP on the KitProg board is used to program and debug the target PSoC 5LP device. The KitProg PSoC 5LP connects to the USB port of the PC through the PCB USB connector and to the SWD interface of the target PSoC 5LP device.

Figure 4-3. Schematic of PSoC 5LP (KitProg)



4.2.3 Power Supply System

The power supply system on this board is dependent on the source of the power. For most applications, you can use the 5-V supply from the USB connection to power the system. You can also connect an external power supply to the board for low-voltage applications. The kit supports the following connections:

- 5 V from the KitProg USB
- 5 V from the PSoC 5LP target USB (this will not power the KitProg section of the board)
- 3.3 V to 5.5 V from a regulated supply connected to VDD (this will not power the KitProg section of the board)

Note: To use an external power supply, while KitProg is connected to the PCB USB, remove diode, D1, from the board. This ensures that VTARG supply from KitProg is not supplied to the target device. KitProg measures the target voltage and adjusts the logic levels on the programming pins accordingly.

This prototyping kit does not have an onboard ESD protection circuitry. Therefore, the power source for the PSoC 5LP Prototyping Kit must be of a high quality to ensure that the board is protected from any over-current conditions and swapped-power connections.

4.2.3.1 Measure PSoC 5LP Current Consumption

You can measure the current consumption of the PSoC 5LP device by using one of these methods:

Method 1:

1. Separate the KitProg board by 'snapping' the perforated edge between the two boards.
2. Power the remaining prototyping board via any of the VDD or VTARG terminals.
3. Place an ammeter in series with the VDD or VTARG connection to measure the current consumption.

Method 2:

1. Remove the resistor R20 and install a 2-pin jumper in the supplied holes of J4.
2. Connect an ammeter across the 2-pin jumper to measure the current to the PSoC 5LP device.

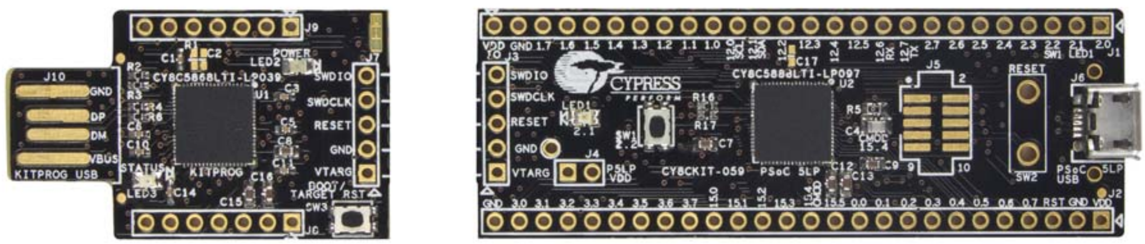
This method can be used either with USB power or with power supplied to one of the VTARG pins but not when supplying to one of the VDD pins.

4.2.4 Board Separation (Snapping)

The PSoC 5LP Prototyping Kit consists of both a PSoC 5LP and a KitProg board. To separate the two boards for testing or development, break the two boards apart at the built-in perforated edge.

The easiest method of separating the two boards is to place the kit on the edge of a table, where the edge of the table is directly below the perforated edge and the smaller KitProg board is off the table edge. Press gently on the KitProg board and snap the two boards apart. If any material is removed from the edge of the boards, use sheers to clean up the edge of the kit.

Figure 4-4. PSoC 5LP Prototyping Kit Broken into Two Parts



4.2.5 Header Connections

The PSoC 5LP Prototyping Kit supports a number of unpopulated headers on both the KitProg and the target PSoC 5LP boards.

4.2.5.1 Functionality of the J1 and J2 Headers (Target Board)

The target board contains two dual-inline headers (J1 and J2). These headers are both 1×26-pin headers and include all of the I/O available on the PSoC 5LP device. These headers support all of the available ports, GND, VDD, and connections to passive elements and user-input devices.

The J1 and J2 headers support 100-mil spacing, so you can solder connectors to connect the target board to any development breadboard.

Figure 4-5. J1 and J2 Headers

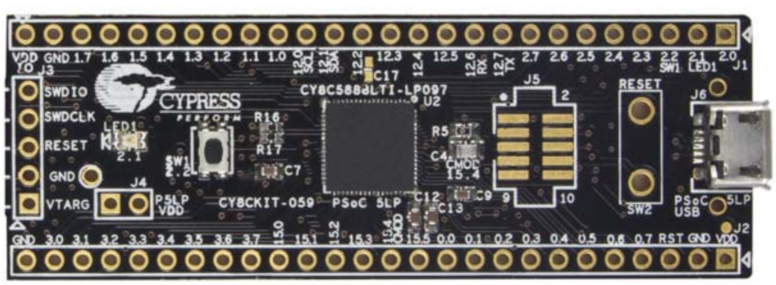


Table 4-1. J1 Header Pin Details

PSoC 5LP Prototyping Kit GPIO Header (J1)		
Pin	**Signal**	**Description**
J1_01	P2.0	GPIO
J1_02	P2.1	GPIO/LED
J1_03	P2.2	GPIO/SW
J1_04	P2.3	GPIO
J1_05	P2.4	GPIO
J1_06	P2.5	GPIO
J1_07	P2.6	GPIO
J1_08	P2.7	GPIO
J1_09	P12.7	GPIO/UART_TX
J1_10	P12.6	GPIO/UART_RX
J1_11	P12.5	GPIO
J1_12	P12.4	GPIO
J1_13	P12.3	GPIO
J1_14	P12.2	GPIO
J1_15	P12.1	GPIO/I2C_SDA
J1_16	P12.0	GPIO/I2C_SCL
J1_17	P1.0	GPIO
J1_18	P1.1	GPIO
J1_19	P1.2	GPIO
J1_20	P1.3	GPIO
J1_21	P1.4	GPIO
J1_22	P1.5	GPIO
J1_23	P1.6	GPIO
J1_24	P1.7	GPIO
J1_25	GND	Ground
J1_26	VDDIO	Power

Table 4-2. J2 Header Pin Details

PSoC 5LP Prototyping Kit GPIO Header (J2)		
Pin	**Signal**	**Description**
J2_01	VDD	Power
J2_02	GND	Ground
J2_03	RESET	Reset
J2_04	P0.7	GPIO
J2_05	P0.6	GPIO
J2_06	P0.5	GPIO
J2_07	P0.4	GPIO/BYPASS CAP
J2_08	P0.3	GPIO/BYPASS CAP
J2_09	P0.2	GPIO/BYPASS CAP
J2_10	P0.1	GPIO
J2_11	P0.0	GPIO
J2_12	P15.5	GPIO
J2_13	P15.4	GPIO/CMOD
J2_14	P15.3	GPIO/XTAL_IN
J2_15	P15.2	GPIO/XTAL_OUT
J2_16	P15.1	GPIO
J2_17	P15.0	GPIO
J2_18	P3.7	GPIO
J2_19	P3.6	GPIO
J2_20	P3.5	GPIO
J2_21	P3.4	GPIO
J2_22	P3.3	GPIO
J2_23	P3.2	GPIO/BYPASS CAP
J2_24	P3.1	GPIO
J2_25	P3.0	GPIO
J2_26	GND	Ground

4.2.5.2 Functionality of J7 and J3 Headers (PSoC 5LP to KitProg)

The KitProg and target boards each contain a 1x5-pin header. These headers provide a physical connection between the two devices. Specifically, the connection includes the SWD interface, required to program/debug the target PSoC 5LP device, power, ground, and reset.

Figure 4-6. J7 and J3 Headers

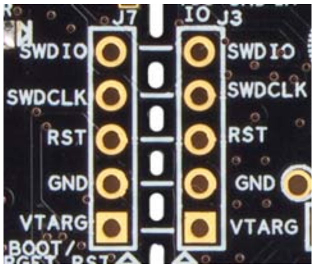


Table 4-3. Pin Details of J7 Header

PSoC 5LP to KitProg Header (J7)		
Pin	Signal	Description
J7_01	VTARG	Power
J7_02	GND	Ground
J7_03	P12.4	RESET
J7_04	P12.3	SWDCLK
J7_05	P12.2	SWDIO

Table 4-4. Pin Details of J3 Header

PSoC 5LP (Target) Program and Debug Header (J3)		
Pin	Signal	Description
J3_01	VTARG	Power
J3_02	GND	Ground
J3_03	XRES	RESET
J3_04	P1.1	SWDCLK
J3_05	P1.0	SWDIO

When the boards are separated, the KitProg board can be used to program any other PSoC 3, PSoC 4, or PSoC 5LP family of devices via J7.

4.2.5.3 *Functionality of J8 and J9 Headers (KitProg)*

The KitProg board contains two dual-inline headers (J8 and J9). These headers are both 1x7-pin-headers, used to pull out several pins of PSoC 5LP to support advanced features like a low-speed oscilloscope and a low-speed digital logic analyzer. This header also contains the KitProg bridge pins that can be used when the two boards are separated.

The J8 and J9 headers support 100-mil spacing, so you can solder connectors to connect the KitProg board to any development breadboard.

Figure 4-7. J8 and J9 Headers

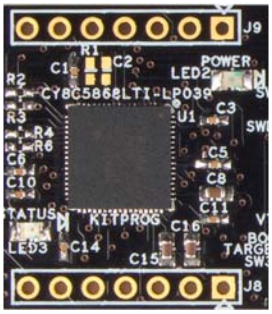


Table 4-5. Pin Details of J9

KitProg GPIO Header (J9)		
Pin	**Signal**	**Description**
J9_01	VBUS	Power
J9_02	GND	Ground
J9_03	P12.5	GPIO
J9_04	P12.0	GPIO/I2C_SCL
J9_05	P12.1	GPIO/I2C_SDA
J9_06	P12.6	GPIO/UART_RX
J9_07	P12.7	GPIO/UART_TX

Table 4-6. Pin Details of J8

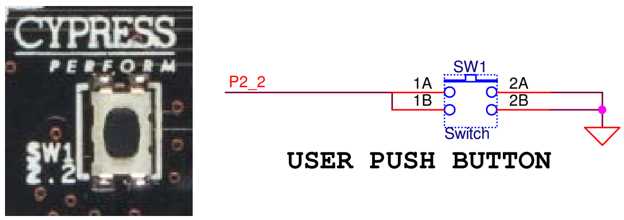
KitProg GPIO Header (J8)		
Pin	**Signal**	**Description**
J8_01	GND	Ground
J8_02	P3.0	GPIO
J8_03	P3.4	GPIO
J8_04	P3.5	GPIO
J8_05	P3.6	GPIO
J8_06	P0.0	GPIO
J8_07	P0.1	GPIO

4.2.6 User and Passive Inputs

4.2.6.1 Push Button

The target PSoC 5LP board contains a single push button connected to the P2.2 pin on the PSoC 5LP device. This button can be used for general user inputs or to control different states in an application.

Figure 4-8. Push Button on the Board



4.2.6.2 Reset/Boot Button

The KitProg board contains a push button connected to the XRES pin on the target PSoC 5LP device and P12_4 of the KitProg device. This button serves two functions:

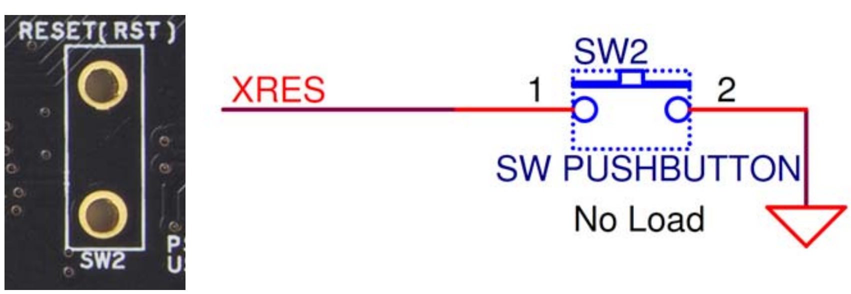
- Reset the PSoC 5LP device: When this button is pressed, XRES line of the PSoC 5LP is connected to ground, which, in turn, resets the target device.
- Bootload the KitProg: When this button is pressed while plugging the KitProg into the USB port of the PC, the KitProg enters the bootloader mode. In this mode, bootloadable applications can be downloaded on the KitProg device.

Figure 4-9. Reset/Boot Button

Reset Button

The target board also provides a footprint for a through-hole switch, which can be used to reset the device when the two boards are separated.

Figure 4-10. Reset (RST) Button



4.2.6.3 LEDs

The PSoC 5LP Prototyping Kit contains three LEDs:

- Amber LED: Indicates that the board is powered from the PCB USB connector. This LED will not light when the board is powered from the micro-USB connector or from VDD or VTARG directly.
- Green LED: Indicates the KitProg status, connected to P3.1 of the KitProg PSoC 5LP device. For more details on the KitProg status LED, refer to the *KitProg User Guide*.
- Blue LED: This is the user LED, connected to P2.1 of the target PSoC 5LP device.

Figure 4-11. Power LED

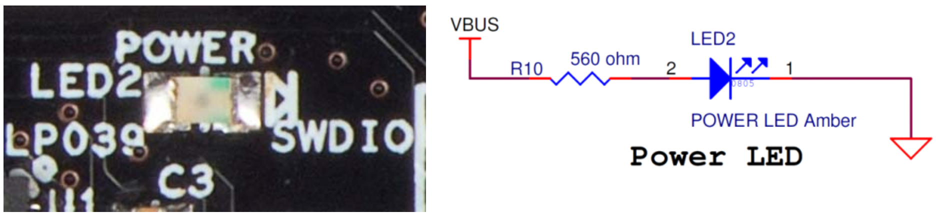


Figure 4-12. Status LED

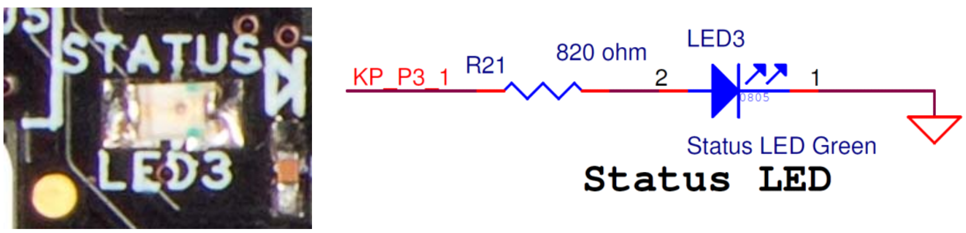
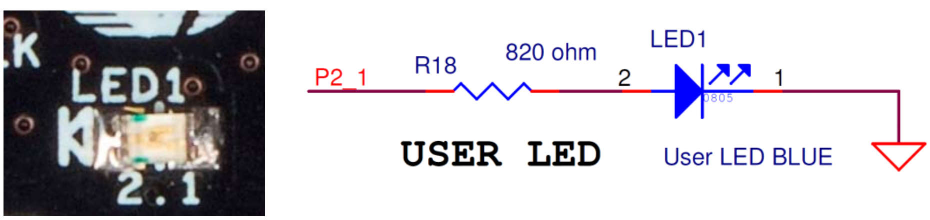


Figure 4-13. User LED



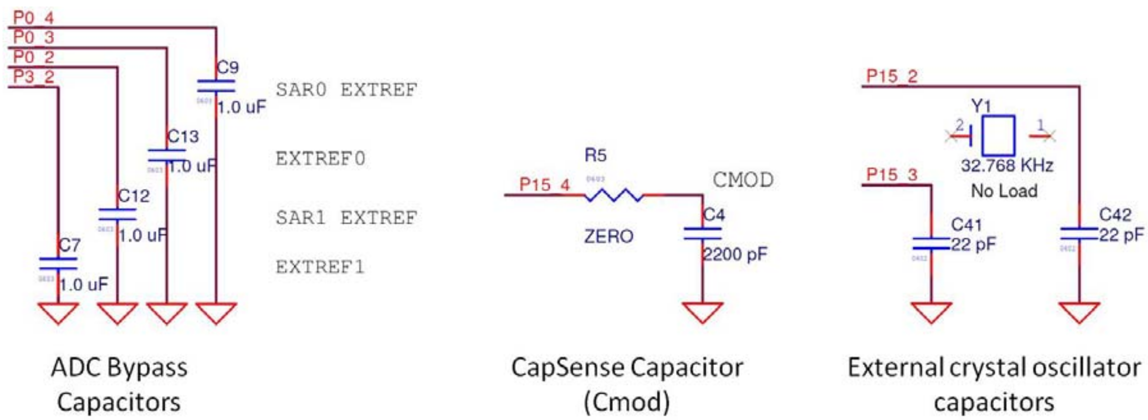
4.2.6.4 System Capacitors

The PSoC 5LP Prototyping Kit has seven capacitors, which are used when ADC operation at high frequencies, CapSense, or external 32-kHz crystal oscillator is required in the application.

- Four ADC bypass capacitors: Required for proper ADC sampling at high frequencies:
  - C9 and C12 – For two SAR ADCs
  - C7 and C13 – For Delta Sigma ADC
- A CapSense capacitor (CMOD): Required for proper CapSense functionality.
- Two biasing capacitors: Required for interfacing an external 32-kHz crystal oscillator. These capacitors are added in the Rev *A version of the PSoC 5LP Prototyping Kit.

Note: The **c**rystal oscillator is not placed on the board, it can be soldered on pins **P15_2** and **P15_3**.

Figure 4-14. System Capacitors Circuit Diagram



5. Code Examples

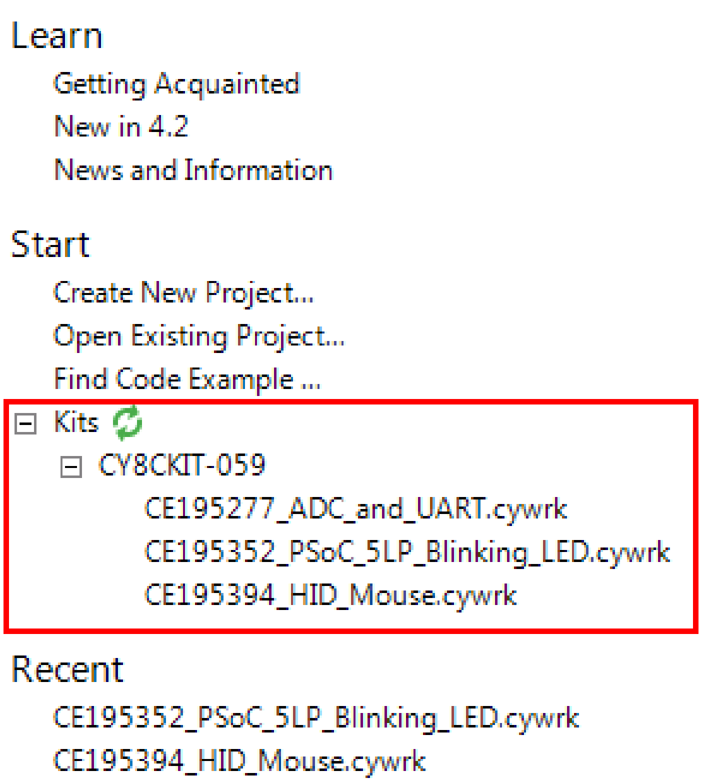
This chapter explains the code examples provided along with the PSoC 5LP Prototyping Kit. To access these code examples, download and install the CY8CKIT-059 PSoC 5LP Prototyping Kit setup file from the kit webpage: www.cypress.com/CY8CKIT-059. After installation, the code examples will be available from **Start** > **Kits** > **CY8CKIT-059** on the PSoC Creator Start Page.

5.1 Using the Kit Code Examples

Follow these steps to open and use the code examples.

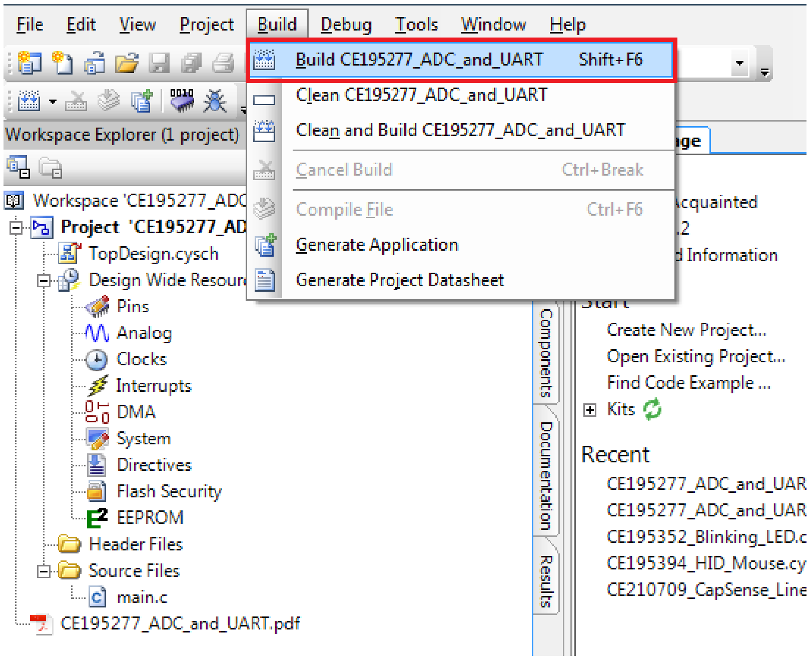
1. Launch PSoC Creator from the Windows Start menu (**Start** > **All Programs** > **Cypress** > **PSoC Creator<version>** > **PSoC Creator <version>**).
2. On the Start page, click **CY8CKIT-059** under **Start** > **Kits**. A list of code examples appears, as shown in Figure 5-1.
3. Click on the desired code example and save it at a desired location. For the remaining steps, *CE195277_ADC_and_UART.cywrk* is used as reference.

Figure 5-1. Open Code Example from PSoC Creator



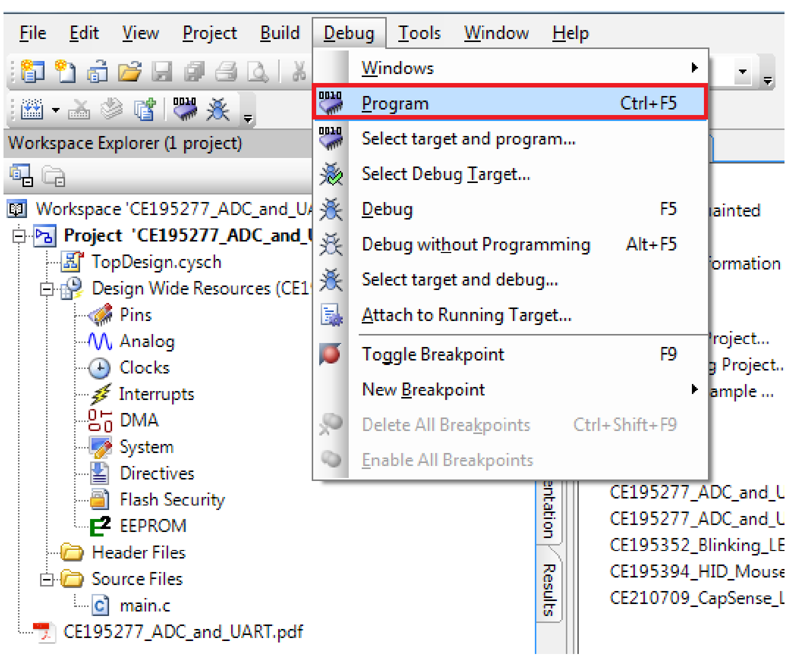
4. Build the code example by choosing **Build** > **Build <Project Name>**, as shown in Figure 5-2. A .hex file is generated after the build process.

Figure 5-2. Open Code Example from PSoC Creator



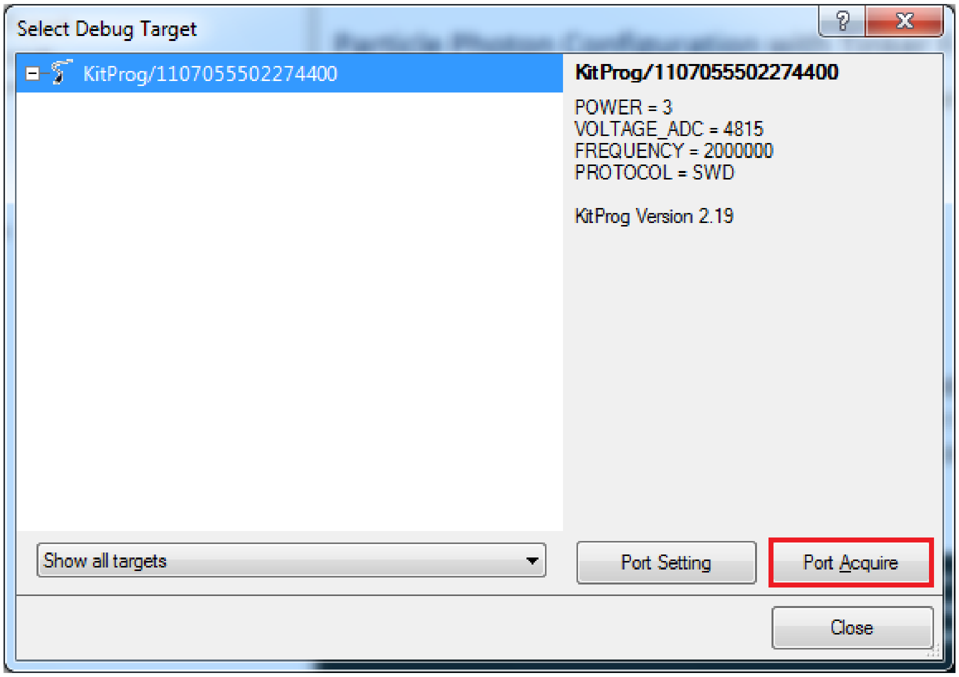
5. Connect the PSoC 5LP Prototyping Kit to the PC using the KitProg PCB USB port, J10 as described in Figure 3-2 on page 17 to program the kit with this code example.
6. Choose **Debug** > **Program** in PSoC Creator as shown in Figure 5-3.

Figure 5-3. Program Device in PSoC Creator



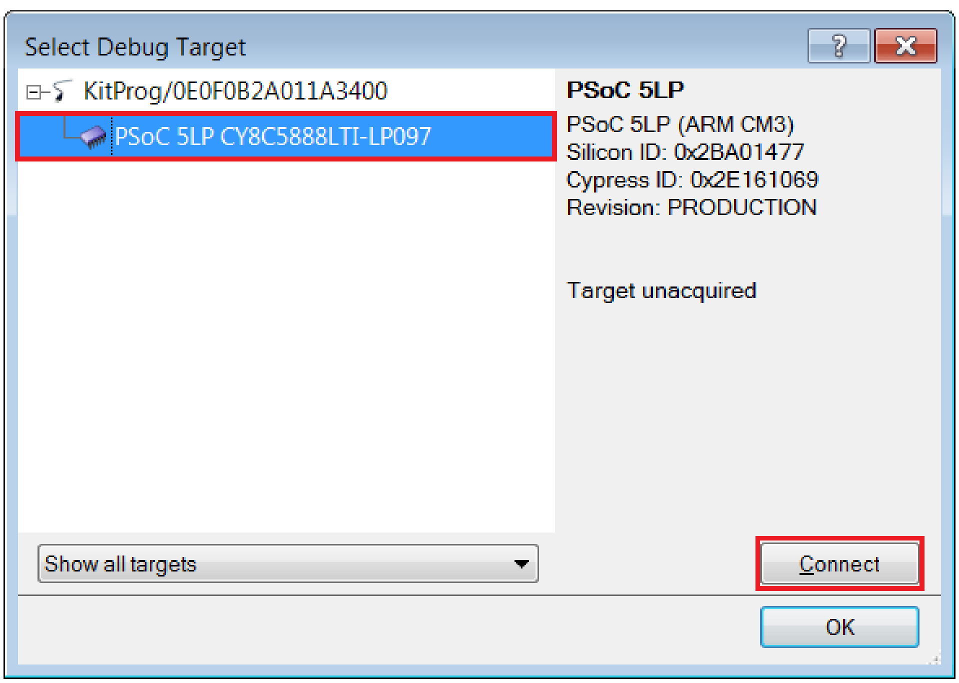
7. PSoC Creator opens the programming window if the device is not yet acquired. Select **KitProg** and click the **Port Acquire** button, as shown in Figure 5-4.

Figure 5-4. Port Acquire



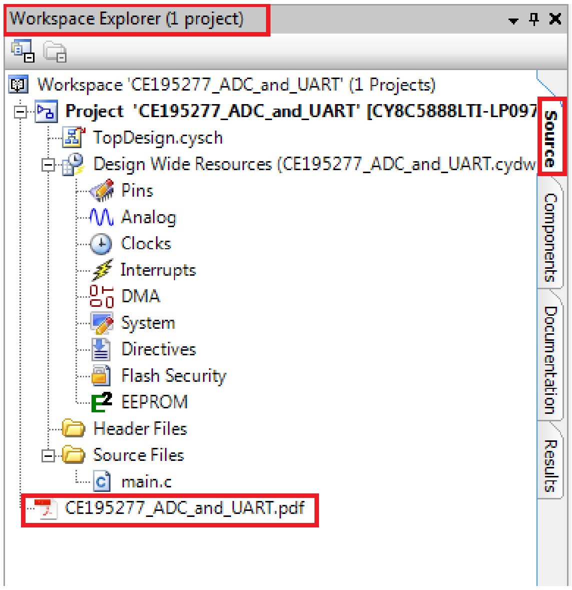
8. After the device is acquired, it is shown in a tree structure below the KitProg. Click the **Connect** button and then **OK** to exit the window and start programming, as shown in Figure 5-5.

Figure 5-5. Connect Device From PSoC Creator and Program



9. From the workspace explorer in PSoC Creator, open the *CE195277_ADC_and_UART.pdf* as shown in Figure 5-6.

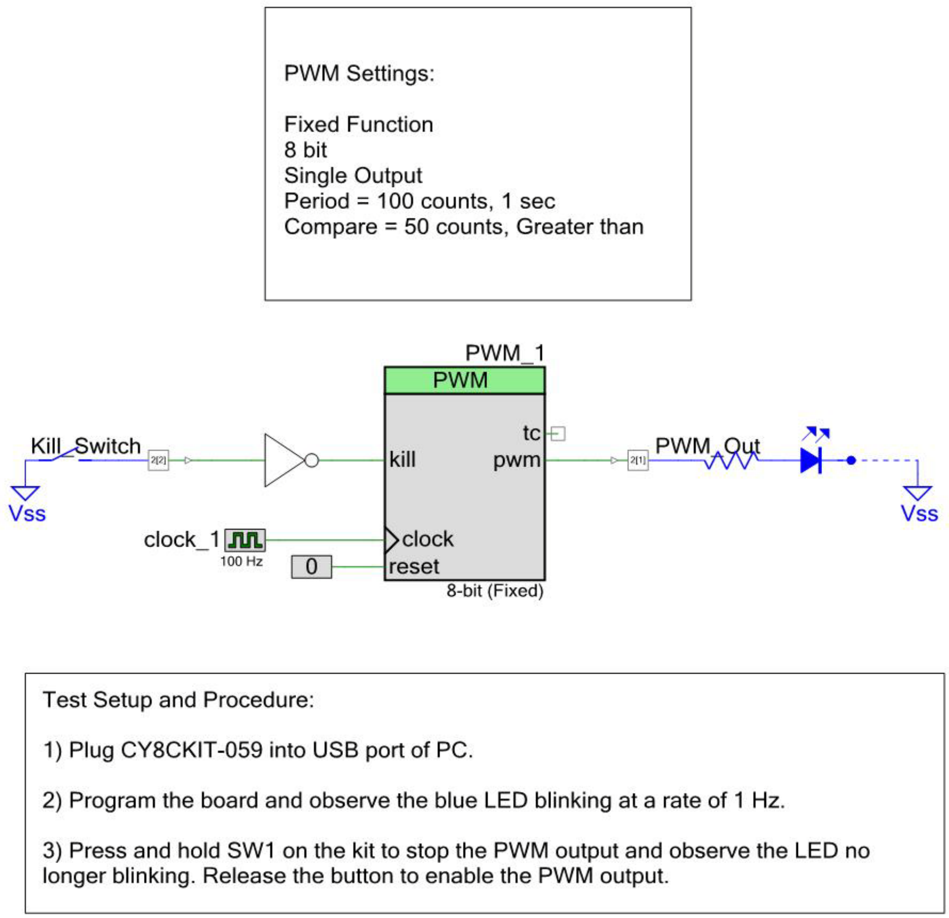
Figure 5-6. Project Datasheet - CE195277_ADC_and_UART.pdf



5.2 CE195352_PSoC_5LP_Blinking_LED

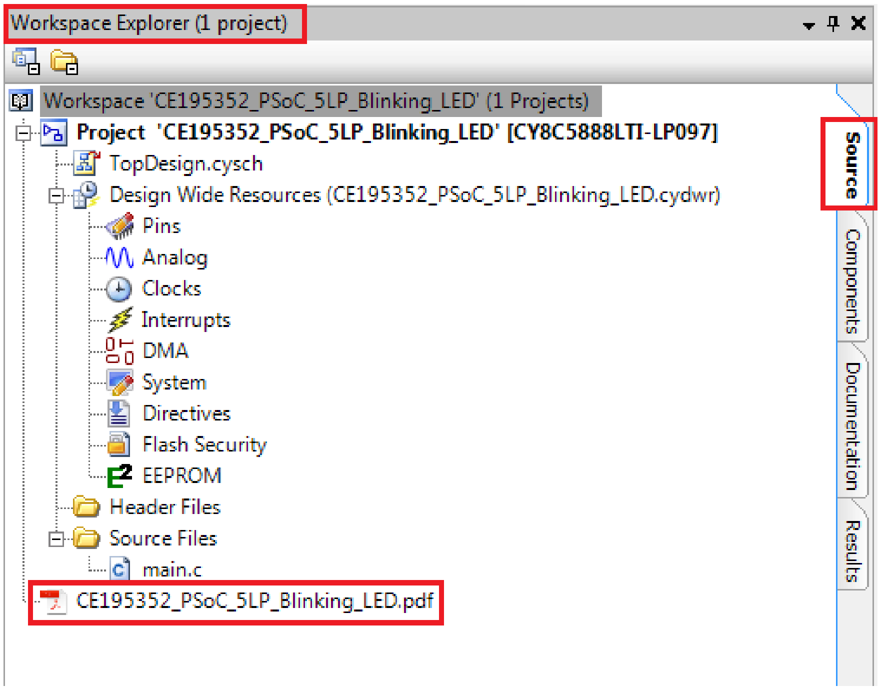
This code example demonstrates the use of a fixed-function PWM. The PWM is set up to output a 50-percent duty cycle digital signal with a period of 1 second. This signal can be used to drive an LED for visual testing of the PWM output. A switch is routed into the kill input of the PWM. When the switch is pressed the PWM output is shut off.

Figure 5-7. TopDesign for CE195352_PSoC_5LP_Blinking_LED



For a detailed description, refer to the *CE195352_PSoC_5LP_Blinking_LED.pdf* from PSoC Creator.

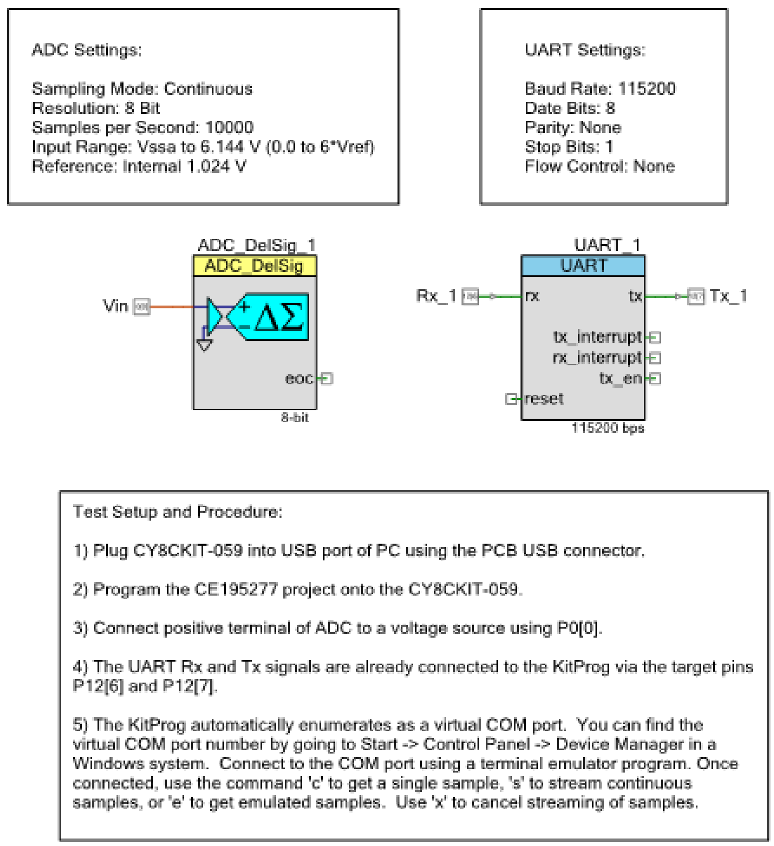
Figure 5-8. Project Datasheet - CE195352_PSoC_5LP_Blinking_LED.pdf



5.3 CE195277_ADC_and_UART

This code example implements a simple data collection system using the DelSig ADC and the UART component. The ADC continuously samples an analog input. The resulting samples can be sent to a PC over a UART connection a single sample at a time or continuously. Emulated data, which is just an incrementing number, can also be sent over the UART connection to test the communication. The USB-UART Bridge in the KitProg is used to create an RS-232 connection to a terminal program on a PC. The terminal program is used to send commands to get the ADC sample data and read the resulting responses.

Figure 5-9. TopDesign CE195277_ADC_and_UART

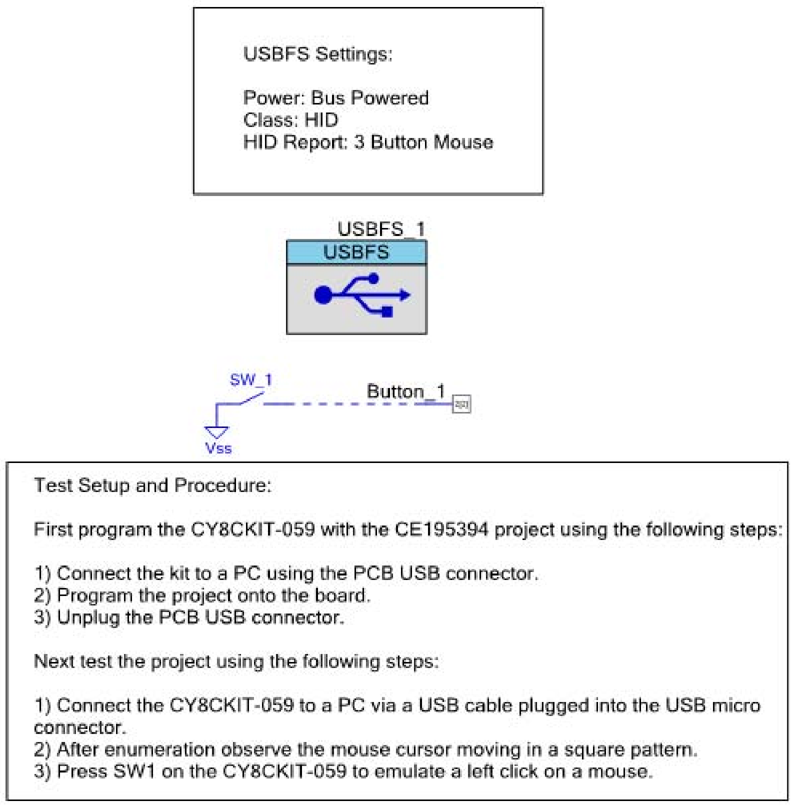


For detailed operation, refer to the *CE195277_ADC_and_UART.pdf* from PSoC Creator.

5.4 CE195394_HID_Mouse

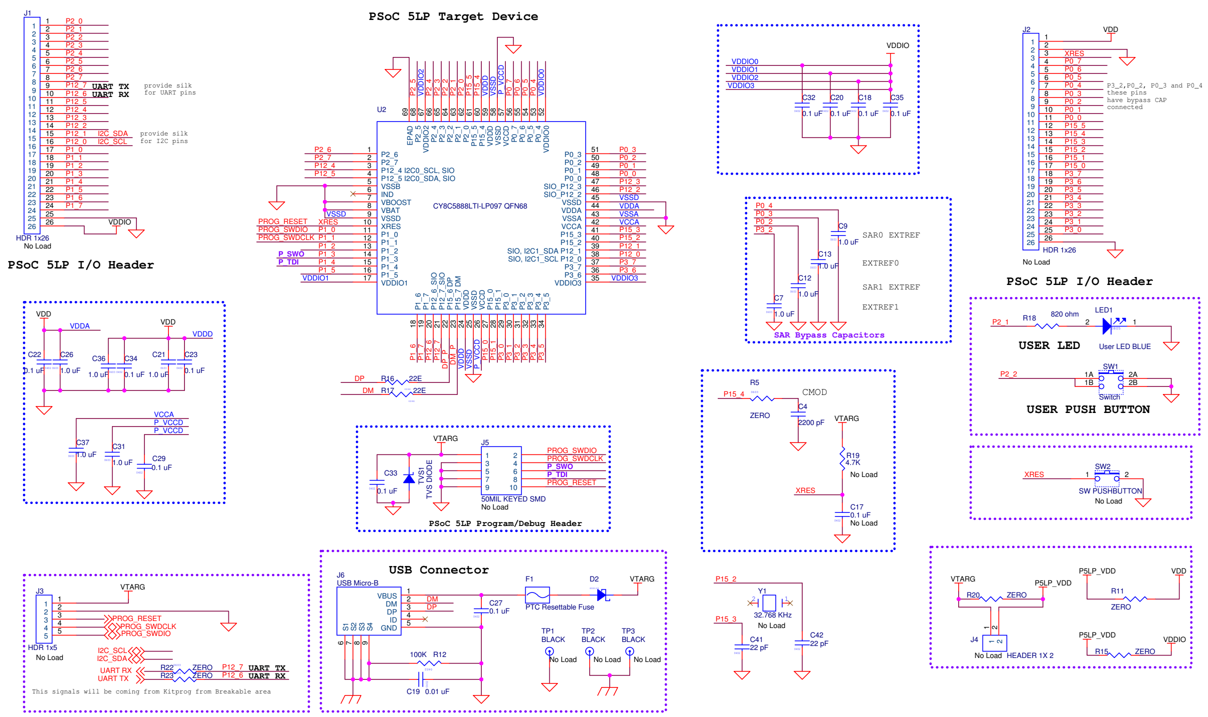
This code example demonstrates the use of the USBFS component to implement a HID mouse. Using the standard HID mouse descriptor, the PSoC enumerates as a mouse on the PC. Once the enumeration is complete the PSoC sends data about the relative movement of the mouse to the PC. A single button is also implemented in the project to emulate the left button, or button 1, on a standard mouse. You can hold down the button on the kit and watch the cursor highlight text or select items on a desktop while it draws the box.

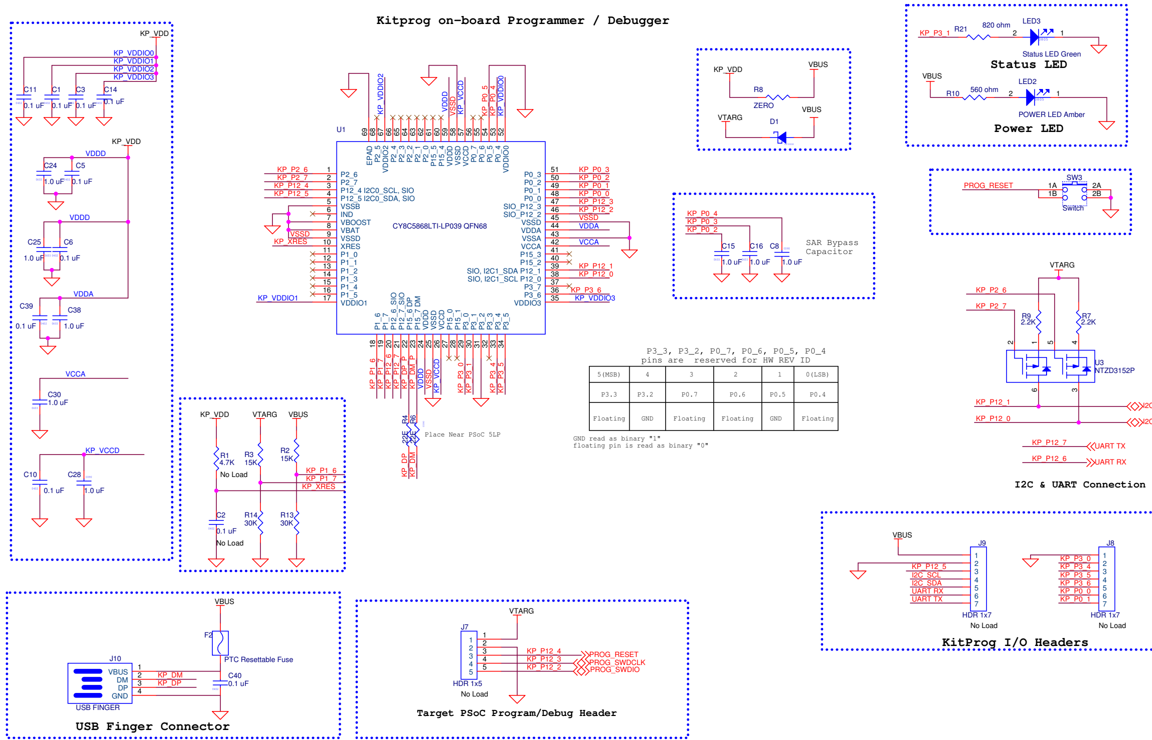
Figure 5-10. CE195394_HID_Mouse



For detailed operation, refer to the *CE195394_HID_Mouse.pdf* from PSoC Creator.

A.1 PSoC 5LP Prototyping Kit Schematics

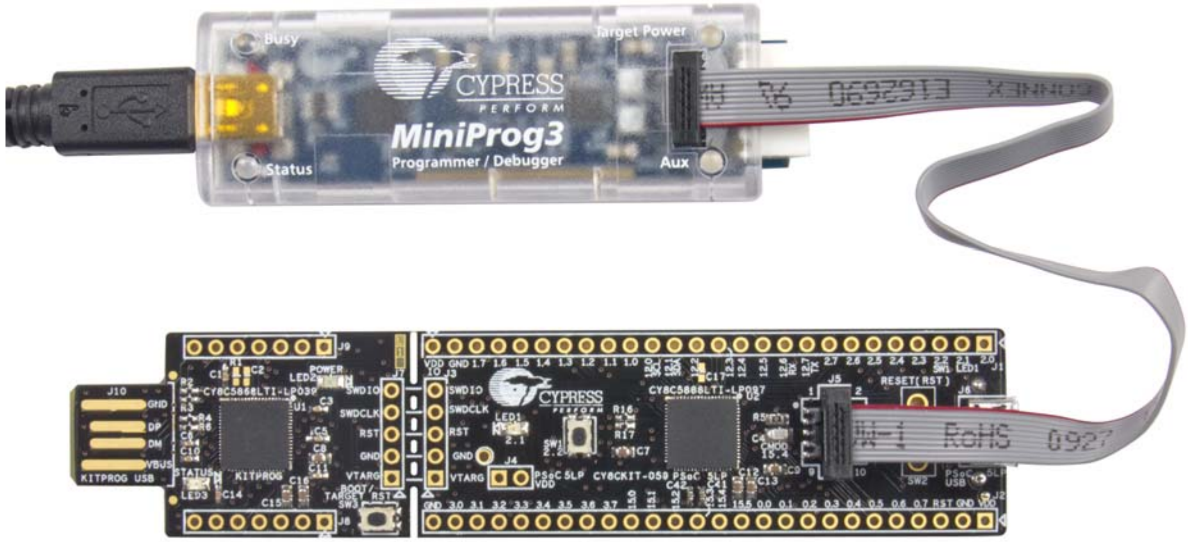



Kitprog on-board Programmer / Debugger
CY8C5868LTI-LP039 QFN68
Status LED
Power LED
SAR Bypass Capacitor
P3_3, P3_2, P0_7, P0_6, P0_5, P0_4 pins are reserved for HW REV ID
GND read as binary "1"
floating pin is read as binary "0"
Place Near PSoC 5LP
I2C & UART Connection
KitProg I/O Headers
USB Finger Connector
Target PSoC Program/Debug Header

A.2 Programming PSoC 5LP Prototyping Kit Using MiniProg3/KitProg

The target board has a provision to program the PSoC 5LP device using MiniProg3 or an external KitProg via the 5-pin SWD header or the 10-pin JTAG header. To do this, connect wires or a 5-pin 100-mil spaced header to J3 or a 10-pin JTAG header to J5 on the target board. The PSoC 5LP Prototyping Kit supports both power cycle and reset programming modes.

Figure A-1. Connecting CY8CKIT-059 to MiniProg3



Note: CY8CKIT-002 MiniProg3 is not part of the PSoC 5LP Prototyping Kit contents and can be purchased from the Cypress Online Store.

A.3 Bill of Materials

Item	Qty	Reference	Value	Description	Mfr Name	Mfr Part Number
1	1	N/A	N/A	PCB, 108.89mm × 24.13mm, High Tg, ENIG finish, 2 layer, Color = BLACK, Silk = WHITE	Cypress Semiconductor	600-60178-01
2	19	C1, C3, C5, C6, C10, C11, C14, C18, C20, C22, C23, C27, C29, C32, C33, C34, C35, C39, C40	0.1 uF	CAP .1UF 16V CERAMIC Y5V 0402	AVX Corporation	0402YG104ZAT2A
3	1	C4	2200 pF	CAP CER 2200PF 50V 5% NP0 0805	Murata Electronics	GRM2165C1H222JA01D
4	17	C7, C8, C9, C12, C13, C15, C16, C21, C24, C25, C26, C28, C30, C31, C36, C37, C38	1.0 uF	CAP CERAMIC 1.0UF 25V X5R 0603 10%	Taiyo Yuden	TMK107BJ105KA-T
5	1	C19	0.01 uF	CAP 10000PF 16V CERAMIC 0402 SMD	TDK Corporation	C1005X7R1C103K050BA
6	2	C41, C42	22 pF	CAP CER 22PF 50V 2% C0G 0402	TDK Corporation	C1005C0G1H220G050BA
7	2	D1, D2	MBR0520L	DIODE, SCHOTTKY, 20V, 0.5A, 400mW, SOD-123	Fairchild Semiconductor	MBR0520L
8	2	F1, F2	PTC Resettable Fuse	FUSE, PTC Resettable, 0.50A, 16V, 1210, SMD	Bel Fuse Inc	0ZCH0050FF2G
9	1	J6	USB Micro-B	CONN RCPT STD MICRO USB TYPE B	FCI	10103594-0001LF
10	1	LED1	User LED BLUE	LED, BLUE, CLEAR, 0805, SMD	Lite-On Inc	LTST-C170TBKT
11	1	LED2	POWER LED Amber	LED 595NM AMB DIFF 0805 SMD	Avago Technologies US Inc.	HSMA-C170
12	1	LED3	Status LED Green	LED GREEN CLEAR 0805 SMD	Chicago Miniature/ Visual Communications Company-VCC	CMD17-21VGC/TR8
13	2	R2, R3	15K	RES SMD 15K OHM 5% 1/10W 0402	Panasonic - ECG	ERJ-2GEJ153X
14	4	R4, R6, R16, R17	22E	RES, 22 OHM, 1%, 100PPM, 1/16W, 0402	Panasonic - ECG	ERJ-2RKF22R0X

Item	Qty	Reference	Value	Description	Mfr Name	Mfr Part Number
15	3	R5, R22, R23	ZERO	RES SMD 0.0 OHM JUMPER 06O3 1/10W	Panasonic - ECG	ERJ-3GEY0R00V
16	2	R7, R9	2.2K	RES 2.2K OHM 1/10W 5% 0603 SMD	Panasonic - ECG	ERJ-3GEYJ222V
17	1	R10	560 ohm	RES, 560 OHM, 5%, 200PPM, 1/10W, 0603, SMD	Panasonic - ECG	ERJ-3GEYJ561V
18	1	R12	100K	RES 100K OHM 1/10W 5% 0402 SMD	Panasonic - ECG	ERJ-2GEJ104X
19	2	R13, R14	30K	RES SMD 30K OHM 5% 1/10W 0402	Panasonic - ECG	ERJ-2GEJ303X
20	4	R8, R11, R15, R20	ZERO	RES SMD 0.0 OHM JUMPER 1/8W 0805	Panasonic - ECG	ERJ-6GEY0R00V
21	2	R18, R21	820 ohm	RES, 820 OHM, 5%, 1/10W, 0603	Panasonic - ECG	ERJ-3GEYJ821V
22	2	SW1, SW3	Switch	SW, TACTILE SWITCH, SPST-NO, 0.05A, 32V	C&K Components	KMR221GLFS
23	1	TVS1	TVS DIODE	DIODE, TVS, 5V, 350W, SOD-323	Semtech	SD05.TCT
24	1	U1	CY8C5868LTI-LP039 QFN68	PSoC 5LP CYC58LP, 67 MHz	Cypress Semiconductor	CY8C5868LTI-LP039
25	1	U2	CY8C5888LTI-LP097 QFN68	PSoC 5LP CYC58LP, 80 MHz	Cypress Semiconductor	CY8C5888LTI-LP097
26	1	U3	NTZD3152P	FET DUAL P-CH 20V 430mA SOT-563	ON Semiconductor	NTZD3152PT1G
No Load Components						
1	2	C2, C17	0.1 uF	CAP .1UF 16V CERAMIC Y5V 0402	AVX Corporation	0402YG104ZAT2A
2	2	J1, J2	HDR 1x26	CONN HDR BRKWAY 26POS VERT 2.54mm,15AU, TH	TE Connectivity	2-104427-4
3	2	J3, J7	HDR 1x5	CONN HEADER 5POS .100 VERT TIN	Molex	22-23-2051
4	1	J4	HDR 1x2	CONN HEADR BRKWAY .100 02POS STR	TE Connectivity	9-146280-0-02
5	1	J5	50MIL KEYED SMD	CONN, HEADER, MALE, 1.27mm, 10POS, GOLD, SMD	Samtec Inc	FTSH-105-01-L-DV-K
6	2	J8, J9	HDR 1x7	CONN HEADER FEMALE 7POS .1" GOLD	Sullins Connector Solutions	PPPC071LFBN-RC
7	2	R1, R19	4.7K	RES SMD 4.7K OHM 5% 1/10W 0402	Panasonic - ECG	ERJ-2GEJ472X
8	1	SW2	SW PUSH-BUTTON	SWITCH TACTILE SPST-NO 0.05A 12V	C&K Components	PTS635SL50 LFS

Item	Qty	Reference	Value	Description	Mfr Name	Mfr Part Number
9	3	TP1, TP2, TP3	BLACK	TP, TEST POINT, 0.040"D, BLACK, TH	Keystone Electronics	5000
10	1	Y1	BLACK	CRYSTAL 32.768KHZ 12.5PF THRU	Citizen Finetech Miyota	CFS308-32.768KDZF-UB
Label						
38	1	N/A		LBL, PCA Label, Vendor Code, Datecode, Serial Number 121-60210-01 REV 01 (YYWWVVXXXXX)	Cypress Semiconductor	
39	1	N/A		LBL, PCBA Anti-Static Warning, 10mm × 10mm	Cypress Semiconductor	

Revision History

CY8CKIT-059 PSoC® 5LP Prototyping Kit Guide Revision History

Document Title: CY8CKIT-059 PSoC® 5LP Prototyping Kit Guide Document Number: 001-96498				
Revision	**ECN**	**Issue Date**	**Origin of Change**	**Description of Change**
**	4668422	02/23/2015	PMAD	New kit guide
*A	4710488	04/02/2015	PMAD	Updated Introduction chapter on page 7: Updated description. Updated "PSoC Creator" on page 8: Updated "PSoC Creator Code Examples" on page 9: Updated description. Added "Kit Code Examples" on page 10. Updated Software Installation chapter on page 13: Updated "Before You Begin" on page 13: Updated description. Updated "Install Software" on page 13: Updated description. Updated Kit Operation chapter on page 16: Updated "Theory of Operation" on page 16: Updated description. Updated Figure 3-1. Updated "KitProg" on page 17: Updated description. Removed "KitProg USB Connection". Updated "Programming and Debugging the PSoC 5LP Target Device" on page 17: Updated "Programming using PSoC Creator" on page 17: Updated description. Updated "Programming using PSoC Programmer" on page 19: Updated description. Updated "USB-UART Bridge" on page 19: Updated description. Removed table "Specifications Supported by USB-UART Bridge". Updated "USB-I2C Bridge" on page 19: Updated description. Removed figure "KitProg USB-I2C Connected in Bridge Control Panel". Updated "Updating KitProg Firmware" on page 19: Updated description. Removed figure "KitProg Firmware Update Warning". Removed figure "Upgrade Firmware Message in PSoC Programmer". Removed figure "Firmware Updated in PSoC Programmer".

CY8CKIT-059 PSoC® 5LP Prototyping Kit Guide Revision History *(continued)*

Document Title: CY8CKIT-059 PSoC® 5LP Prototyping Kit Guide Document Number: 001-96498				
Revision	**ECN**	**Issue Date**	**Origin of Change**	**Description of Change**
*A (cont.)	4710488	04/02/2015	PMAD	Updated Hardware chapter on page 20: Updated “Board Details” on page 20: Updated Figure 4-1. Updated “Hardware Details” on page 21: Updated “Power Supply System” on page 23: Updated description. Updated “Header Connections” on page 24: Updated “Functionality of the J1 and J2 Headers (Target Board)” on page 24: Updated Table 4-2. Updated “User and Passive Inputs” on page 28: Updated “Push Button” on page 28: Updated Figure 4-8. Removed figure “Push Button Schematic”. Updated Figure 4-14. Updated “LEDs” on page 29: Updated description. Updated “System Capacitors” on page 30: Updated description. Updated Figure 4-14. Updated Code Examples chapter on page 31: Updated “CE195352_Blinking_LED” on page 35: Updated Figure 5-7. Updated “CE195277_ADC_and_UART” on page 37: Updated description. Updated Figure 5-9. Updated “CE195394_HID_Mouse” on page 38: Updated description. Updated Figure 5-10. Updated Appendix chapter on page 39: Updated “Programming PSoC 5LP Prototyping Kit Using MiniProg3/KitProg” on page 41: Updated Figure A-1. Updated “Bill of Materials” on page 42: Added Item 10 under “No Load Components”. Added “Label” and added corresponding items under the same.
*B	4866765	07/30/2015	VRNK	Updated Hardware chapter on page 20: Updated “Hardware Details” on page 21: Updated “Header Connections” on page 24: Updated “Functionality of the J1 and J2 Headers (Target Board)” on page 24: Updated Table 4-2: Added “/BYPASS CAP” in the “Description” column corresponding to pins P0.4 and P3.2. Remove “/BYPASS CAP” in the “Description” column corresponding to pin P3.3.
*C	4891134	08/20/2015	SHIB	Updated Appendix chapter on page 39: Updated “Bill of Materials” on page 42: Updated Item 10 under “No Load Components”.
*D	5740232	05/17/2017	AESATMP8	Updated logo and Copyright.

CY8CKIT-059 PSoC® 5LP Prototyping Kit Guide Revision History *(continued)*

Document Title: CY8CKIT-059 PSoC® 5LP Prototyping Kit Guide Document Number: 001-96498				
Revision	**ECN**	**Issue Date**	**Origin of Change**	**Description of Change**
*E	6041084	01/22/2018	SAGA / GRSK	Updated Introduction chapter on page 7: Updated "PSoC Creator" on page 8: Updated "PSoC Creator Code Examples" on page 9: Updated Figure 1-3. Updated "Getting Started" on page 11: Updated description. Updated "Additional Learning Resources" on page 11: Updated hyperlinks. Updated Software Installation chapter on page 13: Updated "Install Software" on page 13: Updated description. Updated Figure 2-1, and Figure 2-2. Updated Kit Operation chapter on page 16: Updated "Theory of Operation" on page 16: Updated description. Updated "Programming and Debugging the PSoC 5LP Target Device" on page 17: Updated "Debugging using PSoC Creator" on page 19: Updated description. Updated Hardware chapter on page 20: Updated "Hardware Details" on page 21: Updated "Header Connections" on page 24: Updated "Functionality of J7 and J3 Headers (PSoC 5LP to KitProg)" on page 26: Updated Table 4-3, and Table 4-4. Updated "Functionality of J8 and J9 Headers (KitProg)" on page 27: Updated Table 4-5, and Table 4-6. Updated Code Examples chapter on page 31: Updated "Using the Kit Code Examples" on page 31: Updated description. Updated Figure 5-1, Figure 5-2, Figure 5-3, Figure 5-4, and Figure 5-6. Updated "CE195352_Blinking_LED" on page 35: Updated description. Updated Figure 5-8. Updated "CE195277_ADC_and_UART" on page 37: Updated description. Updated Figure 5-9. Updated "CE195394_HID_Mouse" on page 38: Updated description. Updated Figure 5-10. Updated Appendix chapter on page 39: Updated "PSoC 5LP Prototyping Kit Schematics" on page 39: Updated all figures. Updated "Bill of Materials" on page 42: Updated entire table. Completing Sunset Review.
*F	6077263	02/21/2018	SAGA	Updated Software Installation chapter on page 13: Updated "Install Software" on page 13: Updated description. Updated Kit Operation chapter on page 16: Updated "Programming and Debugging the PSoC 5LP Target Device" on page 17: Updated "Programming using PSoC Programmer" on page 19: Updated description.

CY8CKIT-059 PSoC® 5LP Prototyping Kit Guide Revision History *(continued)*

Document Title: CY8CKIT-059 PSoC® 5LP Prototyping Kit Guide **Document Number: 001-96498**				
Revision	**ECN**	**Issue Date**	**Origin of Change**	**Description of Change**
*G	6095702	03/12/2018	SAGA	Updated the code example title in Section 5.2. Updated Figure 5.1 and Figure 5-8.

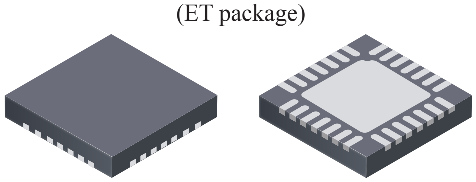
DMOS Microstepping Driver with Translator And Overcurrent Protection

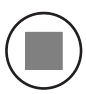
Features and Benefits

- Low $R_{DS(ON)}$ outputs
- Automatic current decay mode detection/selection
- Mixed and Slow current decay modes
- Synchronous rectification for low power dissipation
- Internal UVLO
- Crossover-current protection
- 3.3 and 5 V compatible logic supply
- Thermal shutdown circuitry
- Short-to-ground protection
- Shorted load protection
- Five selectable step modes: full, $^1/_2$, $^1/_4$, $^1/_8$, and $^1/_{16}$

Package:

28-contact QFN
with exposed thermal pad
5 mm × 5 mm × 0.90 mm
(ET package)





Approximate size

Description

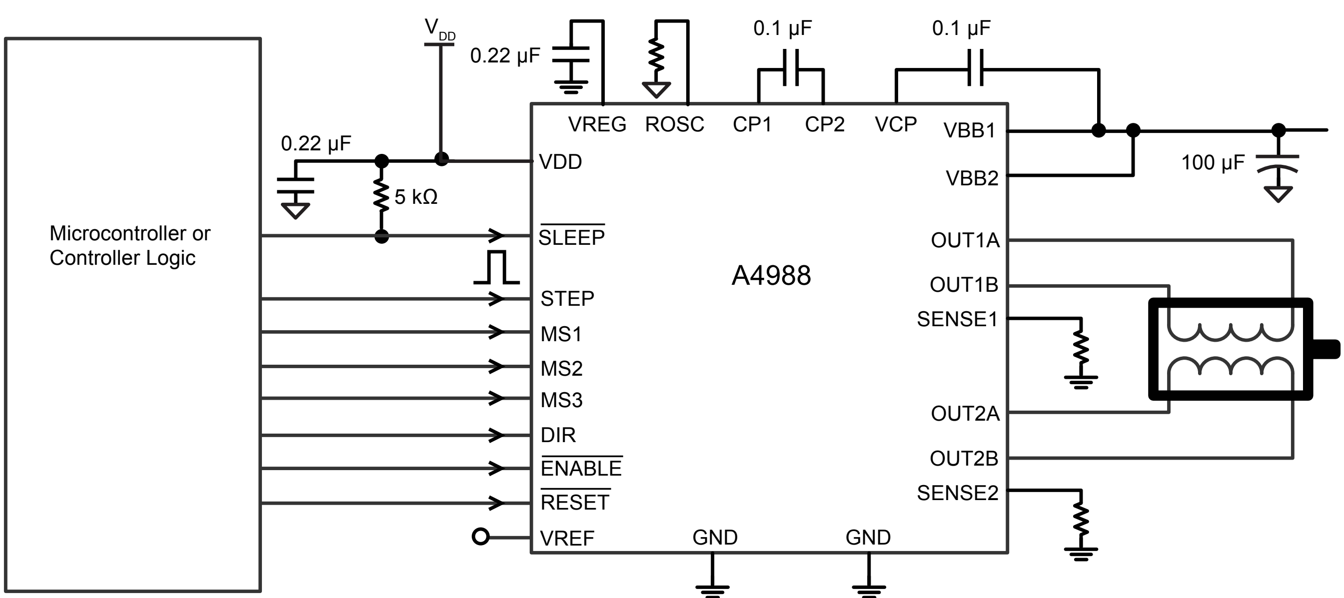
The A4988 is a complete microstepping motor driver with built-in translator for easy operation. It is designed to operate bipolar stepper motors in full-, half-, quarter-, eighth-, and sixteenth-step modes, with an output drive capacity of up to 35 V and ±2 A. The A4988 includes a fixed off-time current regulator which has the ability to operate in Slow or Mixed decay modes.

The translator is the key to the easy implementation of the A4988. Simply inputting one pulse on the STEP input drives the motor one microstep. There are no phase sequence tables, high frequency control lines, or complex interfaces to program. The A4988 interface is an ideal fit for applications where a complex microprocessor is unavailable or is overburdened.

During stepping operation, the chopping control in the A4988 automatically selects the current decay mode, Slow or Mixed. In Mixed decay mode, the device is set initially to a fast decay for a proportion of the fixed off-time, then to a slow decay for the remainder of the off-time. Mixed decay current control results in reduced audible motor noise, increased step accuracy, and reduced power dissipation.

Continued on the next page…

Typical Application Diagram



Description (continued)

Internal synchronous rectification control circuitry is provided to improve power dissipation during PWM operation. Internal circuit protection includes: thermal shutdown with hysteresis, undervoltage lockout (UVLO), and crossover-current protection. Special power-on sequencing is not required.

The A4988 is supplied in a surface mount QFN package (ES), 5 mm × 5 mm, with a nominal overall package height of 0.90 mm and an exposed pad for enhanced thermal dissipation. It is lead (Pb) free (suffix –T), with 100% matte tin plated leadframes.

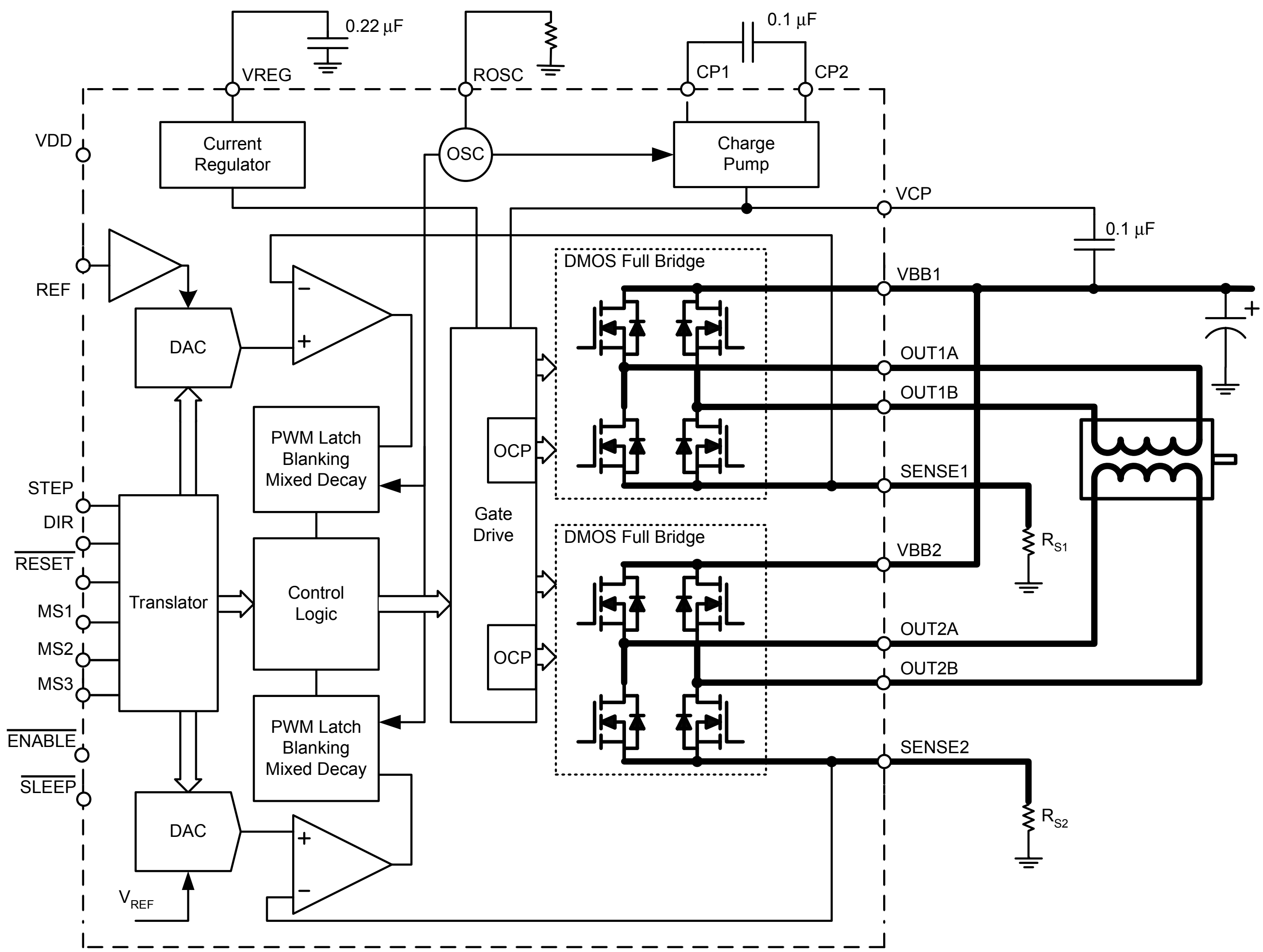
Selection Guide

Part Number	Package	Packing
A4988SETTR-T	28-contact QFN with exposed thermal pad	1500 pieces per 7-in. reel

Absolute Maximum Ratings

Characteristic	Symbol	Notes	Rating	Units
Load Supply Voltage	V_{BB}		35	V
Output Current	I_{OUT}		±2	A
Logic Input Voltage	V_{IN}		–0.3 to 5.5	V
Logic Supply Voltage	V_{DD}		–0.3 to 5.5	V
Motor Outputs Voltage			–2.0 to 37	V
Sense Voltage	V_{SENSE}		–0.5 to 0.5	V
Reference Voltage	V_{REF}		5.5	V
Operating Ambient Temperature	T_A	Range S	–20 to 85	ºC
Maximum Junction	$T_J(max)$		150	ºC
Storage Temperature	T_{stg}		–55 to 150	ºC

Functional Block Diagram



ELECTRICAL CHARACTERISTICS[1] at T_A = 25°C, V_{BB} = 35 V (unless otherwise noted)

Characteristics	Symbol	Test Conditions	Min.	Typ.[2]	Max.	Units
Output Drivers						
Load Supply Voltage Range	V_{BB}	Operating	8	–	35	V
Logic Supply Voltage Range	V_{DD}	Operating	3.0	–	5.5	V
Output On Resistance	R_{DSON}	Source Driver, I_{OUT} = –1.5 A	–	320	430	mΩ
		Sink Driver, I_{OUT} = 1.5 A	–	320	430	mΩ
Body Diode Forward Voltage	V_F	Source Diode, I_F = –1.5 A	–	–	1.2	V
		Sink Diode, I_F = 1.5 A	–	–	1.2	V
Motor Supply Current	I_{BB}	f_{PWM} < 50 kHz	–	–	4	mA
		Operating, outputs disabled	–	–	2	mA
Logic Supply Current	I_{DD}	f_{PWM} < 50 kHz	–	–	8	mA
		Outputs off	–	–	5	mA
Control Logic						
Logic Input Voltage	$V_{IN(1)}$		V_{DD}×0.7	–	–	V
	$V_{IN(0)}$		–	–	V_{DD}×0.3	V
Logic Input Current	$I_{IN(1)}$	V_{IN} = V_{DD}×0.7	–20	<1.0	20	µA
	$I_{IN(0)}$	V_{IN} = V_{DD}×0.3	–20	<1.0	20	µA
Microstep Select	R_{MS1}	MS1 pin	–	100	–	kΩ
	R_{MS2}	MS2 pin	–	50	–	kΩ
	R_{MS3}	MS3 pin	–	100	–	kΩ
Logic Input Hysteresis	$V_{HYS(IN)}$	As a % of V_{DD}	5	11	19	%
Blank Time	t_{BLANK}		0.7	1	1.3	µs
Fixed Off-Time	t_{OFF}	OSC = VDD or GND	20	30	40	µs
		R_{OSC} = 25 kΩ	23	30	37	µs
Reference Input Voltage Range	V_{REF}		0	–	4	V
Reference Input Current	I_{REF}		–3	0	3	µA
Current Trip-Level Error[3]	err_I	V_{REF} = 2 V, $\%I_{TripMAX}$ = 38.27%	–	–	±15	%
		V_{REF} = 2 V, $\%I_{TripMAX}$ = 70.71%	–	–	±5	%
		V_{REF} = 2 V, $\%I_{TripMAX}$ = 100.00%	–	–	±5	%
Crossover Dead Time	t_{DT}		100	475	800	ns
Protection						
Overcurrent Protection Threshold[4]	I_{OCPST}		2.1	–	–	A
Thermal Shutdown Temperature	T_{TSD}		–	165	–	°C
Thermal Shutdown Hysteresis	T_{TSDHYS}		–	15	–	°C
VDD Undervoltage Lockout	V_{DDUVLO}	V_{DD} rising	2.7	2.8	2.9	V
VDD Undervoltage Hysteresis	$V_{DDUVLOHYS}$		–	90	–	mV

[1]For input and output current specifications, negative current is defined as coming out of (sourcing) the specified device pin.

[2]Typical data are for initial design estimations only, and assume optimum manufacturing and application conditions. Performance may vary for individual units, within the specified maximum and minimum limits.

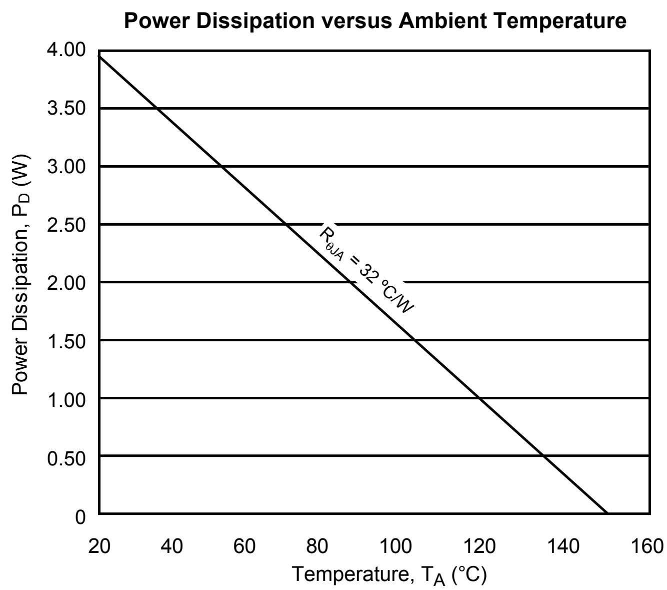
[3]$V_{ERR} = [(V_{REF}/8) – V_{SENSE}] / (V_{REF}/8)$.

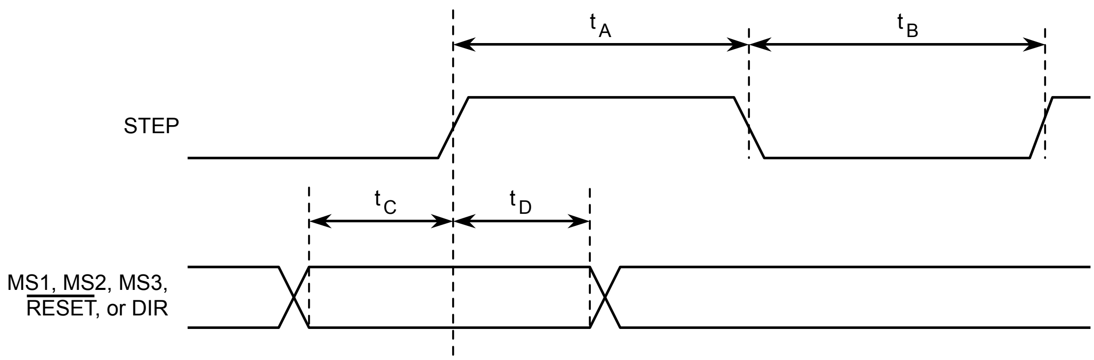
[4]Overcurrent protection (OCP) is tested at T_A = 25°C in a restricted range and guaranteed by characterization.

THERMAL CHARACTERISTICS

Characteristic	Symbol	Test Conditions*	Value	Units
Package Thermal Resistance	$R_{\theta JA}$	Four-layer PCB, based on JEDEC standard	32	ºC/W

*Additional thermal information available on Allegro Web site.





Time Duration	Symbol	Typ.	Unit
STEP minimum, HIGH pulse width	t_A	1	μs
STEP minimum, LOW pulse width	t_B	1	μs
Setup time, input change to STEP	t_C	200	ns
Hold time, input change to STEP	t_D	200	ns

Figure 1: Logic Interface Timing Diagram

Table 1: Microstepping Resolution Truth Table

MS1	MS2	MS3	Microstep Resolution	Excitation Mode
L	L	L	Full Step	2 Phase
H	L	L	Half Step	1-2 Phase
L	H	L	Quarter Step	W1-2 Phase
H	H	L	Eighth Step	2W1-2 Phase
H	H	H	Sixteenth Step	4W1-2 Phase

Functional Description

Device Operation. The A4988 is a complete microstepping motor driver with a built-in translator for easy operation with minimal control lines. It is designed to operate bipolar stepper motors in full-, half-, quarter-, eighth, and sixteenth-step modes. The currents in each of the two output full-bridges and all of the N-channel DMOS FETs are regulated with fixed off-time PWM (pulse width modulated) control circuitry. At each step, the current for each full-bridge is set by the value of its external current-sense resistor (R_{S1} and R_{S2}), a reference voltage (V_{REF}), and the output voltage of its DAC (which in turn is controlled by the output of the translator).

At power-on or reset, the translator sets the DACs and the phase current polarity to the initial Home state (shown in Figures 9 through 13), and the current regulator to Mixed Decay Mode for both phases. When a step command signal occurs on the STEP input, the translator automatically sequences the DACs to the next level and current polarity. (See Table 2 for the current-level sequence.) The microstep resolution is set by the combined effect of the MSx inputs, as shown in Table 1.

When stepping, if the new output levels of the DACs are lower than their previous output levels, then the decay mode for the active full-bridge is set to Mixed. If the new output levels of the DACs are higher than or equal to their previous levels, then the decay mode for the active full-bridge is set to Slow. This automatic current decay selection improves microstepping performance by reducing the distortion of the current waveform that results from the back EMF of the motor.

Microstep Select (MSx). The microstep resolution is set by the voltage on logic inputs MSx, as shown in Table 1. The MS1 and MS3 pins have a 100 kΩ pull-down resistance, and the MS2 pin has a 50 kΩ pull-down resistance. When changing the step mode the change does not take effect until the next STEP rising edge.

If the step mode is changed without a translator reset, and absolute position must be maintained, it is important to change the step mode at a step position that is common to both step modes in order to avoid missing steps. When the device is powered down, or reset due to TSD or an over current event the translator is set to the home position which is by default common to all step modes.

Mixed Decay Operation. The bridge operates in Mixed decay mode, at power-on and reset, and during normal running according to the ROSC configuration and the step sequence, as shown in Figures 9 through 13. During Mixed decay, when the trip point is reached, the A4988 initially goes into a fast decay mode for 31.25% of the off-time, t_{OFF}. After that, it switches to Slow decay mode for the remainder of t_{OFF}. A timing diagram for this feature appears on the next page.

Typically, mixed decay is only necessary when the current in the winding is going from a higher value to a lower value as determined by the state of the translator. For most loads automatically-selected mixed decay is convenient because it minimizes ripple when the current is rising and prevents missed steps when the current is falling. For some applications where microstepping at very low speeds is necessary, the lack of back EMF in the winding causes the current to increase in the load quickly, resulting in missed steps. This is shown in Figure 2. By pulling the ROSC pin to ground, mixed decay is set to be active 100% of the time, for both rising and falling currents, and prevents missed steps as shown in Figure 3. If this is not an issue, it is recommended that automatically-selected mixed decay be used, because it will produce reduced ripple currents. Refer to the Fixed Off-Time section for details.

Low Current Microstepping. Intended for applications where the minimum on-time prevents the output current from regulating to the programmed current level at low current steps. To prevent this, the device can be set to operate in Mixed decay mode on both rising and falling portions of the current waveform. This feature is implemented by shorting the ROSC pin to ground. In this state, the off-time is internally set to 30 µs.

Reset Input ($\overline{\text{RESET}}$). The $\overline{\text{RESET}}$ input sets the translator to a predefined Home state (shown in Figures 9 through 13), and turns off all of the FET outputs. All STEP inputs are ignored until the $\overline{\text{RESET}}$ input is set to high.

Step Input (STEP). A low-to-high transition on the STEP

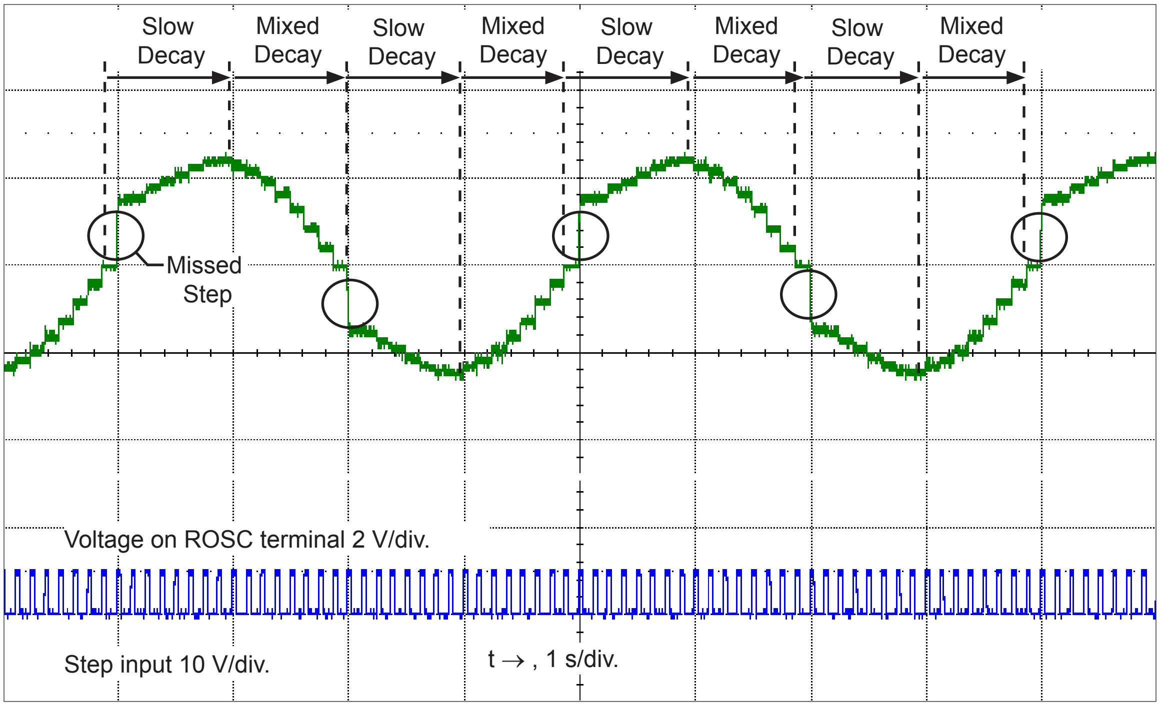


Figure 2: Missed Steps in Low-Speed Microstepping

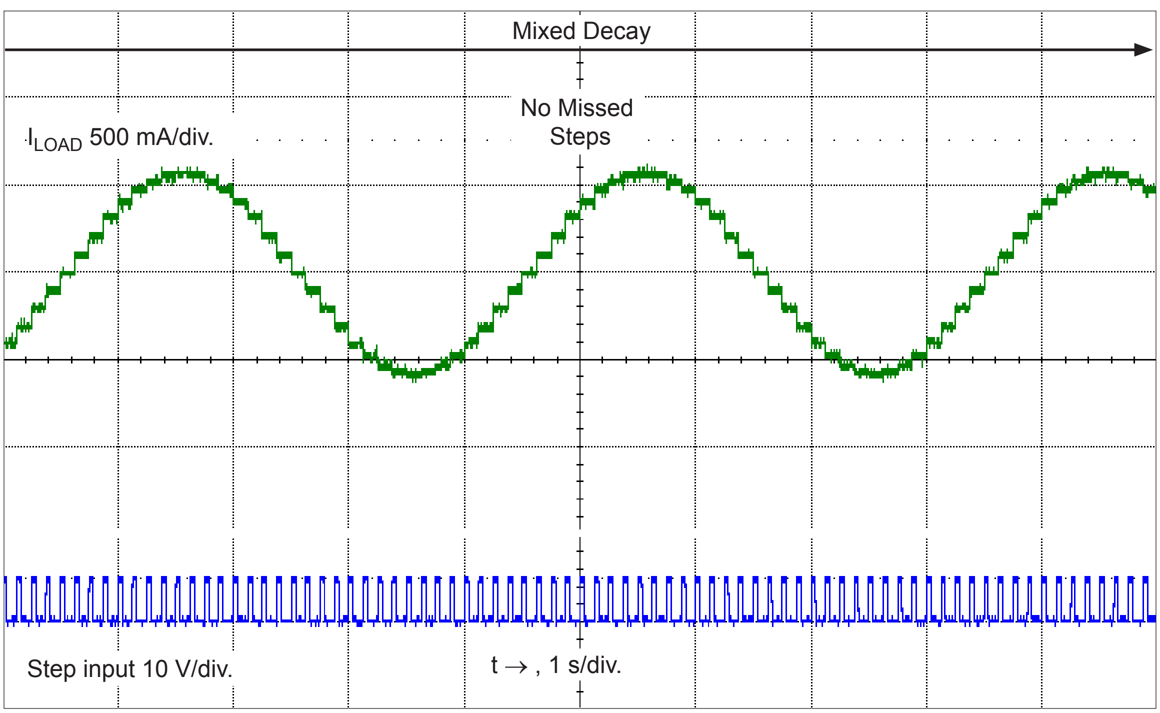


Figure 3: Continuous Stepping Using Automatically-Selected Mixed Stepping (ROSC pin grounded)

input sequences the translator and advances the motor one increment. The translator controls the input to the DACs and the direction of current flow in each winding. The size of the increment is determined by the combined state of the MSx inputs.

Direction Input (DIR). This determines the direction of rotation of the motor. Changes to this input do not take effect until the next STEP rising edge.

Internal PWM Current Control. Each full-bridge is controlled by a fixed off-time PWM current control circuit that limits the load current to a desired value, I_{TRIP}. Initially, a diagonal pair of source and sink FET outputs are enabled and current flows through the motor winding and the current sense resistor, R_{Sx}. When the voltage across R_{Sx} equals the DAC output voltage, the current sense comparator resets the PWM latch. The latch then turns off the appropriate source driver and initiates a fixed off time decay mode

The maximum value of current limiting is set by the selection of R_{Sx} and the voltage at the VREF pin. The transconductance function is approximated by the maximum value of current limiting, $I_{TripMAX}$ (A), which is set by

$$I_{TripMAX} = V_{REF} / (8 \times R_S)$$

where R_S is the resistance of the sense resistor (Ω) and V_{REF} is the input voltage on the REF pin (V).

The DAC output reduces the V_{REF} output to the current sense comparator in precise steps, such that

$$I_{trip} = (\%I_{TripMAX} / 100) \times I_{TripMAX}$$

(See Table 2 for $\%I_{TripMAX}$ at each step.)

It is critical that the maximum rating (0.5 V) on the SENSE1 and SENSE2 pins is not exceeded.

Fixed Off-Time. The internal PWM current control circuitry uses a one-shot circuit to control the duration of time that the DMOS FETs remain off. The off-time, t_{OFF}, is determined by the ROSC terminal. The ROSC terminal has three settings:

- ROSC tied to VDD — off-time internally set to 30 µs, decay mode is automatic Mixed decay except when in full step where decay mode is set to Slow decay
- ROSC tied directly to ground — off-time internally set to 30 µs, current decay is set to Mixed decay for both increasing and decreasing currents for all step modes.
- ROSC through a resistor to ground — off-time is determined by the following formula, the decay mode is automatic Mixed decay for all step modes except full step whic is set to slow decay.

$$t_{OFF} \approx R_{OSC} / 825$$

Where t_{OFF} is in µs.

Blanking. This function blanks the output of the current sense comparators when the outputs are switched by the internal current control circuitry. The comparator outputs are blanked to prevent false overcurrent detection due to reverse recovery currents of the clamp diodes, and switching transients related to the capacitance of the load. The blank time, t_{BLANK} (µs), is approximately

$$t_{BLANK} \approx 1\ \mu s$$

Shorted-Load and Short-to-Ground Protection. If the motor leads are shorted together, or if one of the leads is shorted to ground, the driver will protect itself by sensing the overcurrent event and disabling the driver that is shorted, protecting the device from damage. In the case of a short-to-ground, the device will remain disabled (latched) until the $\overline{\text{SLEEP}}$ input goes high or VDD power is removed. A short-to-ground overcurrent event is shown in Figure 4.

When the two outputs are shorted together, the current path is through the sense resistor. After the blanking time (≈1 µs) expires, the sense resistor voltage is exceeding its trip value, due to the overcurrent condition that exists. This causes the driver to go into a fixed off-time cycle. After the fixed off-time expires the driver turns on again and the process repeats. In this condition the driver is completely protected against overcurrent events, but the short is repetitive with a period equal to the fixed off-time of the driver. This condition is shown in Figure 5.

During a shorted load event it is normal to observe both a positive and negative current spike as shown in Figure 3, due to the direction change implemented by the Mixed decay feature. This is shown in Figure 6. In both instances the overcurrent circuitry is protecting the driver and prevents damage to the device.

Charge Pump (CP1 and CP2). The charge pump is used to generate a gate supply greater than that of VBB for driving the source-side FET gates. A 0.1 µF ceramic capacitor, should be connected between CP1 and CP2. In addition, a 0.1 µF ceramic capacitor is required between VCP and VBB, to act as a reservoir for operating the high-side FET gates.

Capacitor values should be Class 2 dielectric ±15% maximum, or tolerance R, according to EIA (Electronic Industries Alliance) specifications.

V_{REG} (VREG). This internally-generated voltage is used to operate the sink-side FET outputs. The nominal output voltage of the VREG terminal is 7 V. The VREG pin must be decoupled with a 0.22 µF ceramic capacitor to ground. V_{REG} is internally monitored. In the case of a fault condition, the FET outputs of the A4988 are disabled.

Capacitor values should be Class 2 dielectric ±15% maximum, or tolerance R, according to EIA (Electronic Industries Alliance) specifications.

Enable Input ($\overline{\text{ENABLE}}$). This input turns on or off all of the FET outputs. When set to a logic high, the outputs are disabled. When set to a logic low, the internal control enables the outputs as required. The translator inputs STEP, DIR, and MSx, as well as the internal sequencing logic, all remain active, independent of the $\overline{\text{ENABLE}}$ input state.

Shutdown. In the event of a fault, overtemperature (excess T_J) or an undervoltage (on VCP), the FET outputs of the A4988 are disabled until the fault condition is removed. At power-on, the UVLO (undervoltage lockout) circuit disables the FET outputs and resets the translator to the Home state.

Sleep Mode ($\overline{\text{SLEEP}}$). To minimize power consumption when the motor is not in use, this input disables much of the internal circuitry including the output FETs, current regulator, and charge pump. A logic low on the $\overline{\text{SLEEP}}$ pin puts the A4988 into Sleep mode. A logic high allows normal operation, as well as start-up (at which time the A4988 drives the motor to the Home microstep position). When emerging from Sleep mode, in order to allow the charge pump to stabilize, provide a delay of 1 ms before issuing a Step command.

Mixed Decay Operation. The bridge operates in Mixed Decay mode, depending on the step sequence, as shown in Figures 9 through 13. As the trip point is reached, the A4988 initially goes into a fast decay mode for 31.25% of the off-time, t_{OFF}. After that, it switches to Slow Decay mode for the remainder of t_{OFF}. A timing diagram for this feature appears in Figure 7.

Synchronous Rectification. When a PWM-off cycle is triggered by an internal fixed-off time cycle, load current recirculates according to the decay mode selected by the control logic. This synchronous rectification feature turns on the appropriate FETs during current decay, and effectively shorts out the body diodes with the low FET $R_{DS(ON)}$. This reduces power dissipation significantly, and can eliminate the need for external Schottky diodes in many applications. Synchronous rectification turns off when the load current approaches zero (0 A), preventing reversal of the load current.

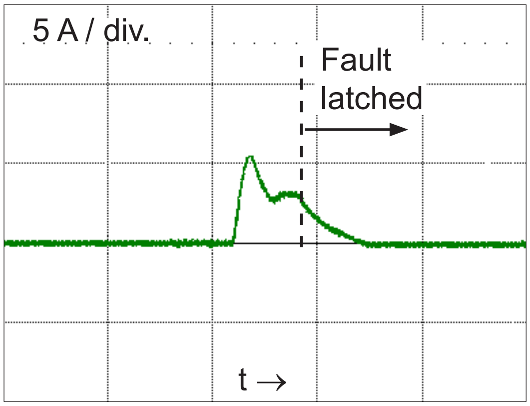


Figure 4: Short-to-Ground Event

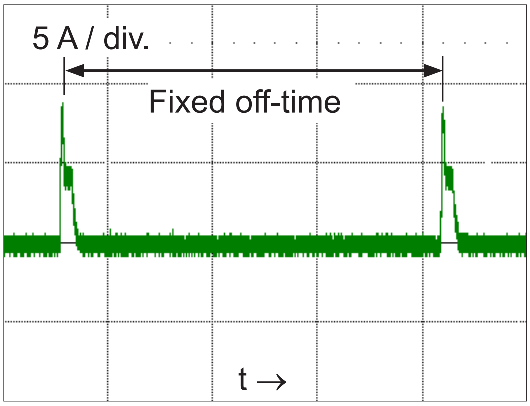


Figure 5. Shorted Load (OUTxA → OUTxB) in Slow Decay Mode

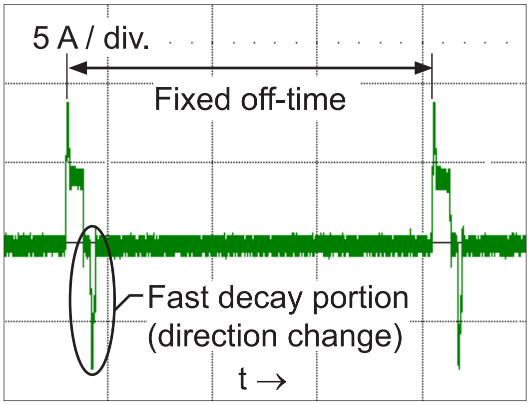
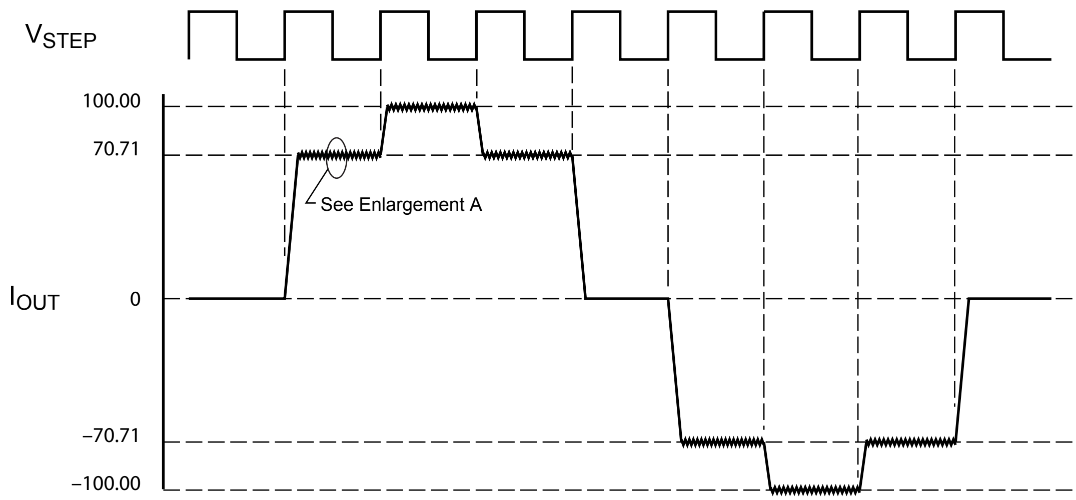
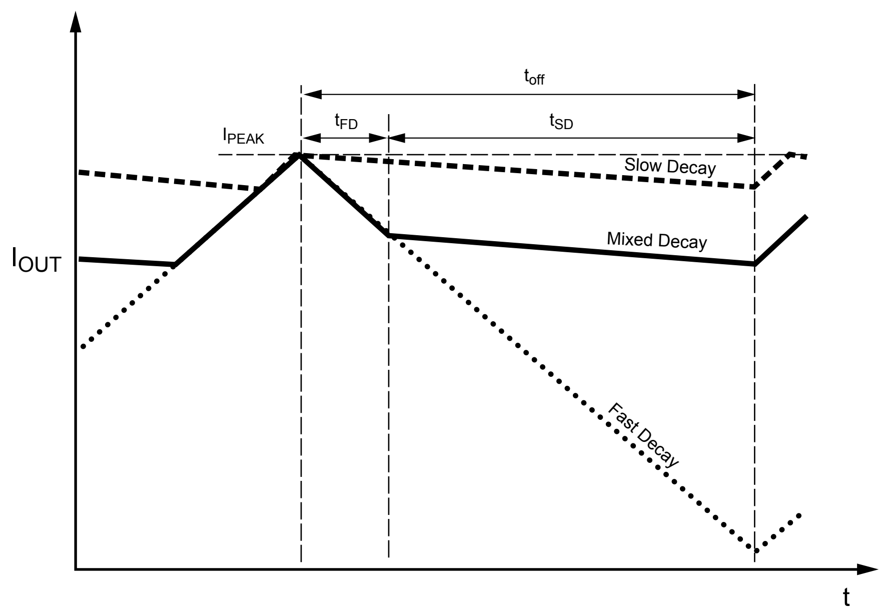


Figure 6: Shorted Load (OUTxA → OUTxB) in Mixed Decay Mode





Symbol	Characteristic
t_{off}	Device fixed off-time
I_{PEAK}	Maximum output current
t_{SD}	Slow decay interval
t_{FD}	Fast decay interval
I_{OUT}	Device output current

Figure 7: Current Decay Modes Timing Chart

Application Layout

Layout. The printed circuit board should use a heavy ground-plane. For optimum electrical and thermal performance, the A4988 must be soldered directly onto the board. Pins 3 and 18 are internally fused, which provides a path for enhanced thermal dissipation. Theses pins should be soldered directly to an exposed surface on the PCB that connects to thermal vias are used to transfer heat to other layers of the PCB.

In order to minimize the effects of ground bounce and offset issues, it is important to have a low impedance single-point ground, known as a *star ground*, located very close to the device. By making the connection between the pad and the ground plane directly under the A4988, that area becomes an ideal location for a star ground point. A low impedance ground will prevent ground bounce during high current operation and ensure that the supply voltage remains stable at the input terminal.

The two input capacitors should be placed in parallel, and as close to the device supply pins as possible. The ceramic capacitor (CIN1) should be closer to the pins than the bulk capacitor (CIN2). This is necessary because the ceramic capacitor will be responsible for delivering the high frequency current components. The sense resistors, RSx, should have a very low impedance path to ground, because they must carry a large current while supporting very accurate voltage measurements by the current sense comparators. Long ground traces will cause additional voltage drops, adversely affecting the ability of the comparators to accurately measure the current in the windings. The SENSEx pins have very short traces to the RSx resistors and very thick, low impedance traces directly to the star ground underneath the device. If possible, there should be no other components on the sense circuits.

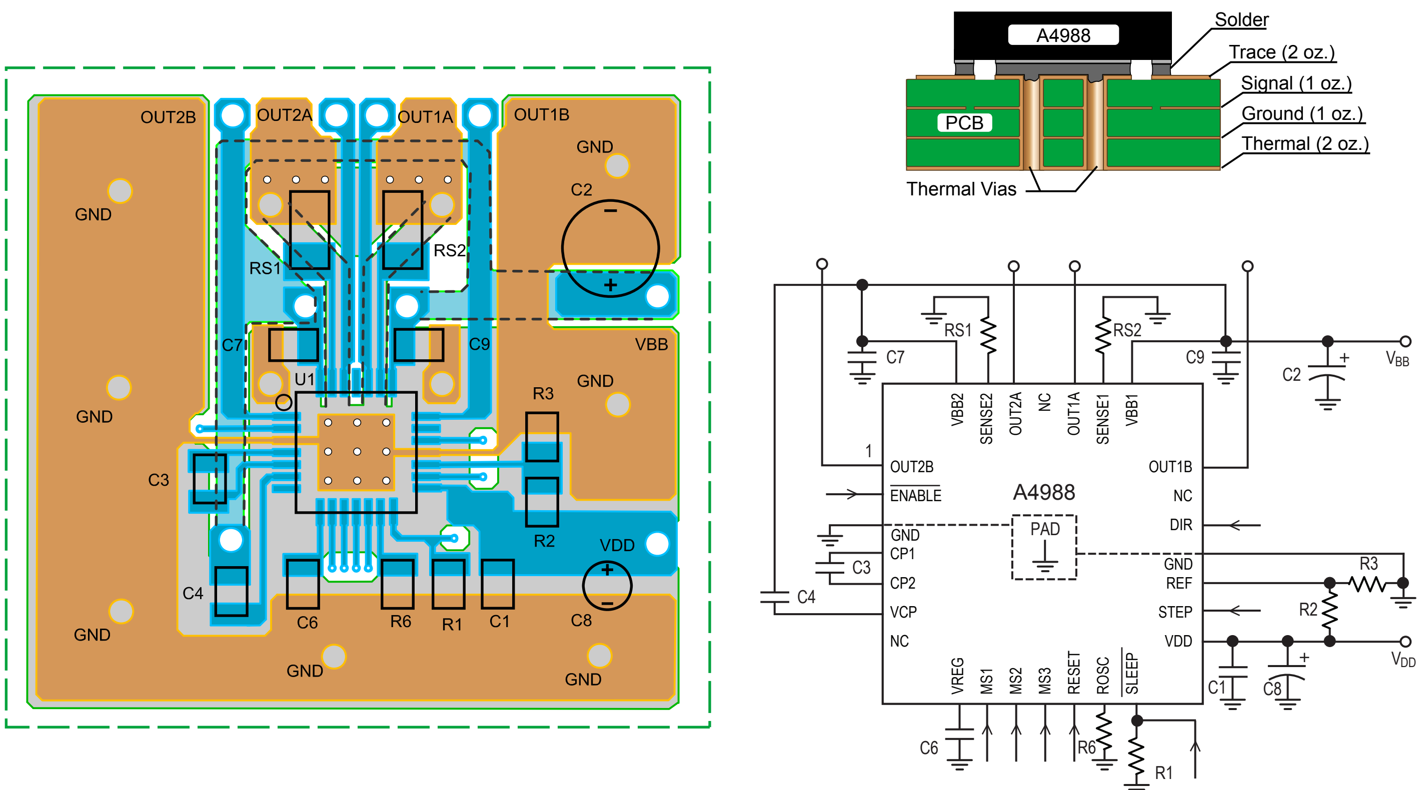
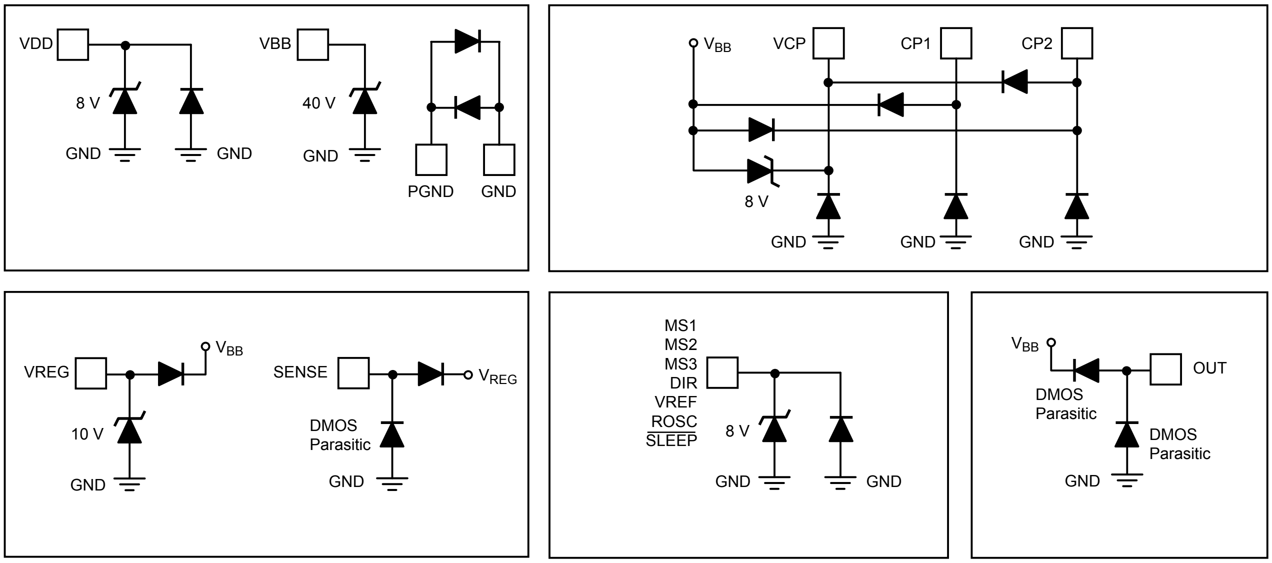


Figure 8: Typical Application and Circuit Layout

Pin Circuit Diagrams



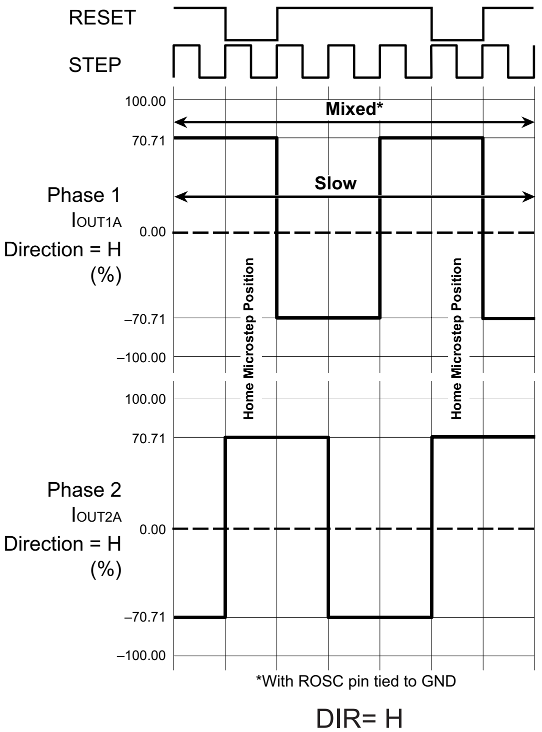


Figure 9: Decay Mode for Full-Step Increments

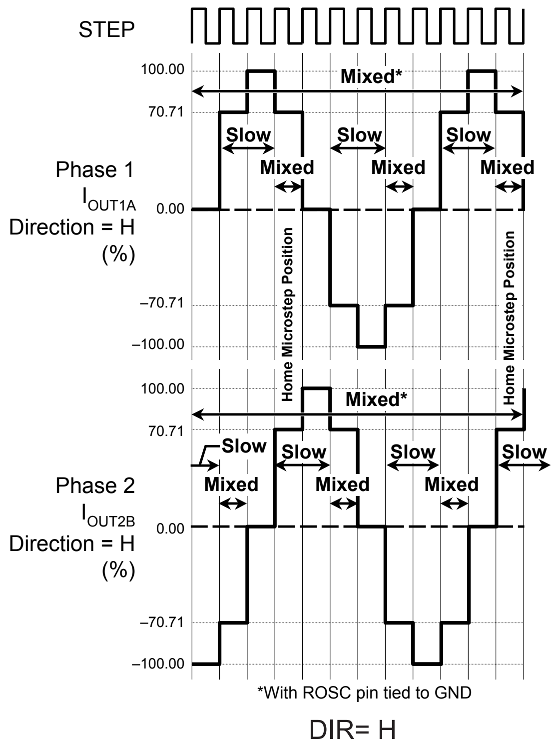


Figure 10: Decay Modes for Half-Step Increments

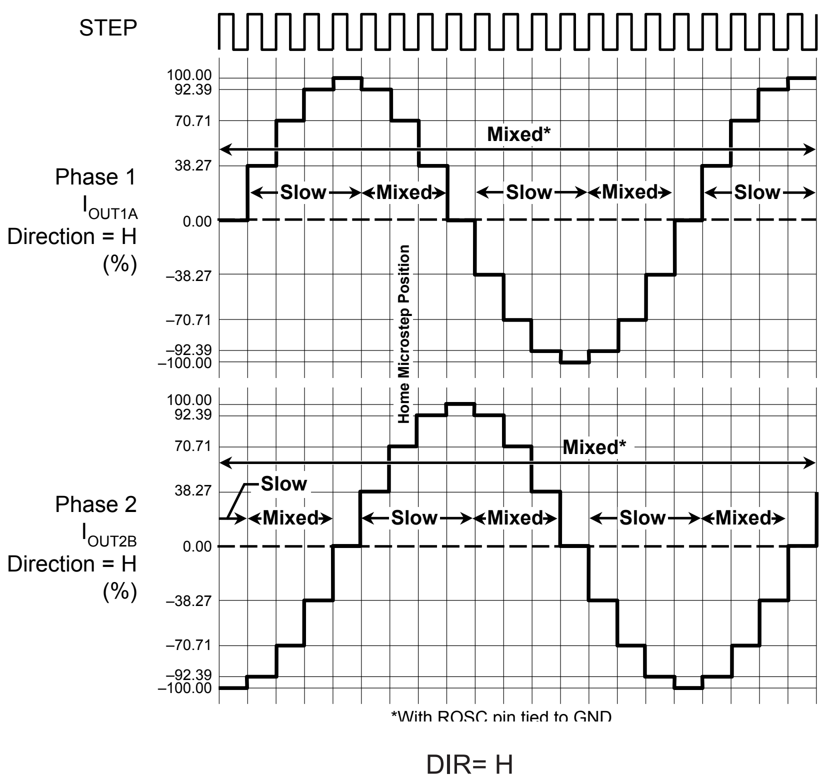


Figure 11: Decay Modes for Quarter-Step Increments

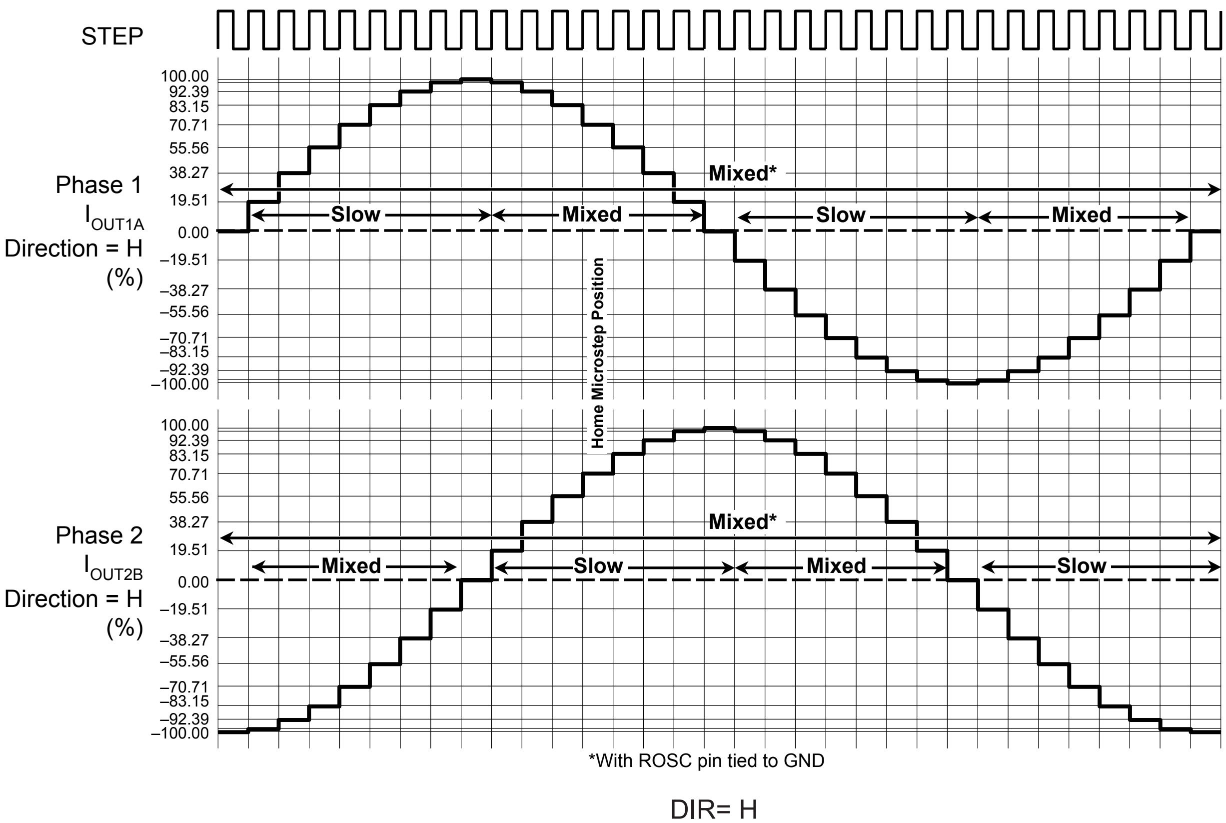


Figure 12: Decay Modes for Eighth-Step Increments

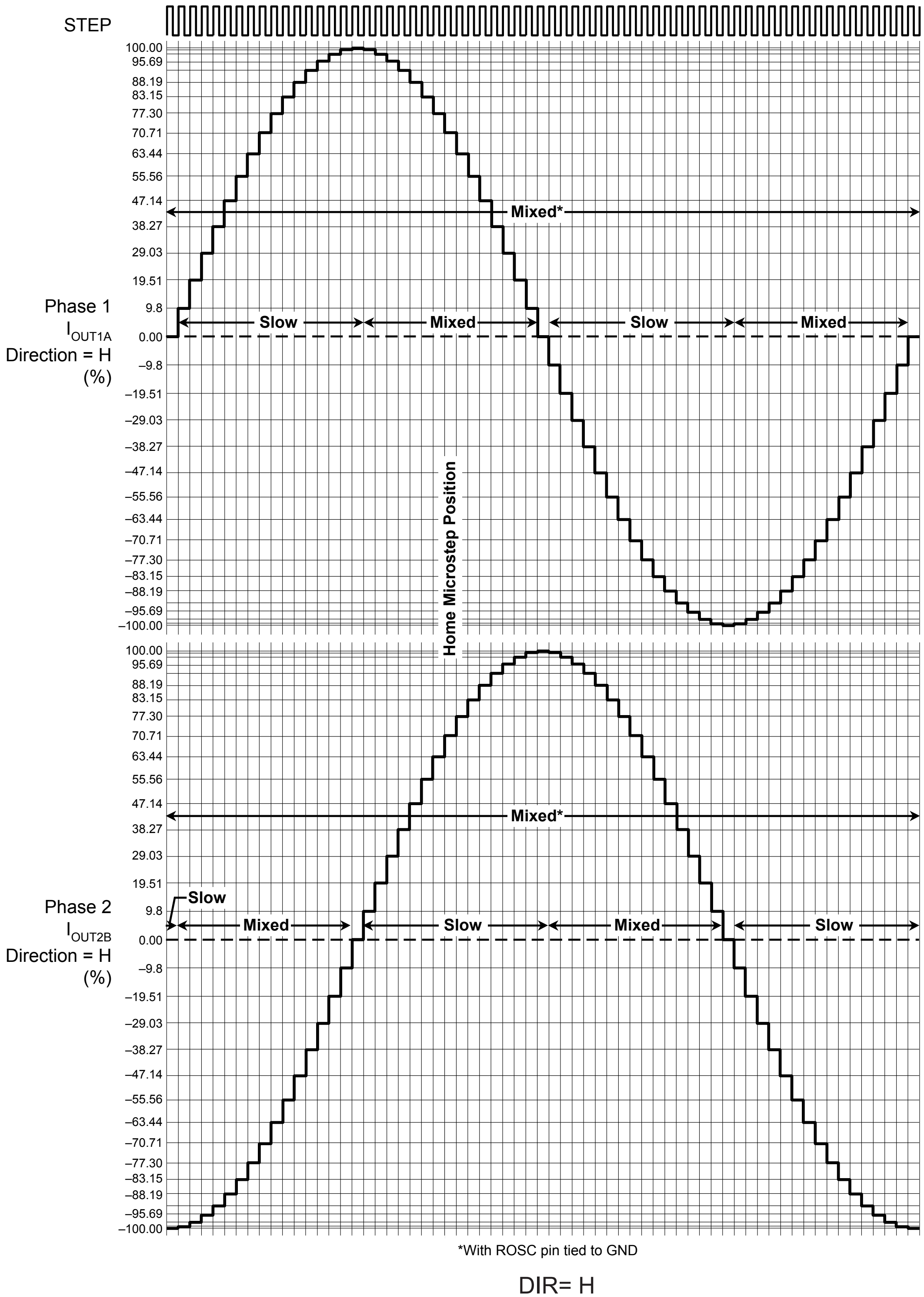


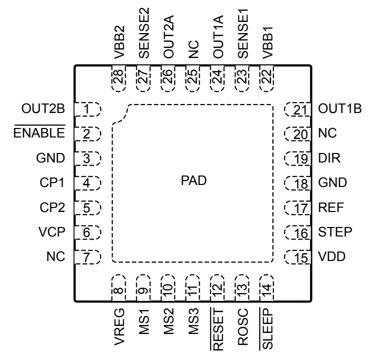
Figure 13: Decay Modes for Sixteenth-Step Increments

Table 2: Step Sequencing Settings

Home microstep position at Step Angle 45º; DIR = H

Full Step #	Half Step #	1/4 Step #	1/8 Step #	1/16 Step #	Phase 1 Current [% $I_{tripMax}$] (%)	Phase 2 Current [% $I_{tripMax}$] (%)	Step Angle (º)	Full Step #	Half Step #	1/4 Step #	1/8 Step #	1/16 Step #	Phase 1 Current [% $I_{tripMax}$] (%)	Phase 2 Current [% $I_{tripMax}$] (%)	Step Angle (º)
	1	1	1	1	100.00	0.00	0.0		5	9	17	33	–100.00	0.00	180.0
				2	99.52	9.80	5.6					34	–99.52	–9.80	185.6
			2	3	98.08	19.51	11.3				18	35	–98.08	–19.51	191.3
				4	95.69	29.03	16.9					36	–95.69	–29.03	196.9
		2	3	5	92.39	38.27	22.5			10	19	37	–92.39	–38.27	202.5
				6	88.19	47.14	28.1					38	–88.19	–47.14	208.1
			4	7	83.15	55.56	33.8				20	39	–83.15	–55.56	213.8
				8	77.30	63.44	39.4					40	–77.30	–63.44	219.4
1	2	3	5	9	70.71	70.71	45.0	3	6	11	21	41	–70.71	–70.71	225.0
				10	63.44	77.30	50.6					42	–63.44	–77.30	230.6
			6	11	55.56	83.15	56.3				22	43	–55.56	–83.15	236.3
				12	47.14	88.19	61.9					44	–47.14	–88.19	241.9
		4	7	13	38.27	92.39	67.5			12	23	45	–38.27	–92.39	247.5
				14	29.03	95.69	73.1					46	–29.03	–95.69	253.1
			8	15	19.51	98.08	78.8				24	47	–19.51	–98.08	258.8
				16	9.80	99.52	84.4					48	–9.80	–99.52	264.4
	3	5	9	17	0.00	100.00	90.0		7	13	25	49	0.00	–100.00	270.0
				18	–9.80	99.52	95.6					50	9.80	–99.52	275.6
			10	19	–19.51	98.08	101.3				26	51	19.51	–98.08	281.3
				20	–29.03	95.69	106.9					52	29.03	–95.69	286.9
		6	11	21	–38.27	92.39	112.5			14	27	53	38.27	–92.39	292.5
				22	–47.14	88.19	118.1					54	47.14	–88.19	298.1
			12	23	–55.56	83.15	123.8				28	55	55.56	–83.15	303.8
				24	–63.44	77.30	129.4					56	63.44	–77.30	309.4
2	4	7	13	25	–70.71	70.71	135.0	4	8	15	29	57	70.71	–70.71	315.0
				26	–77.30	63.44	140.6					58	77.30	–63.44	320.6
			14	27	–83.15	55.56	146.3				30	59	83.15	–55.56	326.3
				28	–88.19	47.14	151.9					60	88.19	–47.14	331.9
		8	15	29	–92.39	38.27	157.5			16	31	61	92.39	–38.27	337.5
				30	–95.69	29.03	163.1					62	95.69	–29.03	343.1
			16	31	–98.08	19.51	168.8				32	63	98.08	–19.51	348.8
				32	–99.52	9.80	174.4					64	99.52	–9.80	354.4

Pin-out Diagram

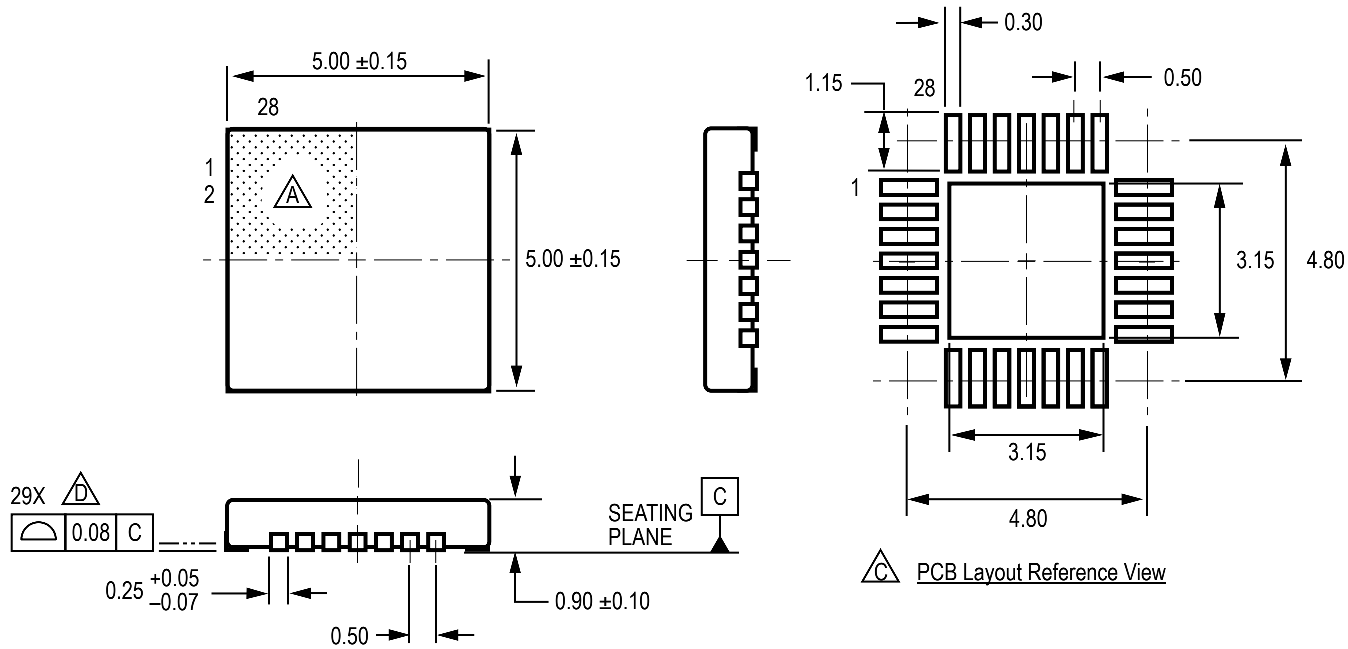


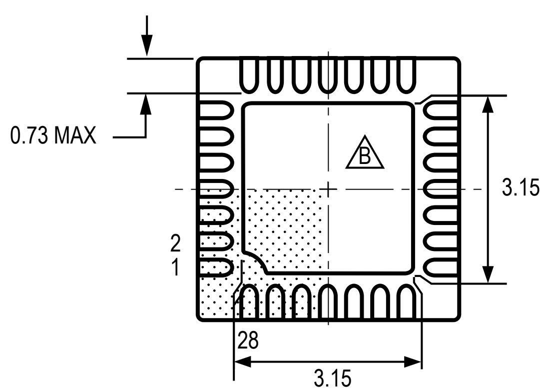
Terminal List Table

Name	Number	Description
CP1	4	Charge pump capacitor terminal
CP2	5	Charge pump capacitor terminal
VCP	6	Reservoir capacitor terminal
VREG	8	Regulator decoupling terminal
MS1	9	Logic input
MS2	10	Logic input
MS3	11	Logic input
$\overline{\text{RESET}}$	12	Logic input
ROSC	13	Timing set
$\overline{\text{SLEEP}}$	14	Logic input
VDD	15	Logic supply
STEP	16	Logic input
REF	17	G_m reference voltage input
GND	3, 18	Ground*
DIR	19	Logic input
OUT1B	21	DMOS Full Bridge 1 Output B
VBB1	22	Load supply
SENSE1	23	Sense resistor terminal for Bridge 1
OUT1A	24	DMOS Full Bridge 1 Output A
OUT2A	26	DMOS Full Bridge 2 Output A
SENSE2	27	Sense resistor terminal for Bridge 2
VBB2	28	Load supply
OUT2B	1	DMOS Full Bridge 2 Output B
$\overline{\text{ENABLE}}$	2	Logic input
NC	7, 20, 25	No connection
PAD	–	Exposed pad for enhanced thermal dissipation*

*The GND pins must be tied together externally by connecting to the PAD ground plane under the device.

ET Package, 28-Pin QFN with Exposed Thermal Pad





For Reference Only; not for tooling use
(reference JEDEC MO-220VHHD-1)
Dimensions in millimeters
Exact case and lead configuration at supplier discretion within limits shown

A Terminal #1 mark area

B Exposed thermal pad (reference only, terminal #1 identifier appearance at supplier discretion)

C Reference land pattern layout (reference IPC7351 QFN50P500X500X100-29V1M);
All pads a minimum of 0.20 mm from all adjacent pads; adjust as necessary to meet application process requirements and PCB layout tolerances; when mounting on a multilayer PCB, thermal vias at the exposed thermal pad land can improve thermal dissipation (reference EIA/JEDEC Standard JESD51-5)

D Coplanarity includes exposed thermal pad and terminals

Revision History

Revision	Revision Date	Description of Revision
4	January 27, 2012	Update I_{OCPST}
5	May 7, 2014	Revised text on pg. 9; revised Figure 8 and Table 2

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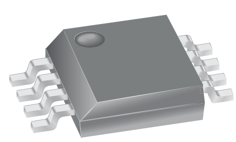
Fully Integrated, Hall Effect-Based Linear Current Sensor with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor

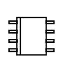
Features and Benefits

- Low-noise analog signal path
- Device bandwidth is set via the new FILTER pin
- 5 µs output rise time in response to step input current
- 80 kHz bandwidth
- Total output error 1.5% at T_A = 25°C
- Small footprint, low-profile SOIC8 package
- 1.2 mΩ internal conductor resistance
- 2.1 kV_{RMS} minimum isolation voltage from pins 1-4 to pins 5-8
- 5.0 V, single supply operation
- 66 to 185 mV/A output sensitivity
- Output voltage proportional to AC or DC currents
- Factory-trimmed for accuracy
- Extremely stable output offset voltage
- Nearly zero magnetic hysteresis
- Ratiometric output from supply voltage

TÜV America
Certificate Number:
U8V 06 05 54214 010

Package: 8 Lead SOIC (suffix LC)



Approximate Scale 1:1 

Description

The Allegro® ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switched-mode power supplies, and overcurrent fault protection.

The device consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is provided by the low-offset, chopper-stabilized BiCMOS Hall IC, which is programmed for accuracy after packaging.

The output of the device has a positive slope (>$V_{IOUT(Q)}$) when an increasing current flows through the primary copper conduction path (from pins 1 and 2, to pins 3 and 4), which is the path used for current sensing. The internal resistance of this conductive path is 1.2 mΩ typical, providing low power

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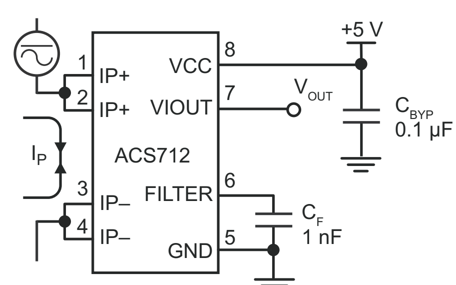
Typical Application



Application 1. The ACS712 outputs an analog signal, V_{OUT}. that varies linearly with the uni- or bi-directional AC or DC primary sensed current, I_P, within the range specified. C_F is recommended for noise management, with values that depend on the application.

Description (continued)

loss. The thickness of the copper conductor allows survival of the device at up to 5× overcurrent conditions. The terminals of the conductive path are electrically isolated from the sensor leads (pins 5 through 8). This allows the ACS712 current sensor to be used in applications requiring electrical isolation without the use of opto-isolators or other costly isolation techniques.

The ACS712 is provided in a small, surface mount SOIC8 package. The leadframe is plated with 100% matte tin, which is compatible with standard lead (Pb) free printed circuit board assembly processes. Internally, the device is Pb-free, except for flip-chip high-temperature Pb-based solder balls, currently exempt from RoHS. The device is fully calibrated prior to shipment from the factory.

Selection Guide

Part Number	Packing*	T_A (°C)	Optimized Range, I_P (A)	Sensitivity, Sens (Typ) (mV/A)
ACS712ELCTR-05B-T	Tape and reel, 3000 pieces/reel	–40 to 85	±5	185
ACS712ELCTR-20A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±20	100
ACS712ELCTR-30A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±30	66

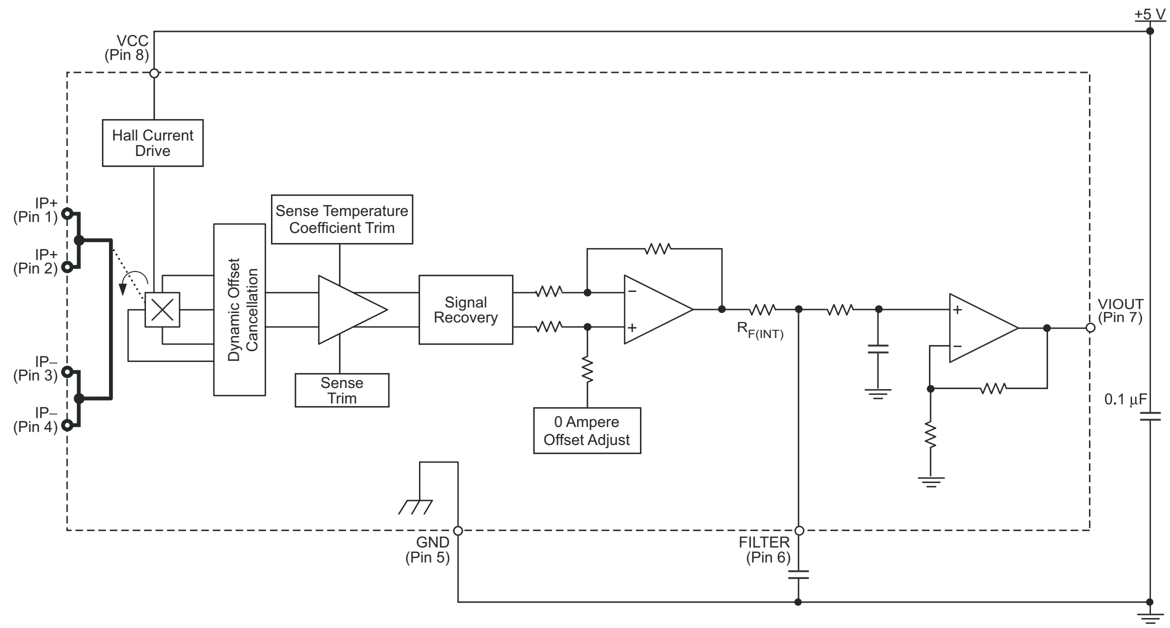
*Contact Allegro for additional packing options.

Absolute Maximum Ratings

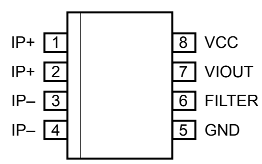
Characteristic	Symbol	Notes	Rating	Units
Supply Voltage	V_{CC}		8	V
Reverse Supply Voltage	V_{RCC}		–0.1	V
Output Voltage	V_{IOUT}		8	V
Reverse Output Voltage	V_{RIOUT}		–0.1	V
Reinforced Isolation Voltage	V_{ISO}	Pins 1-4 and 5-8; 60 Hz, 1 minute, T_A=25°C	2100	V
		Voltage applied to leadframe (Ip+ pins), based on IEC 60950	184	V_{peak}
Basic Isolation Voltage	$V_{ISO(bsc)}$	Pins 1-4 and 5-8; 60 Hz, 1 minute, T_A=25°C	1500	V
		Voltage applied to leadframe (Ip+ pins), based on IEC 60950	354	V_{peak}
Output Current Source	$I_{IOUT(Source)}$		3	mA
Output Current Sink	$I_{IOUT(Sink)}$		10	mA
Overcurrent Transient Tolerance	I_P	1 pulse, 100 ms	100	A
Nominal Operating Ambient Temperature	T_A	Range E	–40 to 85	ºC
Maximum Junction Temperature	T_J(max)		165	ºC
Storage Temperature	T_{stg}		–65 to 170	ºC

Parameter	Specification
Fire and Electric Shock	CAN/CSA-C22.2 No. 60950-1-03 UL 60950-1:2003 EN 60950-1:2001

Functional Block Diagram



Pin-out Diagram



Terminal List Table

Number	Name	Description
1 and 2	IP+	Terminals for current being sensed; fused internally
3 and 4	IP–	Terminals for current being sensed; fused internally
5	GND	Signal ground terminal
6	FILTER	Terminal for external capacitor that sets bandwidth
7	VIOUT	Analog output signal
8	VCC	Device power supply terminal

COMMON OPERATING CHARACTERISTICS[1] over full range of T_A, C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
ELECTRICAL CHARACTERISTICS						
Supply Voltage	V_{CC}		4.5	5.0	5.5	V
Supply Current	I_{CC}	V_{CC} = 5.0 V, output open	–	10	13	mA
Output Capacitance Load	C_{LOAD}	VIOUT to GND	–	–	10	nF
Output Resistive Load	R_{LOAD}	VIOUT to GND	4.7	–	–	kΩ
Primary Conductor Resistance	$R_{PRIMARY}$	T_A = 25°C	–	1.2	–	mΩ
Rise Time	t_r	$I_P = I_P$(max), T_A = 25°C, C_{OUT} = open	–	5	–	μs
Frequency Bandwidth	f	–3 dB, T_A = 25°C; I_P is 10 A peak-to-peak	–	80	–	kHz
Nonlinearity	E_{LIN}	Over full range of I_P	–	1.5	–	%
Symmetry	E_{SYM}	Over full range of I_P	98	100	102	%
Zero Current Output Voltage	$V_{IOUT(Q)}$	Bidirectional; I_P = 0 A, T_A = 25°C	–	V_{CC} × 0.5	–	V
Power-On Time	t_{PO}	Output reaches 90% of steady-state level, T_J = 25°C, 20 A present on leadframe	–	35	–	μs
Magnetic Coupling[2]			–	12	–	G/A
Internal Filter Resistance[3]	$R_{F(INT)}$			1.7		kΩ

[1]Device may be operated at higher primary current levels, I_P, and ambient, T_A, and internal leadframe temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.

[2]1G = 0.1 mT.

[3]$R_{F(INT)}$ forms an RC circuit via the FILTER pin.

COMMON THERMAL CHARACTERISTICS[1]

			Min.	Typ.	Max.	Units
Operating Internal Leadframe Temperature	T_A	E range	–40	–	85	°C
					Value	Units
Junction-to-Lead Thermal Resistance[2]	$R_{\theta JL}$	Mounted on the Allegro ASEK 712 evaluation board			5	°C/W
Junction-to-Ambient Thermal Resistance	$R_{\theta JA}$	Mounted on the Allegro 85-0322 evaluation board, includes the power consumed by the board			23	°C/W

[1]Additional thermal information is available on the Allegro website.

[2]The Allegro evaluation board has 1500 mm² of 2 oz. copper on each side, connected to pins 1 and 2, and to pins 3 and 4, with thermal vias connecting the layers. Performance values include the power consumed by the PCB. Further details on the board are available from the Frequently Asked Questions document on our website. Further information about board design and thermal performance also can be found in the Applications Information section of this datasheet.

x05B PERFORMANCE CHARACTERISTICS T_A = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–5	–	5	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	180	185	190	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 185 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	21	–	mV
Zero Current Output Slope	$\Delta I_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.26	–	mV/°C
		T_A = 25°C to 150°C	–	–0.08	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.054	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.008	–	mV/A/°C
Total Output Error[2]	E_{TOT}	I_P =±5 A, T_A = 25°C	–	±1.5	–	%

[1]Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, $T_{J(max)}$, is not exceeded.

[2]Percentage of I_P, with I_P = 5 A. Output filtered.

x20A PERFORMANCE CHARACTERISTICS T_A = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–20	–	20	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	96	100	104	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 100 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	11	–	mV
Zero Current Output Slope	$\Delta I_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.34	–	mV/°C
		T_A = 25°C to 150°C	–	–0.07	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.017	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.004	–	mV/A/°C
Total Output Error[2]	E_{TOT}	I_P =±20 A, T_A = 25°C	–	±1.5	–	%

[1]Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.

[2]Percentage of I_P, with I_P = 20 A. Output filtered.

x30A PERFORMANCE CHARACTERISTICS T_A = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–30	–	30	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	64	66	68	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 66 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	7	–	mV
Zero Current Output Slope	$\Delta I_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.35	–	mV/°C
		T_A = 25°C to 150°C	–	–0.08	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.007	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.002	–	mV/A/°C
Total Output Error[2]	E_{TOT}	I_P = ±30 A, T_A = 25°C	–	±1.5	–	%

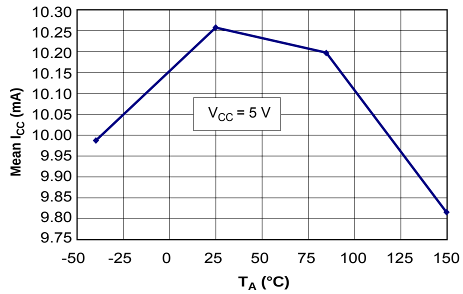
[1]Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.

[2]Percentage of I_P, with I_P = 30 A. Output filtered.

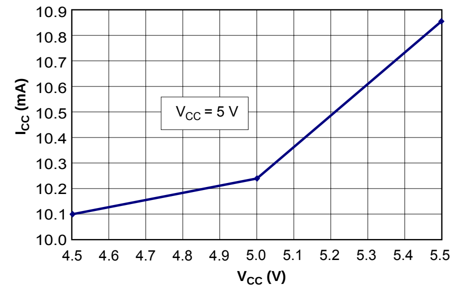
Characteristic Performance

I_P = 5 A, unless otherwise specified

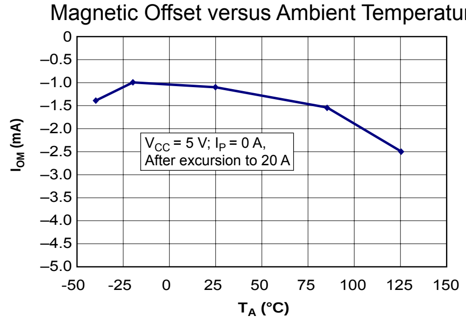
Mean Supply Current versus Ambient Temperature



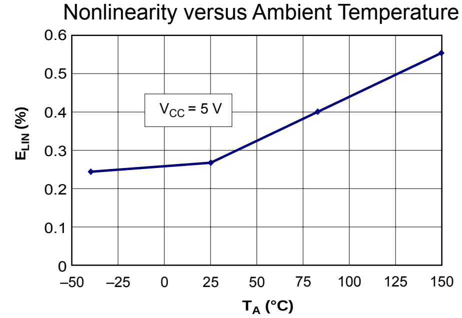
Supply Current versus Supply Voltage



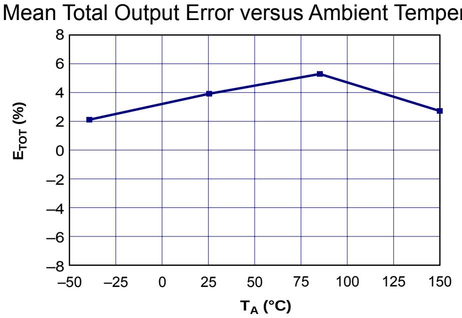
Magnetic Offset versus Ambient Temperature



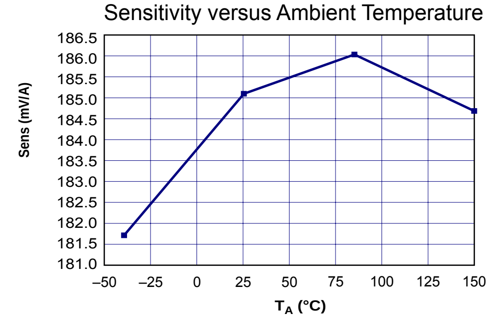
Nonlinearity versus Ambient Temperature



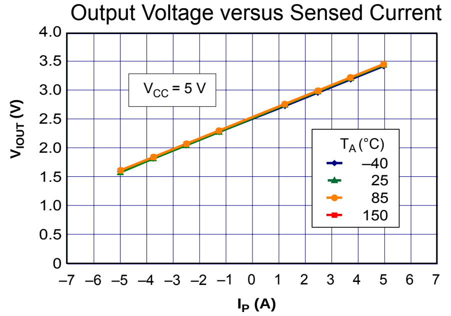
Mean Total Output Error versus Ambient Temperature



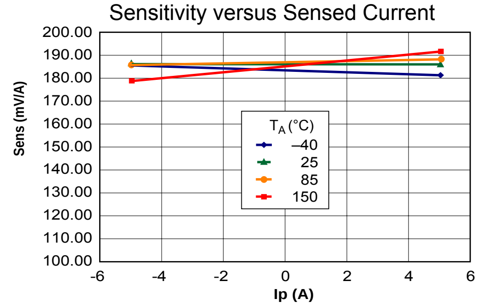
Sensitivity versus Ambient Temperature



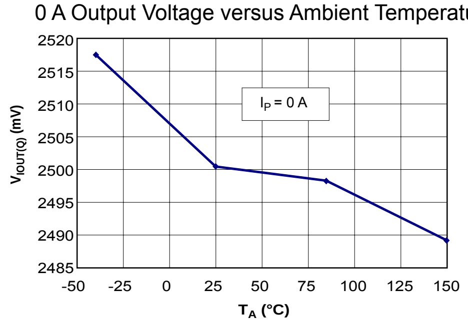
Output Voltage versus Sensed Current



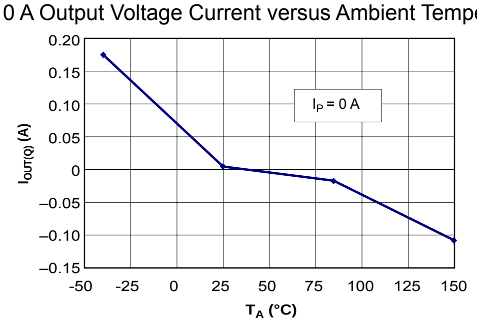
Sensitivity versus Sensed Current



0 A Output Voltage versus Ambient Temperature



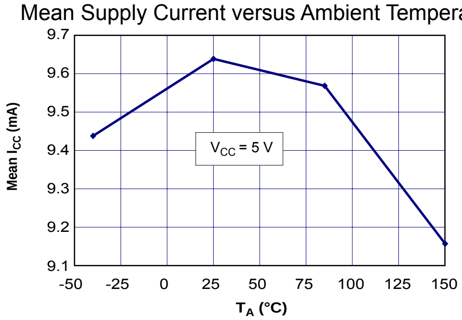
0 A Output Voltage Current versus Ambient Temperature



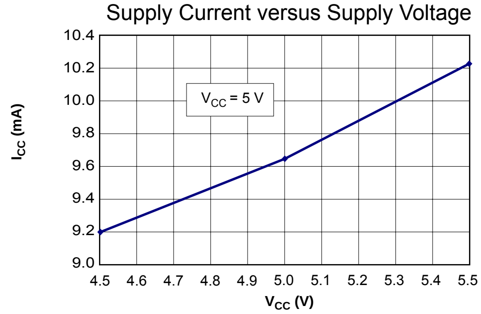
Characteristic Performance

I_P = 20 A, unless otherwise specified

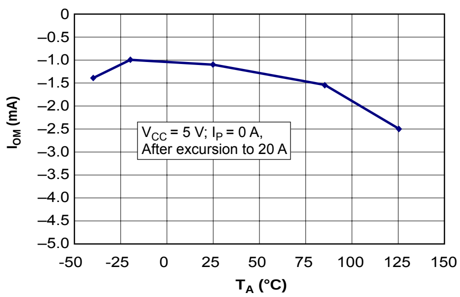
Mean Supply Current versus Ambient Temperature



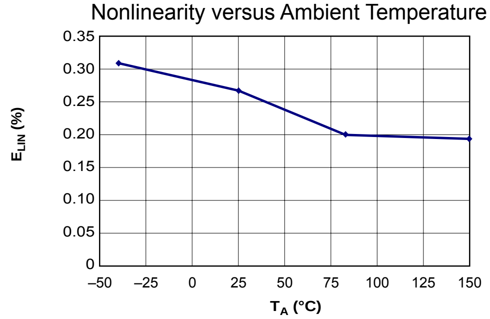
Supply Current versus Supply Voltage



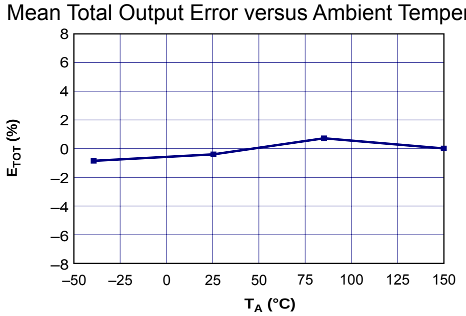
Magnetic Offset versus Ambient Temperature



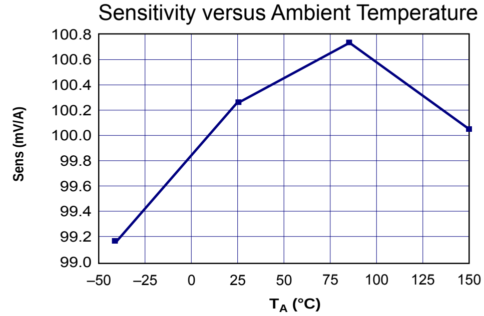
Nonlinearity versus Ambient Temperature



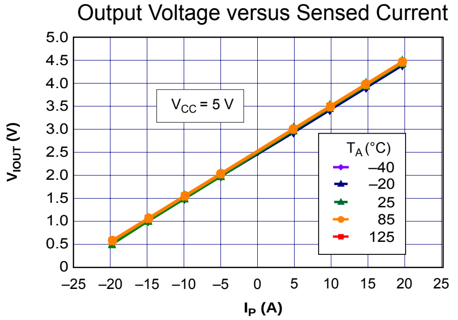
Mean Total Output Error versus Ambient Temperature



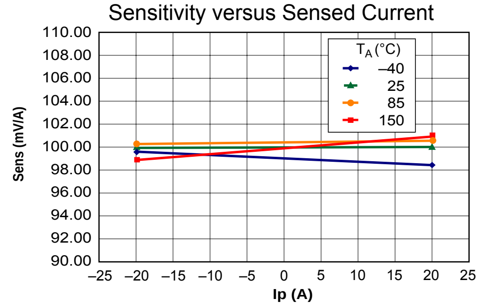
Sensitivity versus Ambient Temperature



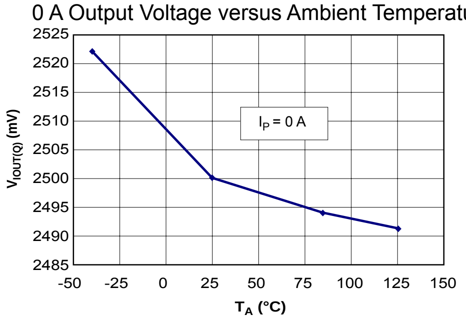
Output Voltage versus Sensed Current



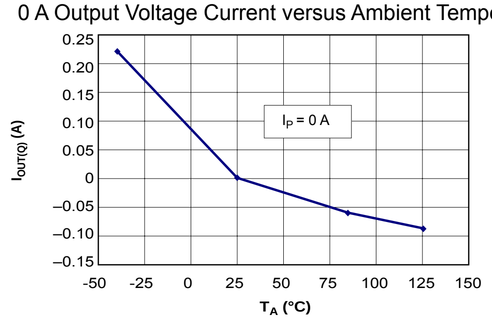
Sensitivity versus Sensed Current



0 A Output Voltage versus Ambient Temperature



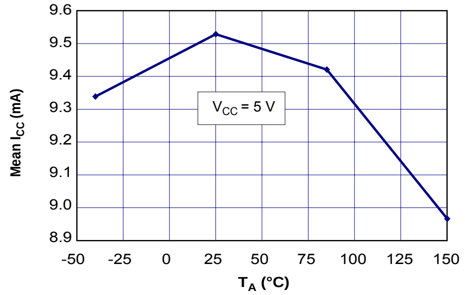
0 A Output Voltage Current versus Ambient Temperature



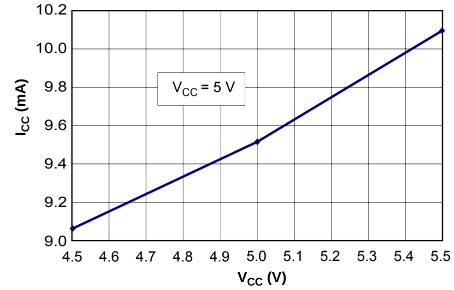
Characteristic Performance

I_P = 30 A, unless otherwise specified

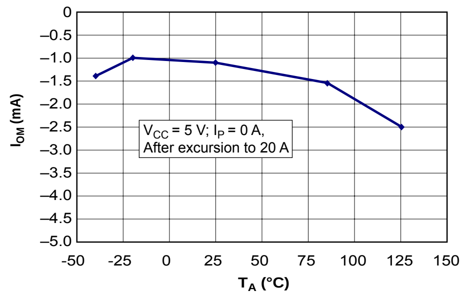
Mean Supply Current versus Ambient Temperature



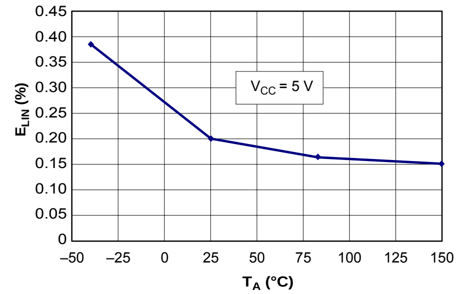
Supply Current versus Supply Voltage



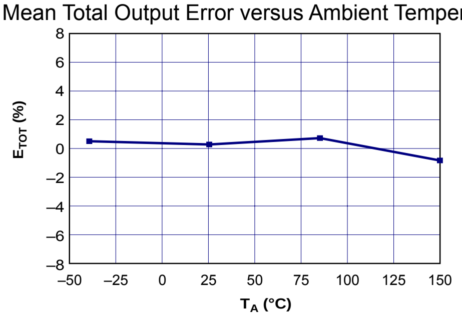
Magnetic Offset versus Ambient Temperature



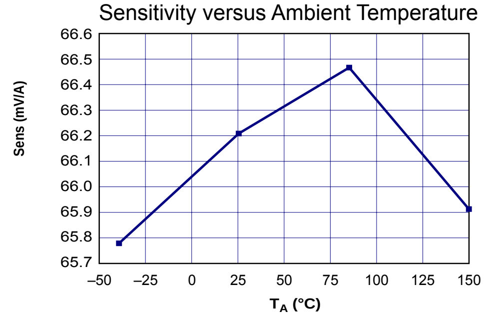
Nonlinearity versus Ambient Temperature



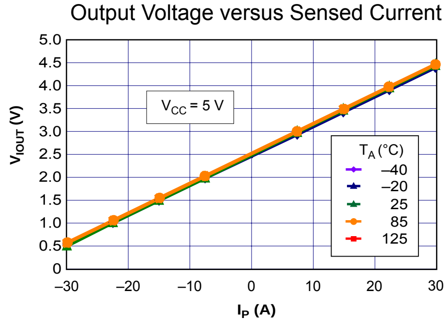
Mean Total Output Error versus Ambient Temperature



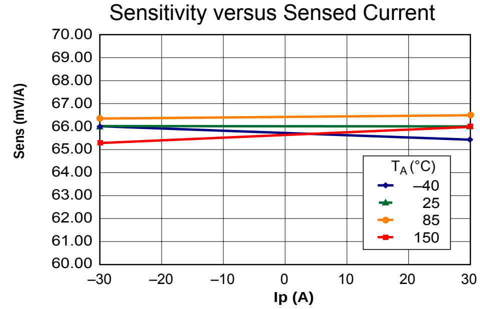
Sensitivity versus Ambient Temperature



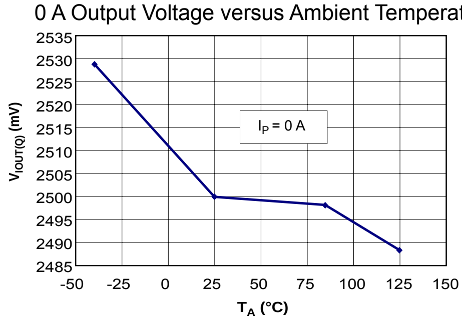
Output Voltage versus Sensed Current



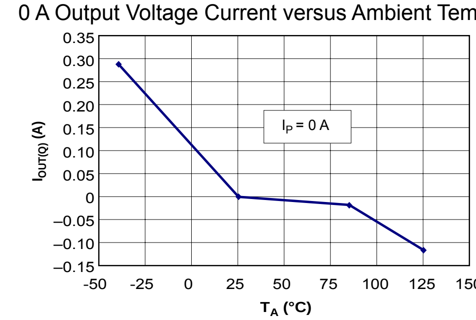
Sensitivity versus Sensed Current



0 A Output Voltage versus Ambient Temperature



0 A Output Voltage Current versus Ambient Temperature



Definitions of Accuracy Characteristics

Sensitivity (Sens). The change in sensor output in response to a 1 A change through the primary conductor. The sensitivity is the product of the magnetic circuit sensitivity (G/A) and the linear IC amplifier gain (mV/G). The linear IC amplifier gain is programmed at the factory to optimize the sensitivity (mV/A) for the full-scale current of the device.

Noise (V_{NOISE}). The product of the linear IC amplifier gain (mV/G) and the noise floor for the Allegro Hall effect linear IC (≈1 G). The noise floor is derived from the thermal and shot noise observed in Hall elements. Dividing the noise (mV) by the sensitivity (mV/A) provides the smallest current that the device is able to resolve.

Linearity (E_{LIN}). The degree to which the voltage output from the sensor varies in direct proportion to the primary current through its full-scale amplitude. Nonlinearity in the output can be attributed to the saturation of the flux concentrator approaching the full-scale current. The following equation is used to derive the linearity:

$$100\left\{1-\left[\frac{\Delta\text{ gain}\times\%\text{ sat }(V_{IOUT\_\text{full-scale amperes}}-V_{IOUT(Q)})}{2\,(V_{IOUT\_\text{half-scale amperes}}-V_{IOUT(Q)})}\right]\right\}$$

where $V_{IOUT\_\text{full-scale amperes}}$ = the output voltage (V) when the sensed current approximates full-scale $\pm I_P$.

Symmetry (E_{SYM}). The degree to which the absolute voltage output from the sensor varies in proportion to either a positive or negative full-scale primary current. The following formula is used to derive symmetry:

$$100\left(\frac{V_{IOUT\_+\text{ full-scale amperes}}-V_{IOUT(Q)}}{V_{IOUT(Q)}-V_{IOUT\_-\text{full-scale amperes}}}\right)$$

Quiescent output voltage ($V_{IOUT(Q)}$). The output of the sensor when the primary current is zero. For a unipolar supply voltage, it nominally remains at $V_{CC}/2$. Thus, V_{CC} = 5 V translates into $V_{IOUT(Q)}$ = 2.5 V. Variation in $V_{IOUT(Q)}$ can be attributed to the resolution of the Allegro linear IC quiescent voltage trim and thermal drift.

Electrical offset voltage (V_{OE}). The deviation of the device output from its ideal quiescent value of $V_{CC}/2$ due to nonmagnetic causes. To convert this voltage to amperes, divide by the device sensitivity, Sens.

Accuracy (E_{TOT}). The accuracy represents the maximum deviation of the actual output from its ideal value. This is also known as the total ouput error. The accuracy is illustrated graphically in the output voltage versus current chart at right.

Accuracy is divided into four areas:

- **0 A at 25°C.** Accuracy of sensing zero current flow at 25°C, without the effects of temperature.
- **0 A over Δ temperature.** Accuracy of sensing zero current flow including temperature effects.
- **Full-scale current at 25°C.** Accuracy of sensing the full-scale current at 25°C, without the effects of temperature.
- **Full-scale current over Δ temperature.** Accuracy of sensing full-scale current flow including temperature effects.

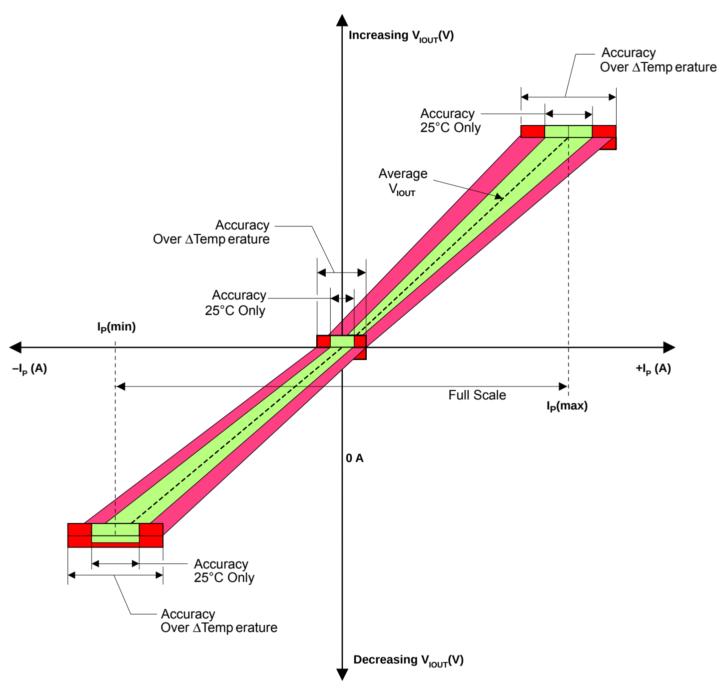
Ratiometry. The ratiometric feature means that its 0 A output, $V_{IOUT(Q)}$, (nominally equal to $V_{CC}/2$) and sensitivity, Sens, are proportional to its supply voltage, V_{CC}. The following formula is used to derive the ratiometric change in 0 A output voltage, $\Delta V_{IOUT(Q)RAT}$ (%).

$$100\left(\frac{V_{IOUT(Q)VCC}\,/\,V_{IOUT(Q)5V}}{V_{CC}\,/\,5\text{ V}}\right)$$

The ratiometric change in sensitivity, $\Delta Sens_{RAT}$ (%), is defined as:

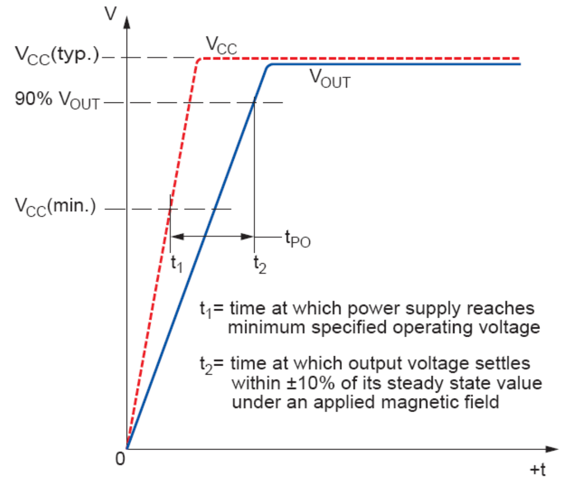
$$100\left(\frac{Sens_{VCC}\,/\,Sens_{5V}}{V_{CC}\,/\,5\text{ V}}\right)$$

Output Voltage versus Sensed Current
Accuracy at 0 A and at Full-Scale Current

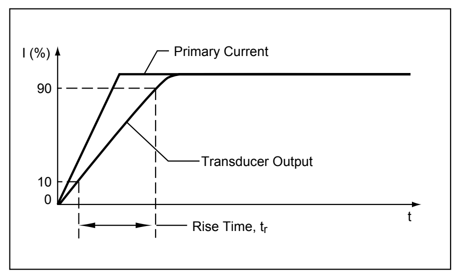


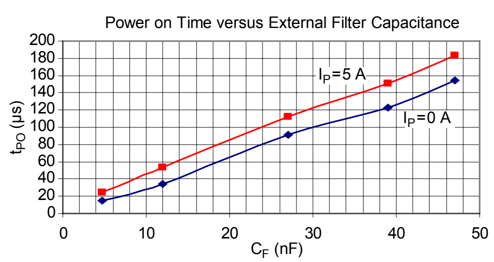
Definitions of Dynamic Response Characteristics

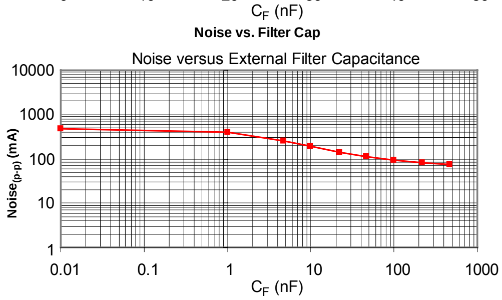
Power-On Time (t_{PO}). When the supply is ramped to its operating voltage, the device requires a finite time to power its internal components before responding to an input magnetic field. Power-On Time, t_{PO} , is defined as the time it takes for the output voltage to settle within ±10% of its steady state value under an applied magnetic field, after the power supply has reached its minimum specified operating voltage, V_{CC}(min), as shown in the chart at right.

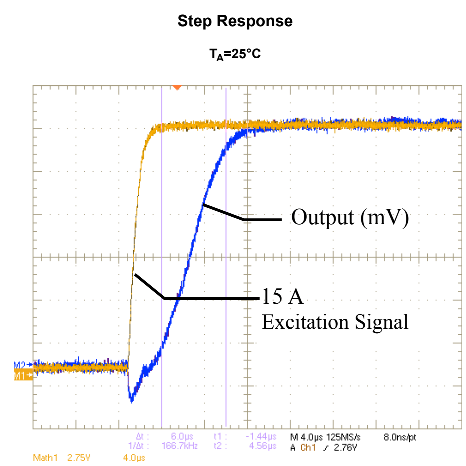


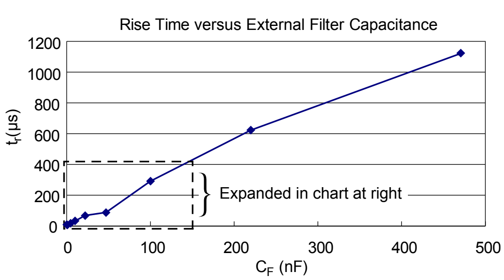
Rise time (t_r). The time interval between a) when the sensor reaches 10% of its full scale value, and b) when it reaches 90% of its full scale value. The rise time to a step response is used to derive the bandwidth of the current sensor, in which $f(-3\text{ dB}) = 0.35/t_r$. Both t_r and $t_{RESPONSE}$ are detrimentally affected by eddy current losses observed in the conductive IC ground plane.



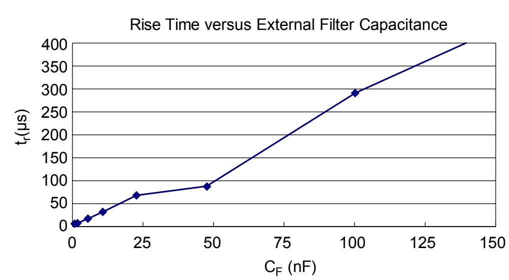








C_F (nF)	t_r (µs)
0	6.6
1	7.7
4.7	17.4
10	32.1
22	68.2
47	88.2
100	291.3
220	623.0
470	1120.0

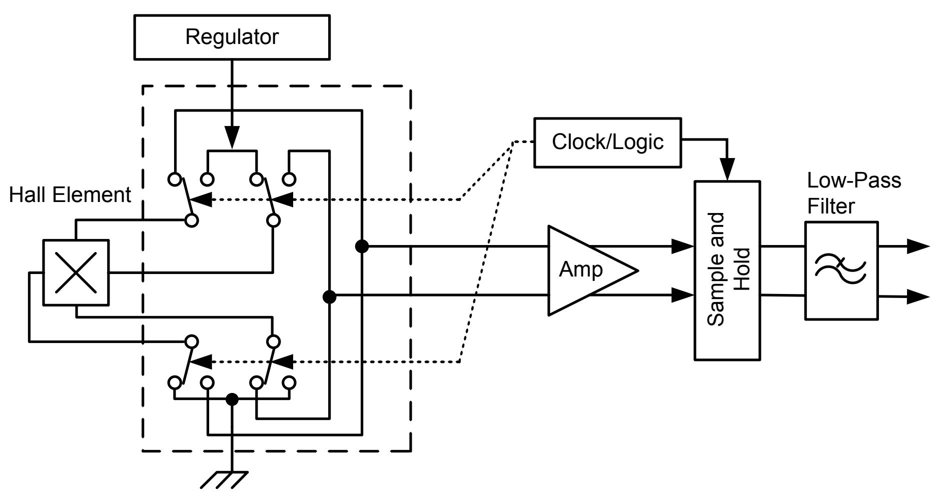


Chopper Stabilization Technique

Chopper Stabilization is an innovative circuit technique that is used to minimize the offset voltage of a Hall element and an associated on-chip amplifier. Allegro patented a Chopper Stabilization technique that nearly eliminates Hall IC output drift induced by temperature or package stress effects. This offset reduction technique is based on a signal modulation-demodulation process. Modulation is used to separate the undesired dc offset signal from the magnetically induced signal in the frequency domain. Then, using a low-pass filter, the modulated dc offset is suppressed while the magnetically induced signal passes through the filter.

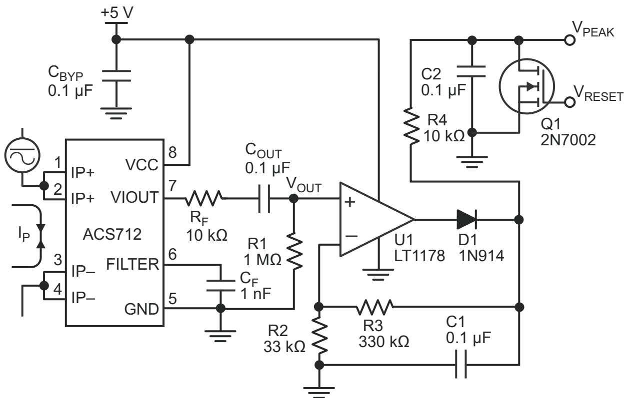
As a result of this chopper stabilization approach, the output voltage from the Hall IC is desensitized to the effects of temperature and mechanical stress. This technique produces devices that have an extremely stable Electrical Offset Voltage, are immune to thermal stress, and have precise recoverability after temperature cycling.

This technique is made possible through the use of a BiCMOS process that allows the use of low-offset and low-noise amplifiers in combination with high-density logic integration and sample and hold circuits.

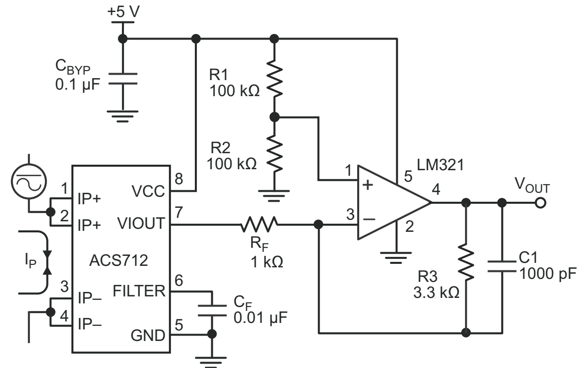


Concept of Chopper Stabilization Technique

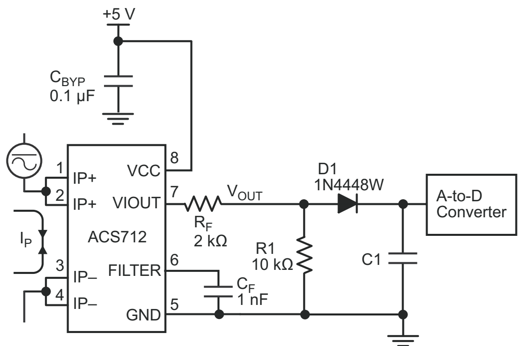
Typical Applications



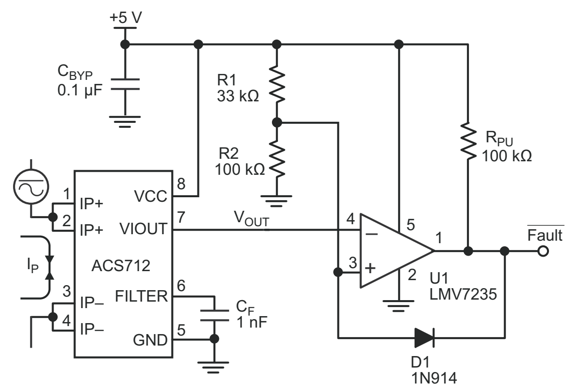
Application 2. Peak Detecting Circuit



Application 3. This configuration increases gain to 610 mV/A (tested using the ACS712ELC-05A).



Application 4. Rectified Output. 3.3 V scaling and rectification application for A-to-D converters. Replaces current transformer solutions with simpler ACS circuit. C1 is a function of the load resistance and filtering desired. R1 can be omitted if the full range is desired.



Application 5. 10 A Overcurrent Fault Latch. Fault threshold set by R1 and R2. This circuit latches an overcurrent fault and holds it until the 5 V rail is powered down.

Improving Sensing System Accuracy Using the FILTER Pin

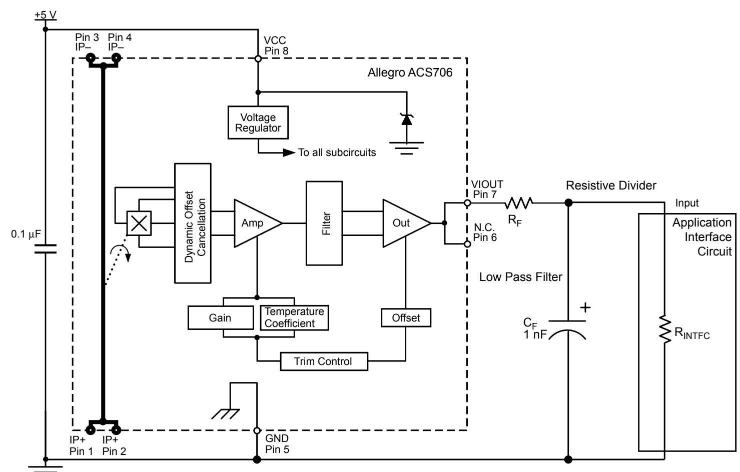
In low-frequency sensing applications, it is often advantageous to add a simple RC filter to the output of the sensor. Such a low-pass filter improves the signal-to-noise ratio, and therefore the resolution, of the sensor output signal. However, the addition of an RC filter to the output of a sensor IC can result in undesirable sensor output attenuation — even for dc signals.

Signal attenuation, ΔV_{ATT}, is a result of the resistive divider effect between the resistance of the external filter, R_F (see Application 6), and the input impedance and resistance of the customer interface circuit, R_{INTFC}. The transfer function of this resistive divider is given by:

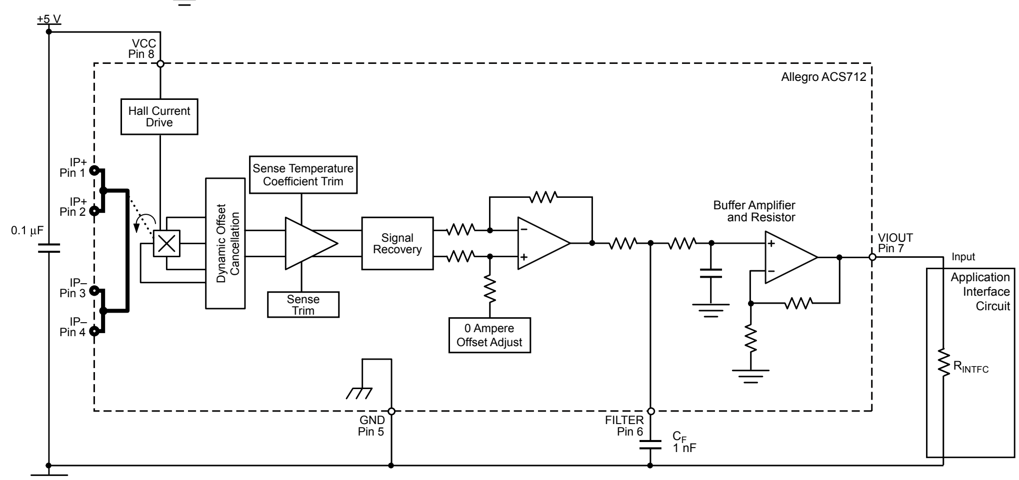
$$\Delta V_{\mathrm{ATT}} = V_{\mathrm{IOUT}}\left(\frac{R_{\mathrm{INTFC}}}{R_{\mathrm{F}} + R_{\mathrm{INTFC}}}\right) .$$

Even if R_F and R_{INTFC} are designed to match, the two individual resistance values will most likely drift by different amounts over temperature. Therefore, signal attenuation will vary as a function of temperature. Note that, in many cases, the input impedance, R_{INTFC}, of a typical analog-to-digital converter (ADC) can be as low as 10 kΩ.

The ACS712 contains an internal resistor, a FILTER pin connection to the printed circuit board, and an internal buffer amplifier. With this circuit architecture, users can implement a simple RC filter via the addition of a capacitor, C_F (see Application 7) from the FILTER pin to ground. The buffer amplifier inside of the ACS712 (located after the internal resistor and FILTER pin connection) eliminates the attenuation caused by the resistive divider effect described in the equation for ΔV_{ATT}. Therefore, the ACS712 device is ideal for use in high-accuracy applications that cannot afford the signal attenuation associated with the use of an external RC low-pass filter.

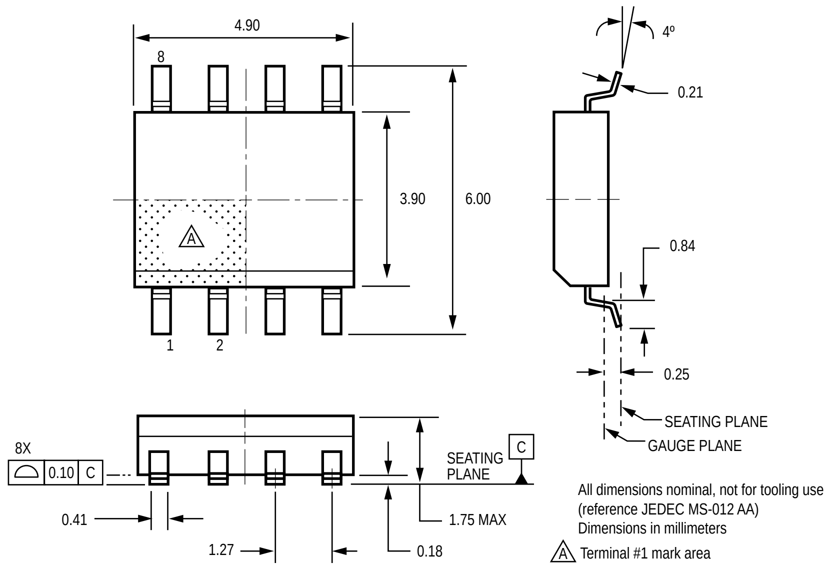


Application 6. When a low pass filter is constructed externally to a standard Hall effect device, a resistive divider may exist between the filter resistor, R_F, and the resistance of the customer interface circuit, R_{INTFC}. This resistive divider will cause excessive attenuation, as given by the transfer function for ΔV_{ATT}.



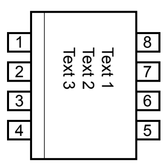
Application 7. Using the FILTER pin provided on the ACS712 eliminates the attenuation effects of the resistor divider between R_F and R_{INTFC}, shown in Application 6.

Package LC, 8-pin SOIC



Package Branding

Two alternative patterns are used



	ACS	Allegro Current Sensor
	712	Device family number
	T	Indicator of 100% matte tin leadframe plating
ACS712T	*R*	Operating ambient temperature range code
RLCPPP	LC	Package type designator
YYWWA	*PPP*	Primary sensed current
	YY	Date code: Calendar year (last two digits)
	WW	Date code: Calendar week
	A	Date code: Shift code

	ACS	Allegro Current Sensor
	712	Device family number
ACS712T	T	Indicator of 100% matte tin leadframe plating
RLCPPP	*R*	Operating ambient temperature range code
L...L	LC	Package type designator
YYWW	*PPP*	Primary sensed current
	L...L	Lot code
	YY	Date code: Calendar year (last two digits)
	WW	Date code: Calendar week

The products described herein are manufactured under one or more of the following U.S. patents: 5,045,920; 5,264,783; 5,442,283; 5,389,889; 5,581,179; 5,517,112; 5,619,137; 5,621,319; 5,650,719; 5,686,894; 5,694,038; 5,729,130; 5,917,320; and other patents pending.

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ALPHA & OMEGA SEMICONDUCTOR

AO4407A

30V P-Channel MOSFET

General Description

The AO4407A uses advanced trench technology to provide excellent $R_{DS(ON)}$, and ultra-low low gate charge with a 25V gate rating. This device is suitable for use as a load switch or in PWM applications.

* RoHS and Halogen-Free Complaint

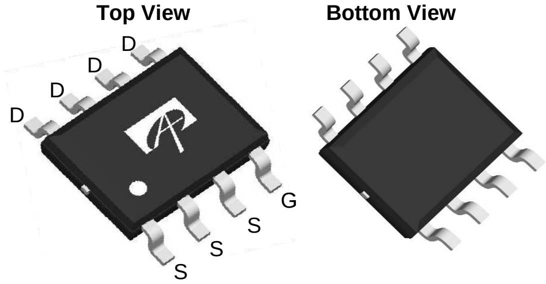
Product Summary

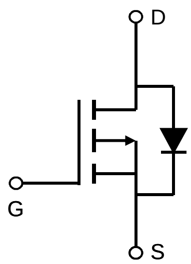
V_{DS} = -30V
I_D = -12A (VGS = -20V)
$R_{DS(ON)}$ < 11mΩ (V_{GS} = -20V)
$R_{DS(ON)}$ < 13mΩ (V_{GS} = -10V)
$R_{DS(ON)}$ < 17mΩ (V_{GS} = -6V)

100% UIS Tested
100% Rg Tested

SOIC-8

Top View **Bottom View**





Absolute Maximum Ratings T_A=25℃ unless otherwise noted				
Parameter		**Symbol**	**Maximum**	**Units**
Drain-Source Voltage		V_{DS}	-30	V
Gate-Source Voltage		V_{GS}	±25	V
Continuous Drain Current [A]	T_A=25℃	I_D	-12	A
	T_A=70℃		-10	
Pulsed Drain Current [B]		I_{DM}	-60	
Avalanche Current [G]		I_{AR}	-26	
Repetitive avalanche energy L=0.3mH [G]		E_{AR}	101	mJ
Power Dissipation [A]	T_A=25℃	P_D	3.1	W
	T_A=70℃		2.0	
Junction and Storage Temperature Range		T_J, T_{STG}	-55 to 150	℃

Thermal Characteristics					
Parameter		**Symbol**	**Typ**	**Max**	**Units**
Maximum Junction-to-Ambient [A]	t ≤ 10s	$R_{\theta JA}$	32	40	℃/W
Maximum Junction-to-Ambient [A]	Steady State		60	75	℃/W
Maximum Junction-to-Lead [C]	Steady State	$R_{\theta JL}$	17	24	℃/W

Electrical Characteristics (T_J=25°C unless otherwise noted)

Symbol	Parameter	Conditions		Min	Typ	Max	Units
STATIC PARAMETERS							
BV_{DSS}	Drain-Source Breakdown Voltage	I_D = -250µA, V_{GS} = 0V		-30			V
I_{DSS}	Zero Gate Voltage Drain Current	V_{DS} = -30V, V_{GS} = 0V				-1	µA
			T_J = 55°C			-5	
I_{GSS}	Gate-Body leakage current	V_{DS} = 0V, V_{GS} = ±25V				±100	nA
$V_{GS(th)}$	Gate Threshold Voltage	V_{DS} = V_{GS} I_D = -250µA		-1.7	-2.3	-3	V
$I_{D(ON)}$	On state drain current	V_{GS} = -10V, V_{DS} = -5V		-60			A
$R_{DS(ON)}$	Static Drain-Source On-Resistance	V_{GS} = -20V, I_D = -12A			8.5	11	mΩ
			T_J=125°C		11.5	15	
		V_{GS} = -10V, I_D = -12A			10	13	
		V_{GS} = -6V, I_D = -10A			12.7	17	
g_{FS}	Forward Transconductance	V_{DS} = -5V, I_D = -10A			21		S
V_{SD}	Diode Forward Voltage	I_S = -1A,V_{GS} = 0V			-0.7	-1	V
I_S	Maximum Body-Diode Continuous Current					-3	A
DYNAMIC PARAMETERS							
C_{iss}	Input Capacitance	V_{GS}=0V, V_{DS}=-15V, f=1MHz			2060	2600	pF
C_{oss}	Output Capacitance				370		pF
C_{rss}	Reverse Transfer Capacitance				295		pF
R_g	Gate resistance	V_{GS}=0V, V_{DS}=0V, f=1MHz			2.4	3.6	Ω
SWITCHING PARAMETERS							
Q_g	Total Gate Charge	V_{GS}=-10V, V_{DS}=-15V, I_D=-12A			30	39	nC
Q_{gs}	Gate Source Charge				4.6		nC
Q_{gd}	Gate Drain Charge				10		nC
$t_{D(on)}$	Turn-On DelayTime	V_{GS}=-10V, V_{DS}=-15V, R_L=1.25Ω, R_{GEN}=3Ω			11		ns
t_r	Turn-On Rise Time				9.4		ns
$t_{D(off)}$	Turn-Off DelayTime				24		ns
t_f	Turn-Off Fall Time				12		ns
t_{rr}	Body Diode Reverse Recovery Time	I_F=-12A, dI/dt=100A/µs			30	40	ns
Q_{rr}	Body Diode Reverse Recovery Charge	I_F=-12A, dI/dt=100A/µs			22		nC

A: The value of $R_{\theta JA}$ is measured with the device mounted on 1 in^2 FR-4 board with 2oz. Copper, in a still air environment with T_A = 25°C. The value in any given application depends on the user's specific board design. The current rating is based on the t ≤ 10s thermal resistance rating.
B: Repetitive rating, pulse width limited by junction temperature.
C. The $R_{\theta JA}$ is the sum of the thermal impedence from junction to lead $R_{\theta JL}$ and lead to ambient.
D. The static characteristics in Figures 1 to 6 are obtained using < 300µs pulses, duty cycle 0.5% max.
E. These tests are performed with the device mounted on 1 in^2 FR-4 board with 2oz. Copper, in a still air environment with T_A=25°C. The SOA curve provides a single pulse rating.
F. The current rating is based on the t ≤ 10s thermal resistance rating.
G. E_{AR} and I_{AR} ratings are based on low frequency and duty cycles to keep T_j=25C.

TYPICAL ELECTRICAL AND THERMAL CHARACTERISTICS

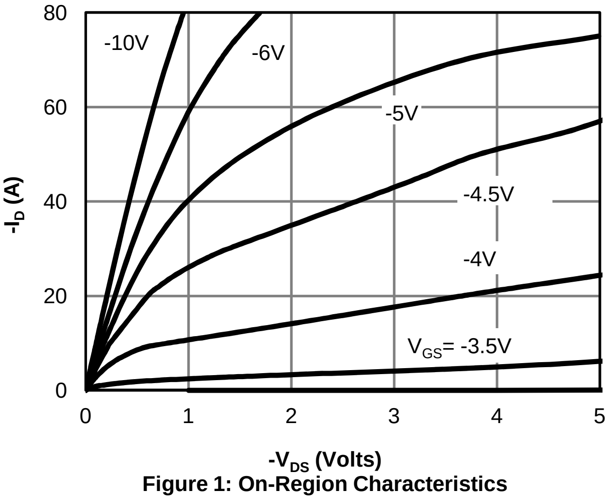


Figure 1: On-Region Characteristics

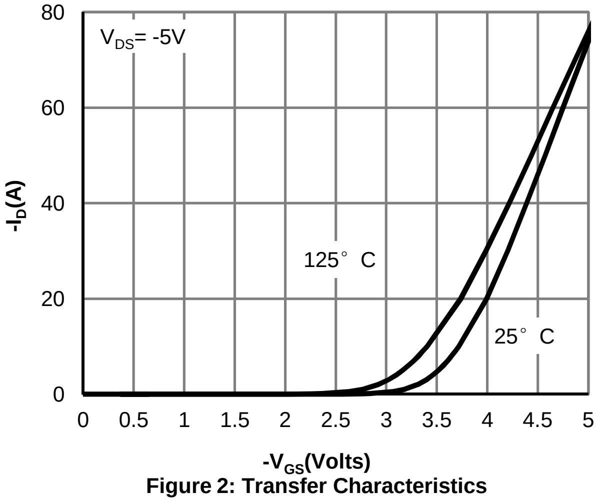


Figure 2: Transfer Characteristics

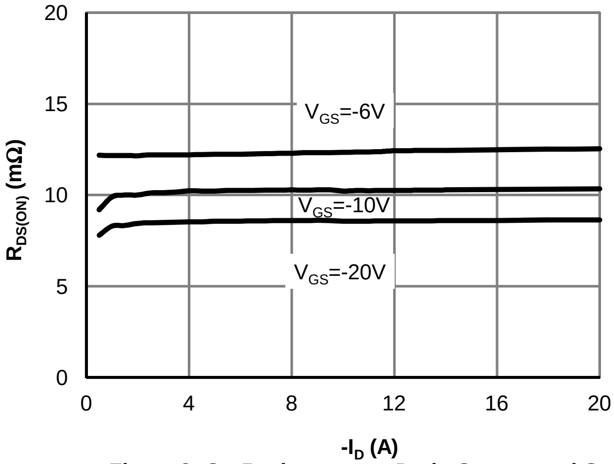


Figure 3: On-Resistance vs. Drain Current and Gate Voltage

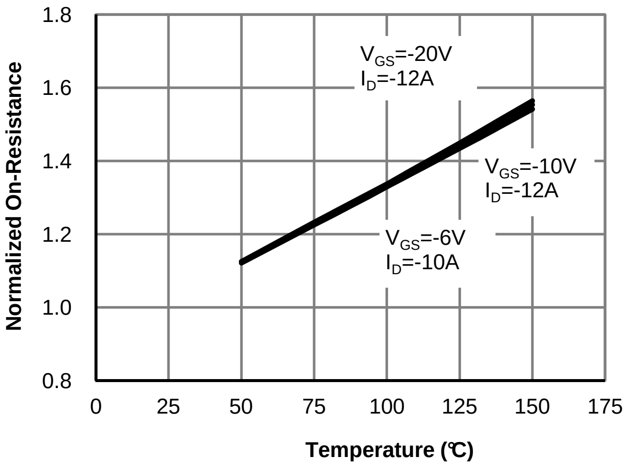


Figure 4: On-Resistance vs. Junction Temperature

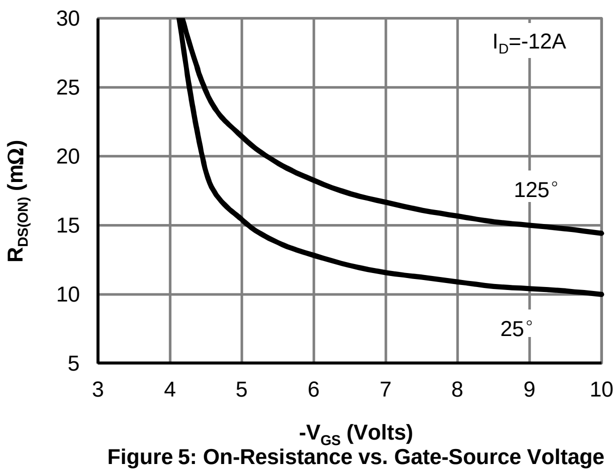


Figure 5: On-Resistance vs. Gate-Source Voltage

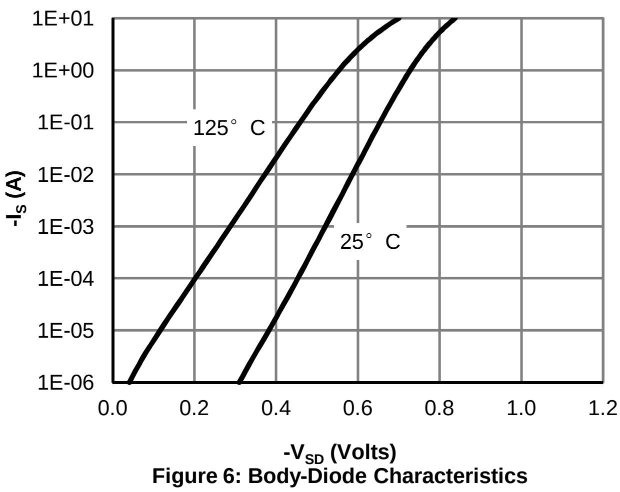


Figure 6: Body-Diode Characteristics

TYPICAL ELECTRICAL AND THERMAL CHARACTERISTICS

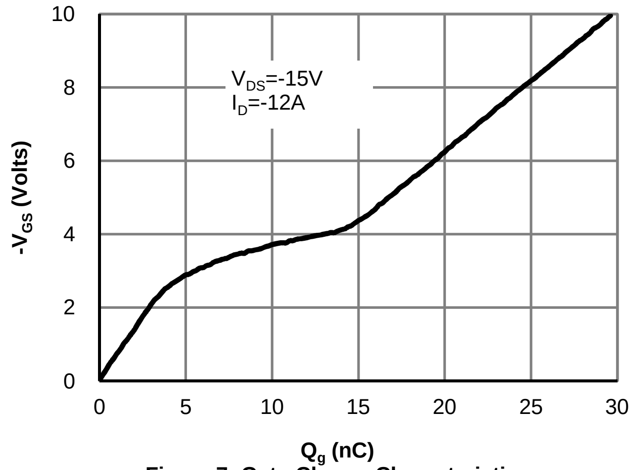


Figure 7: Gate-Charge Characteristics

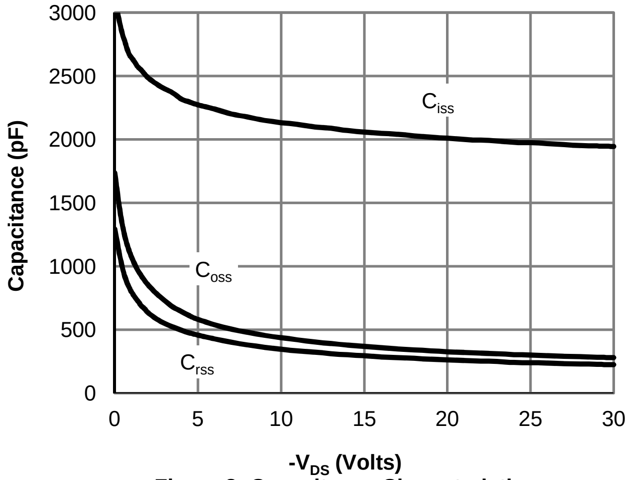


Figure 8: Capacitance Characteristics

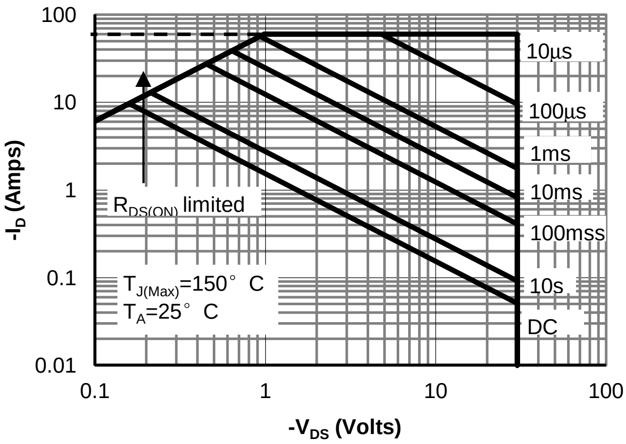


Figure 9: Maximum Forward Biased Safe Operating Area (Note E)

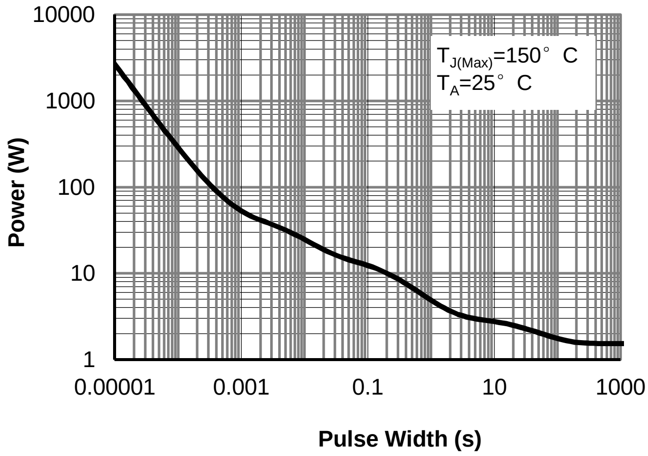


Figure 10: Single Pulse Power Rating Junction-to-Ambient (Note E)

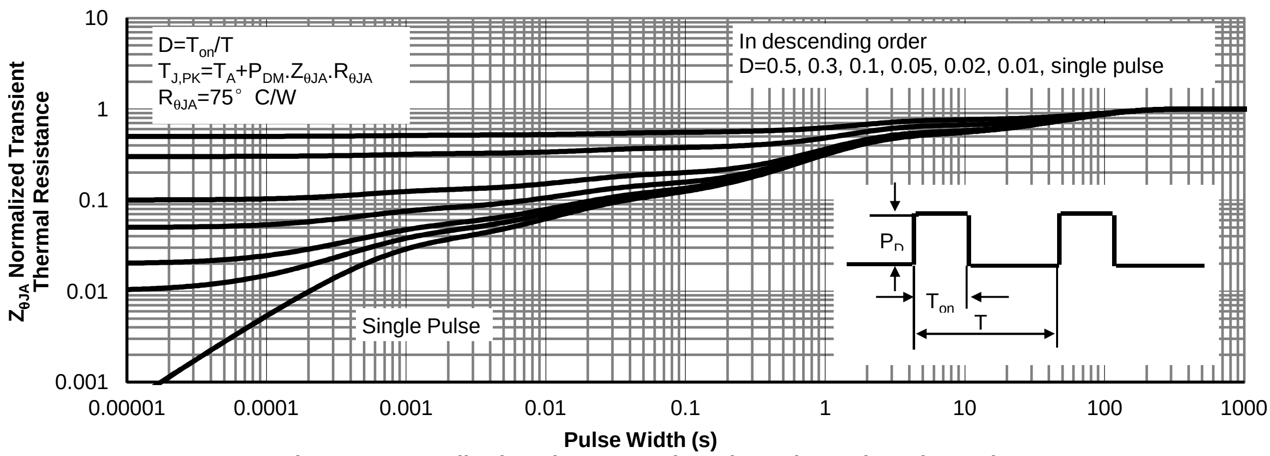
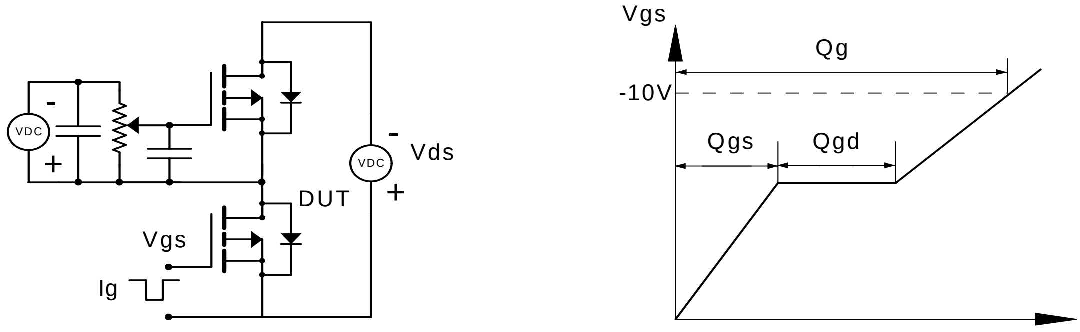
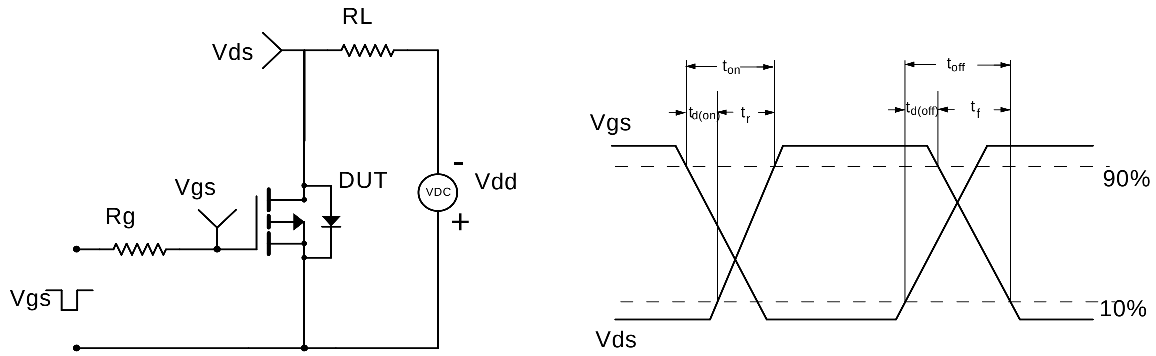


Figure 11: Normalized Maximum Transient Thermal Impedance(Note E)

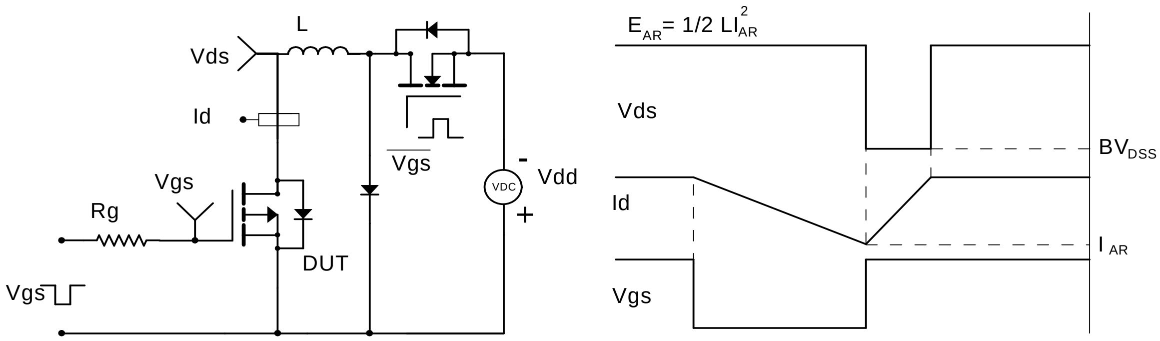
Gate Charge Test Circuit & Waveform



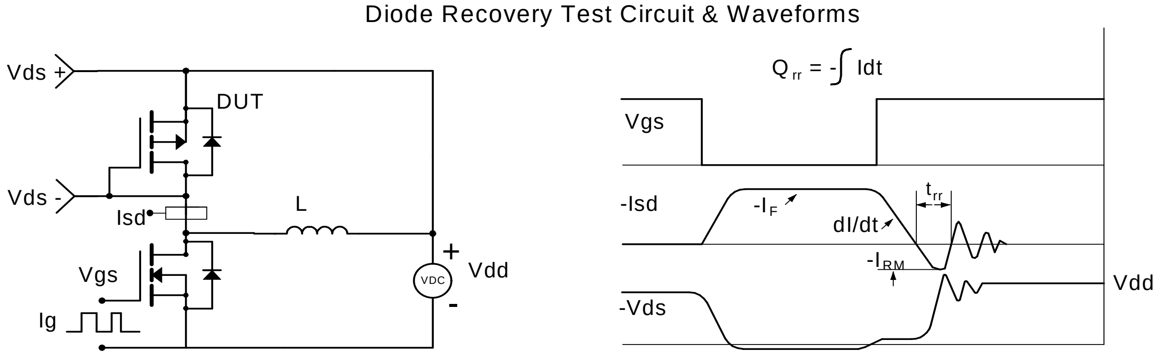
Resistive Switching Test Circuit & Waveforms



Unclamped Inductive Switching (UIS) Test Circuit & Waveforms



Diode Recovery Test Circuit & Waveforms



Lithium-ion Battery

DATA SHEET

Battery Model : LIR18650 2600mAh

Prepared	Authorized	Approved

Manufacturer: EEMB Co., Ltd.
Website: http://eemb.com

1. Scope

This specification describes the technological parameters and testing standard for the lithium ion rechargeable cell manufactured and supplied by EEMB Co. Ltd.

2. Products specified

2.1 Name Cylindrical Lithium Ion Rechargeable Cell

2.2 Type LIR18650-2600mAh

3. References

In this specification reference is made to: GB/T182847-2000, UL1642 and IEC61960-1:2000.

4. Caution:

4.1. Please read these specifications carefully before testing or using the cell as improper handling of a Li-ion cell may result in lose of efficiency, heating, ignition, electrolyte leakage or even explosion.

4.2 While testing the cell by charging and discharging, please use test-equipment especially designed for Li-ion cell. Do not use ordinary constant current and constant voltage (CC/CV) power supplies. These do not protect the cell from being overcharged and over-discharged, resulting in possible loss of functionality or danger.

4.3 When charging and discharging cells or packing them into equipment, reversing the positive and negative terminals will result in overcharging and over-discharging of the cell(s). This could lead to serious loss of efficiency and even explosions.

4.4 Do not solder directly on the cell. Do not resolve the cell.

4.5 Do not put cell(s) in pockets or bags together with metal products such as necklaces, hairpins, coins, screws, etc. Neither stores them together without proper isolation. Do not connect the positive and negative electrode directly with each other through conductive materials. This can result in a short circuit of the cell.

4.6 Do not beat, throw or trample the cell, do not put the cell into washing machines or high-pressure containers.

4.7 Keep the cell away from heat sources such as fires, heaters, etc. Do not use or store cell(s) at locations where the temperature can exceed 60℃， such as in direct sunlight. This may lead to the generation of excessive heat, ignition and lose of efficiency.

4.8 Do not get cells wet or throw them into water. When not in use, place the cells in a dry environment at low temperatures.

4.9 While during use, testing or storing cells, cells become hot, distribute a smell, change color, deform or show any other abnormalities, please stop using or testing immediately. Attempt to isolate the cell and keep it away from other cells.

4.10 Should electrolyte get into the eyes, do not rub the eyes, rinse the eyes with clean water and seek medical attention if problems remain. If electrolyte gets onto the skin or clothing, wash with clean water immediately.

5. BASIC CHARACTERISTICS

5.1 Capacity（25±5℃）	Nominal Capacity： 2600mAh (0.52A Discharge，2.75V) Typical Capacity： 2550mAh（0.52A Discharge，2.75V） Minimum Capacity：2500mAh (0.52A Discharge，2.75V)
5.2 Nominal Voltage	3.7V
5.3 Internal Impedance	≤ 70mΩ
5.4 Discharge Cut-off Voltage	3.0V
5.5 Max Charge Voltage	4.20±0.05V
5.6 Standard Charge Current	0.52A
5.7 Rapid Charge Current	1.3A
5.8 Standard Discharge Current	0.52A
5.9 Rapid Discharge Current	1.3A
5.10 Max Pulse Discharge Current	2.6A
5.11 Weight	46.5±1g
5.12 Max. Dimension	Diameter(Ø): 18.4mm Height (H): 65.2mm
5.13 Operating Temperature	Charge: 0 ~ 45℃ Discharge: -20 ~ 60℃
5.14 Storage Temperature	During 1 month: -5 ~ 35℃ During 6 months: 0 ~ 35℃

6. Standard conditions for test

All the tests need to be done within one month after the delivery date under the following conditions :
Ambient Temperature:25±5℃; Relative Huimdity:65±20%

Standard Charge	Constant Current and Constant Voltage (CC/CV) Current = 0.52A Final charge voltage = 4.2V Final charge Current = 0.052A
Standard Discharge	Constant Current (CC) Current = 0.52A End Voltage = 3.0V

7. Appearance

All surfaces must be clean, without damages, leakage and corrosion. Each product will have a product label identifying the model.

8. Characteristics

In this section, the Standard Conditions of Tests are used as described in part 6.

8.1 Electrical Performances

Items	**Test procedure**	**Requirements**
8.1.1 Nominal Voltage	The average value of the working voltage during the whole discharge process.	3.7V
8.1.2 Discharge Performance	The discharge capacity of the cell, measured with 1.3 A down to 3.0V within 1 hour after a completed charge.	≥114min
8.1.3 Capacity Retention	After 28 days storage at 25±5℃, after having been completely charged and discharged at 0.52A, discharge to 3.0V, the residual capacity is above 80%	Capacity≥2080mAh
8.1.4 Cycle Life	After 299 cycles at 100% DOD. Charge and discharge at 1.3A, and plus 1 day, measured under 0.52A charge and discharge, the residual discharge capacity is above 80% of initial capacity (Cycle life may be determined by conditions of charging, discharging, operating temperature and/or storage.)	300 cycles the residual capacity ≥2050mAh
8.1.5 Storage	(Within 3 months after manufactured) The cells is charged with 1.3A to 40-50% capacity and stored at ambient temperature 25±5℃, 65±20%RH for 12 months. After the 12 months storage period the cell is fully charged and discharged to 3.0V with 0.52A	Discharge time≥4h

8.2 Safety Performances

Items	**Test procedure**	**Requirements**
8.2.1 Short Circuit	The cell is to be short-circuited by connecting the positive and negative terminals of the cell directly with copper wire with a resistance of less than 0.05Ω.	No fire no explosion.
8.2.2 Impact Test	A test sample battery is to be placed on a flat surface. A 5/8 inch (15.8mm) diameter bar is to be placed across the center of the sample. A 20 pound (9.1kg) weight is to be dropped from a height of 24 ±1 inch (610±25mm) onto the sample.	No fire no explosion.

8.2.3 Overcharge (3C/10V)	The cell is connected with a thermocouple and put in a fume hood. The positive and negative terminals are connected to a DC power supply set at 7.8A and 10V until the cell reaches 10V and the current drops to approximately 0A. Monitor the temperature of cell. When the temperature of the cell is approximately 10℃ less than the peak value, the test is completed.	No fire, no explosion.
8.2.4 Thermal shock	After standard charging, heat the cell to 130±2℃ at a rate of 5±2℃ /min and keep it at this temperature during 30 minutes.	No fire, no explosion.

8.3 Environmental tests

Items	Test procedure	Requirements
8.3.1 High temperature performance	The fully charged cell is put at 55±2℃ for 2 hours and then discharged to 3.0V at 1.3A.	Capacity≥2080mAh
8.3.2 Low temperature performance	The fully charged cell is placed during 16-24 hours at -20±2℃ and then discharge to 2.75V at 0.52A.	Capacity≥1800mAh
8.3.3 Anti-vibration	The fully charged cell is fixed on a platform and vibrated in the X , Y and Z directions for 30minutes at the speed 10ct/min Frequency: 10~30Hz, Vibration amplitude 0.38mm. Frequency: 30~55Hz, Vibration amplitude 0.19mm.	No deformation should be visible. Not leak, smoke and/or explode. Voltage should be not less than 3.6V.
8.3.4 Drop Test	The fully charged cell is dropped from a height of 1m onto a 15~20mm hard board in X, Y and Z directions once for all axis. Then the cell is discharged at 1.3A to 3.0V followed by 3 or more cycles with the standard charge rate and a discharge at 1.3A.	No fire, no explosion. Discharge Time≥102min

9 . Packing

Cells are at a half-charged state when packed. The packing box surface will contain the following: name, type, nominal voltage, quantity, gross weight, date, capacity and impedance.

10 . Transportation

During transport, do not subject the cell(s) or the box (es) to violent shaking, bumps, rain and direct sunlight. Keep the cell(s) at a half-charged state.

11 . Long-term Storage

The cell should be used within a short period after charging because long-term storage may cause loss of capacity by self-discharging. If the cell is kept for a long time(3months or more), It is strongly recommended that the cell isstored at dry and low-temperature and Keep the cell(s) at a half-charged state. the cell should be shipped in 50% charged state. In this case, OCV is from 3.65V to 3.85V. Our shipping voltage is 3.75-3.80v . because storage at higher voltage may cause loss of characteristics.

- over a period of 1 month: -5 ~ 35℃, relative humidity: ≤75%. - over a period of 6 months: -20~ 25℃, relative humidity: ≤75%.

12 . Warranty

12.1 The warranty period of this product is 12 months starting at the date of delivery from the factory.

12.2 Warranty will be void if the cells are used outside these specifications.

12.3 EEMB will not be liable for any damages, personal, material, immaterial or otherwise, when the cells are used outside these specifications.

13 . Changes of specifications

The information in this specification is subject to change without prior notice.

14. For reference only

The information contained in this document is for reference only and should not be used as a basis for product guarantee or warranty. For applications other than those described here, please consult EEMB

15.Pack Quality Requirement for safety and quality

15.1 The battery pack's consumption current.

-Sleep Mode : Under 250uA.

-Shut Down Mode : Under 10uA / Under 3.0V.
Under 1uA / Under 2.5V.

15.2 Operating Charging Voltage of a cell.

-Normal operating voltage of a cell is 4.20V

-Max operating voltage of a cell is 4.25V.

15.3 Pre-charging function

-Pre-charge function should be implemented to prevent abnormal high rate charging after deep discharge.

-Pre-charging condition Operation : Under 3.0V

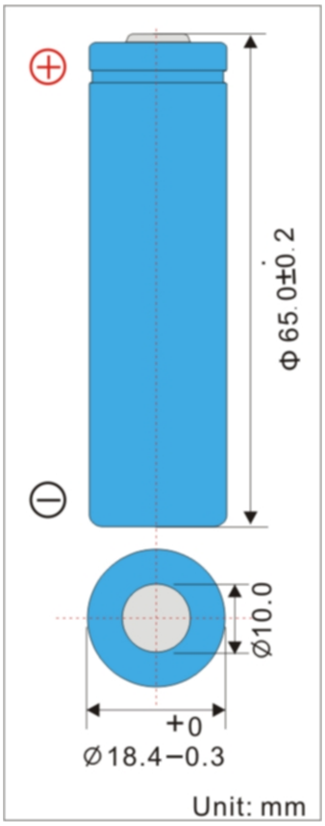
-Charging current : Under 150mA/Cell.(Continuous)

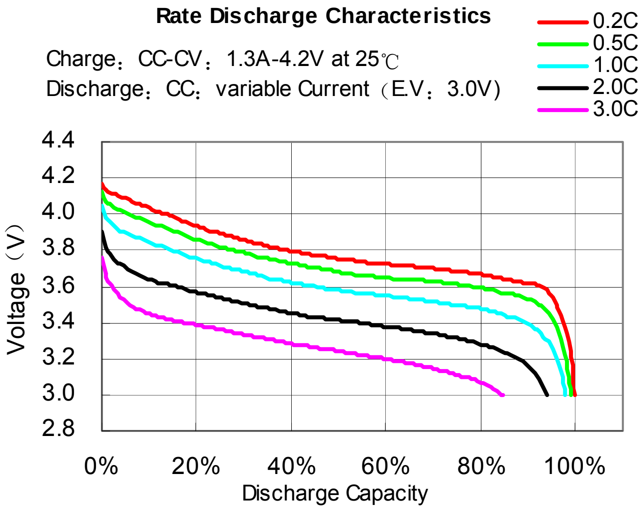
-Pre-charge stop (Normal Charge Start) : All cells reach 3.0V

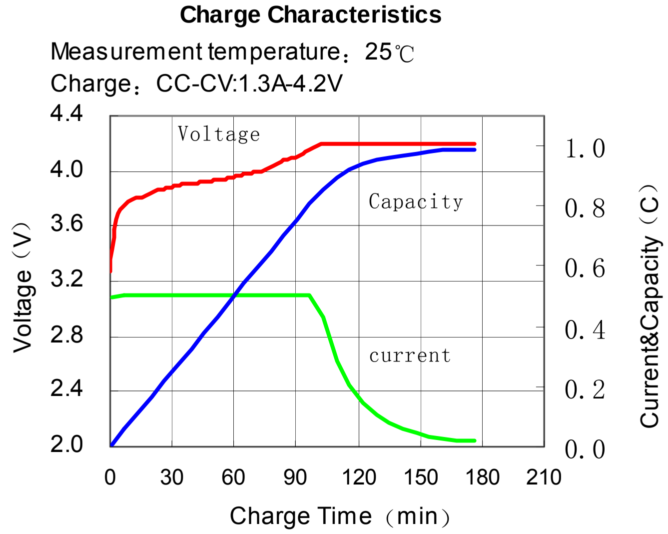
15.4. Cell voltage monitoring system.

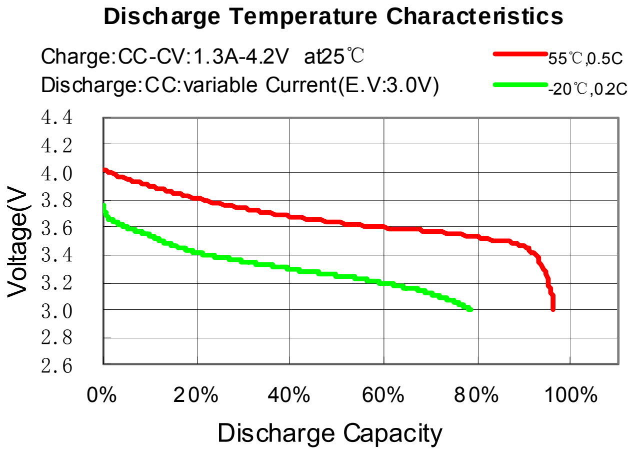
-The system (Charger or Pack) should equip a device to monitor each Cell voltage and to stop charging if a cell imbalance happened.

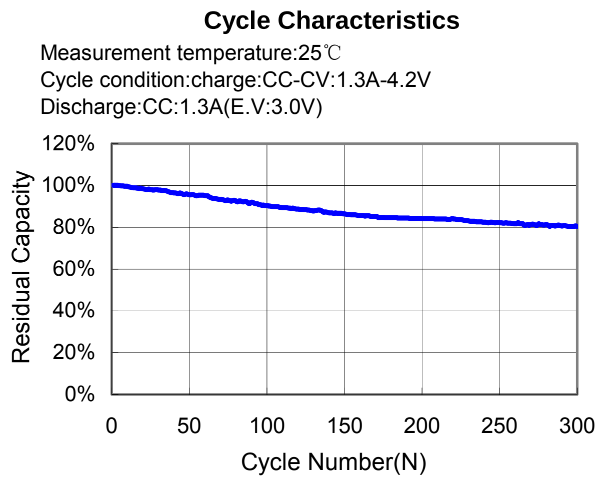
16. Dimension and Performance




Rate Discharge Characteristics
Charge：CC-CV：1.3A-4.2V at 25℃
Discharge：CC：variable Current（E.V：3.0V)
0.2C
0.5C
1.0C
2.0C
3.0C
Voltage（V）
Discharge Capacity


Charge Characteristics
Measurement temperature：25℃
Charge：CC-CV:1.3A-4.2V
Voltage
Capacity
current
Voltage（V）
Current&Capacity（C）
Charge Time（min）


Discharge Temperature Characteristics
Charge:CC-CV:1.3A-4.2V at25℃
Discharge:CC:variable Current(E.V:3.0V)
55℃,0.5C
-20℃,0.2C
Voltage(V
Discharge Capacity


Cycle Characteristics
Measurement temperature:25℃
Cycle condition:charge:CC-CV:1.3A-4.2V
Discharge:CC:1.3A(E.V:3.0V)
Residual Capacity
Cycle Number(N)

! Danger

- When charging the battery, use dedicated chargers and follow the specified conditions.
- Use the battery only in the specified equipment.
- Do not connect battery directly to an electric outlet or cigarette lighter charger.
- Do not heat or throw battery into a fire.
- Do not use, leave battery close to fire or inside of a car where temperature may be above 60℃. Also do not charge / discharge in such conditions.
- Do not immerse, throw, and wet battery in water/ seawater.
- Do not put batteries in your pockets or a bag together with metal objects such as necklaces. Hairpins, coins, or screws. Do not store batteries with such objects.
- Do not short circuit the (+) and (-) terminals with other metals.
- Do not place battery in a device with the (+) and (-) in the wrong way around.
- Do not pierce battery with a sharp object such as a needle.
- Do not hit with a hammer, step on or throw or drop to cause strong shock.
- Do not disassemble or modify the battery.
- Do not solder a battery directly.
- Do not use a battery with serious scar or deformation.
-

! Warning

- Do not put battery into a microware oven, dryer, or high-pressure container.
- Do not use battery with dry cells and other primary batteries, or batteries of a different package, type, or brand.
- Stop charging the battery if charging is not completed within the specified time.
- Stop using the battery if abnormal heat, odor, discoloration, deformation or abnormal condition is detected

During use, charge, or storage.

- Keep away from fire immediately when leakage or foul odor is detected.
- If liquid leaks onto your skin or clothes, wash well with fresh water immediately.

If liquid leaking from the battery gets into your eyes, do not rub your eyes. Wash them well with clean water and go to see a doctor immediately.

! Caution

- Store batteries out of reach of children so that they are not accidentally swallowed.
- If younger children use the battery, their guardians should explain the proper handling.
- Before using the battery, be sure to read the user's manual and cautions on handling thoroughly.
- Thoroughly read the user's manual for the charger before charging the battery.
- For information on installing and removing from equipment, thoroughly read the user's manual for the specific equipment.
- Batteries have life cycles. If the time that the battery powers equipment becomes much shorter than usual, the battery life is at an end. Replace the battery with a new same one.
- Remove a battery whose life cycle has expired from equipment immediately.
- When the battery is thrown away, be sure it is non-conducting by applying vinyl tape to the (+) and (-) terminals.
- When not using battery for an extended period, remove it from the equipment and store in a place

with low humidity and low temperature.

- While the battery pack is charged, used and stored, keep it away from objects or materials with static electric charges.
- If the terminals of the battery become dirty, wipe with a dry clothe before using the battery.
- The battery can be used within the following temperature ranges. Do not exceed these ranges.
  Charge temperature range : 0℃ to 45℃
  Discharge temperature range : -20℃ to 60℃
  (When using equipment)

! Special Notice

Keep the cells in 50% charged state during long period storage. We recommend to charge the battery up to 50% of the total capacity every 3 months after receipt of the battery and maintain the voltage 3.7~4.1V. And store the battery in cool and dry place.

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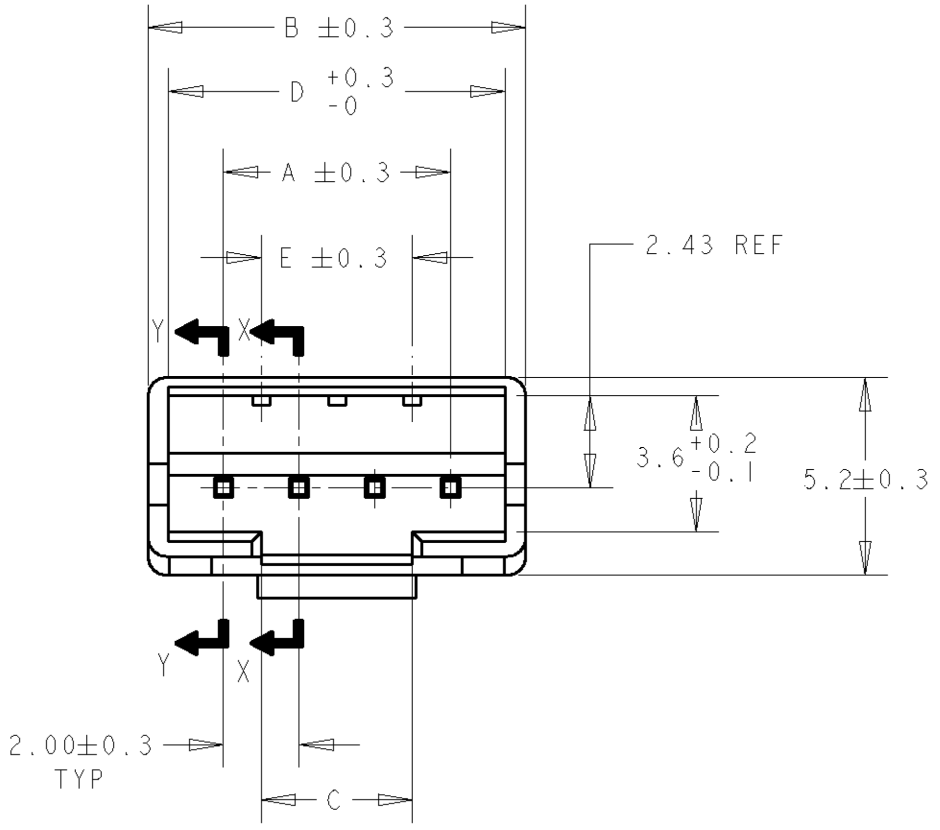
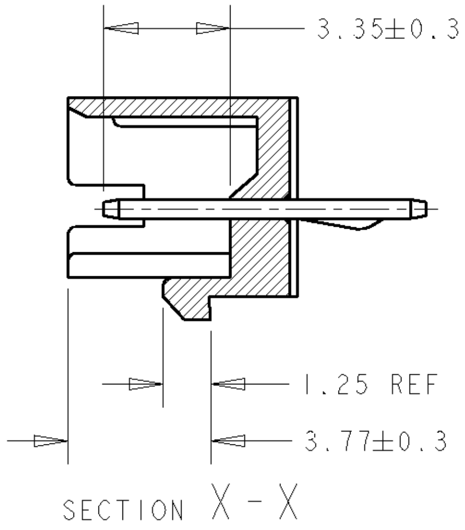
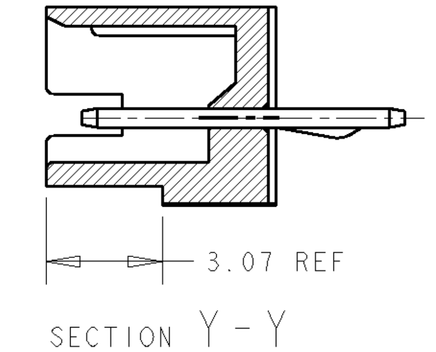
REVISIONS

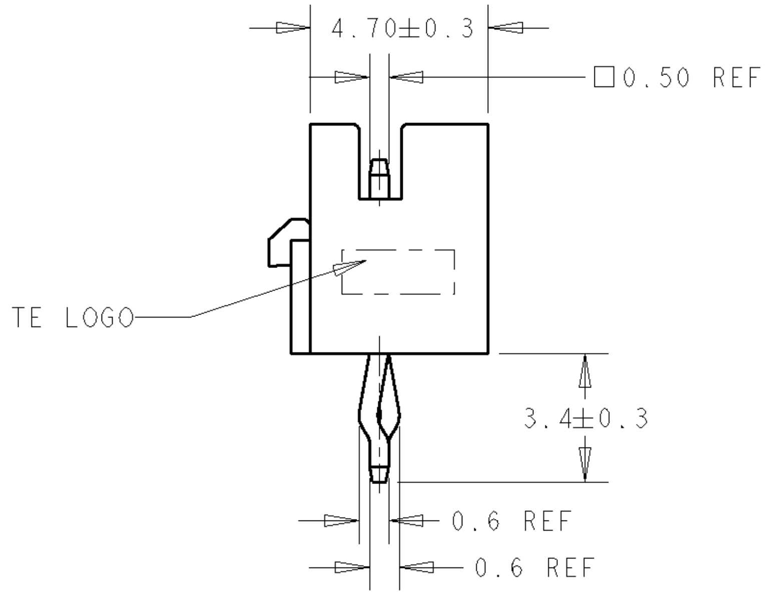
P	LTR	DESCRIPTION	DATE	DWN	APVD
	C1	REVISED PER ECO-11-005139	19MAR11	RK	HMR

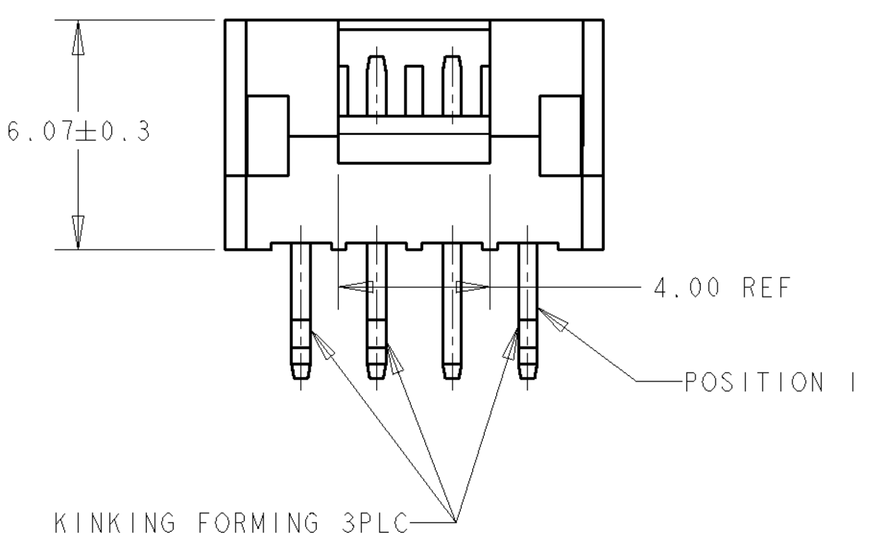
NOTE:
1. MATERIAL: THERMOPLASTIC, UL 94V-0
2. POST CONTACT: COPPER ALLOY
3. FINISH: BRIGHT TIN OVER NICKEL UNDERPLATE ALL OVER
4. SEE FIGURE I FOR KINK 'FOOTPRINT'
5. ⊕ KINK DIRECTION OPPOSITE FROM ●











COLOUR	E	D	C	B	A	POS	PART NUMBER
BLACK	28.0	33.0	28.0±0.2	34.0	30.00	16P	3-1735446-6
	26.0	31.0	26.0±0.2	32.0	28.00	15P	3-1735446-5
	24.0	29.0	24.0±0.2	30.0	26.00	14P	3-1735446-4
	22.0	27.0	22.0±0.2	28.0	24.00	13P	3-1735446-3
	20.0	25.0	20.0±0.2	26.0	22.00	12P	3-1735446-2
	18.0	23.0	18.0±0.2	24.0	20.00	11P	3-1735446-1
	16.0	21.0	16.0±0.2	22.0	18.00	10P	3-1735446-0
	14.0	19.0	14.0±0.2	20.0	16.00	9P	2-1735446-9
	12.0	17.0	12.0±0.2	18.0	14.00	8P	2-1735446-8
	10.0	15.0	10.0±0.2	16.0	12.00	7P	2-1735446-7
	8.0	13.0	8.0±0.2	14.0	10.00	6P	2-1735446-6
	6.0	11.0	6.0±0.2	12.0	8.00	5P	2-1735446-5
	4.0	9.0	4.0±0.2	10.0	6.00	4P	2-1735446-4
	2.0	7.0	$2.0^{+0.2}_{-0.08}$	8.0	4.00	3P	2-1735446-3
NATURAL	28.0	33.0	28.0±0.2	34.0	30.00	16P	1-1735446-6
	26.0	31.0	26.0±0.2	32.0	28.00	15P	1-1735446-5
	24.0	29.0	24.0±0.2	30.0	26.00	14P	1-1735446-4
	22.0	27.0	22.0±0.2	28.0	24.00	13P	1-1735446-3
	20.0	25.0	20.0±0.2	26.0	22.00	12P	1-1735446-2
	18.0	23.0	18.0±0.2	24.0	20.00	11P	1-1735446-1
	16.0	21.0	16.0±0.2	22.0	18.00	10P	1-1735446-0
	14.0	19.0	14.0±0.2	20.0	16.00	9P	1735446-9
	12.0	17.0	12.0±0.2	18.0	14.00	8P	1735446-8
	10.0	15.0	10.0±0.2	16.0	12.00	7P	1735446-7
	8.0	13.0	8.0±0.2	14.0	10.00	6P	1735446-6
	6.0	11.0	6.0±0.2	12.0	8.00	5P	1735446-5
	4.0	9.0	4.0±0.2	10.0	6.00	4P	1735446-4
	2.0	7.0	$2.0^{+0.2}_{-0.08}$	8.0	4.00	3P	1735446-3

DIMENSIONS: mm

TOLERANCES UNLESS OTHERWISE SPECIFIED:
0 PLC ±-
1 PLC ±-
2 PLC ±-
3 PLC ±-
4 PLC ±
ANGLES ±

MATERIAL 1 2

FINISH 3

DWN WYLEE 14 NOV 2006
CHK KT GOH 11 APR 2007
APVD SF LEONG 1 JUN 2007

PRODUCT SPEC 108-51087

APPLICATION SPEC -

WEIGHT -

CUSTOMER DRAWING

TE Connectivity

NAME 2.0mm PITCH HPI POST HEADER WITH LOCK, VERTICAL

SIZE	CAGE CODE	DRAWING NO
A3	00779	C 1735446

SCALE 5:1 SHEET 1 OF 2 REV C1

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LOC	DIST
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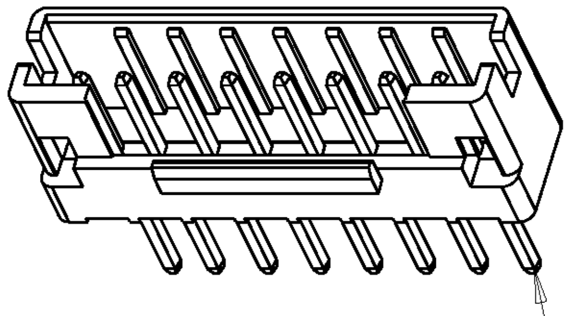
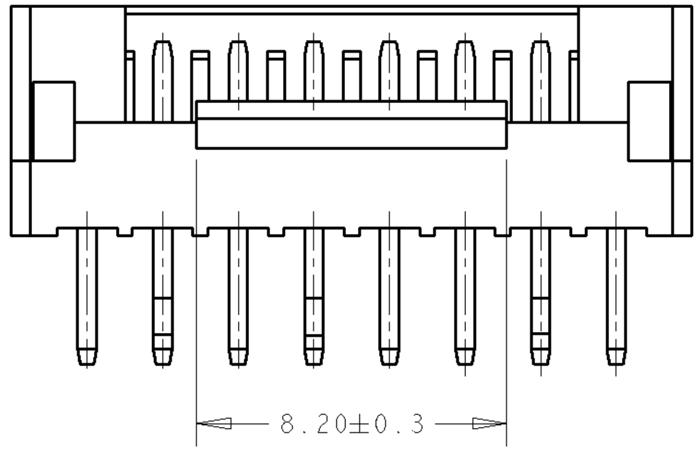
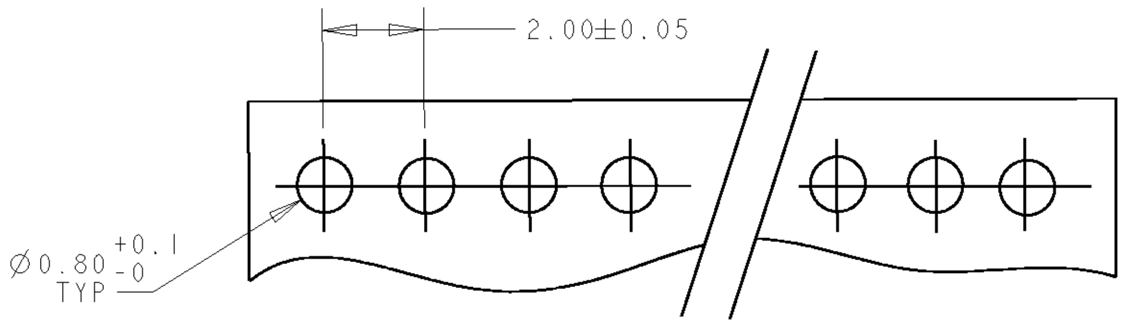
REVISIONS

P	LTR	DESCRIPTION	DATE	DWN	APVD
		SEE SHEET 1			



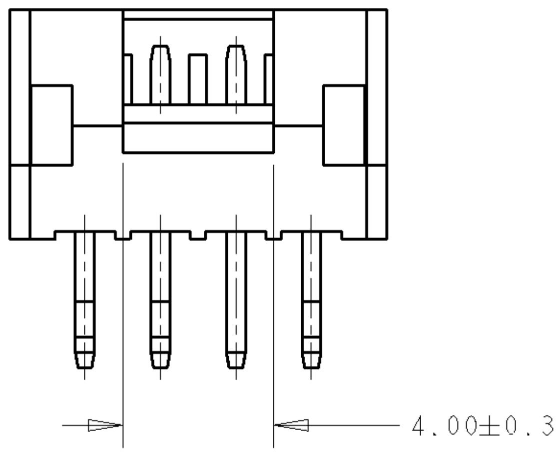


7~16P

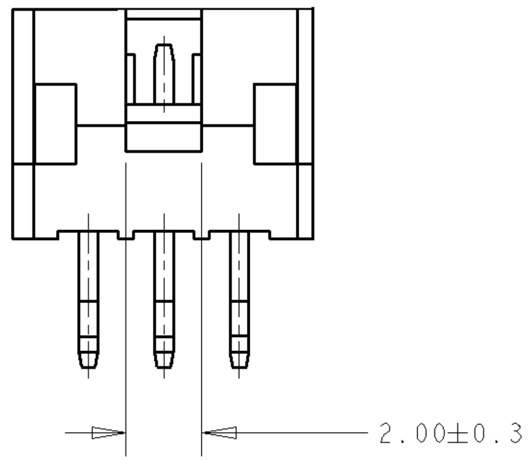


RECOMMENDED PCB LAYOUT

(NON ACCUMULATIVE TOLARANCE)
(PCB THK = 1.0~1.6mm)



4~6P



3P

FIG.1 5

3P	●	⊕	●													
4P	●	○	⊕	●												
5P	●	○	⊕	○	●											
6P	●	○	○	⊕	○	●										
7P	○	●	○	⊕	○	●	○									
8P	○	●	○	○	⊕	○	●	○								
9P	○	●	○	○	⊕	○	○	●	○							
10P	○	●	○	○	○	⊕	○	○	●	○						
11P	○	●	○	○	○	⊕	○	○	○	●	○					
12P	○	●	○	○	○	○	⊕	○	○	○	●	○				
13P	○	●	○	○	○	○	⊕	○	○	○	○	●	○			
14P	○	●	○	○	○	○	○	⊕	○	○	○	○	●	○		
15P	○	●	○	○	○	○	○	⊕	○	○	○	○	○	●	○	
16P	○	●	○	○	○	○	○	○	⊕	○	○	○	○	○	●	○
POS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

DIMENSIONS: mm	TOLERANCES UNLESS OTHERWISE SPECIFIED: 0 PLC ±- 1 PLC ±- 2 PLC ±- 3 PLC ±- 4 PLC ± ANGLES ±
MATERIAL: SEE SHEET 1	FINISH: SEE SHEET 1

DWN	WYLEE	14 NOV 2006
CHK	KT GOH	11 APR 2007
APVD	SF LEONG	1 JUN 2007
PRODUCT SPEC	108-51087	
APPLICATION SPEC	-	
WEIGHT	-	
CUSTOMER DRAWING		

TE Connectivity

NAME: 2.0mm PITCH HPI POST HEADER WITH LOCK, VERTICAL

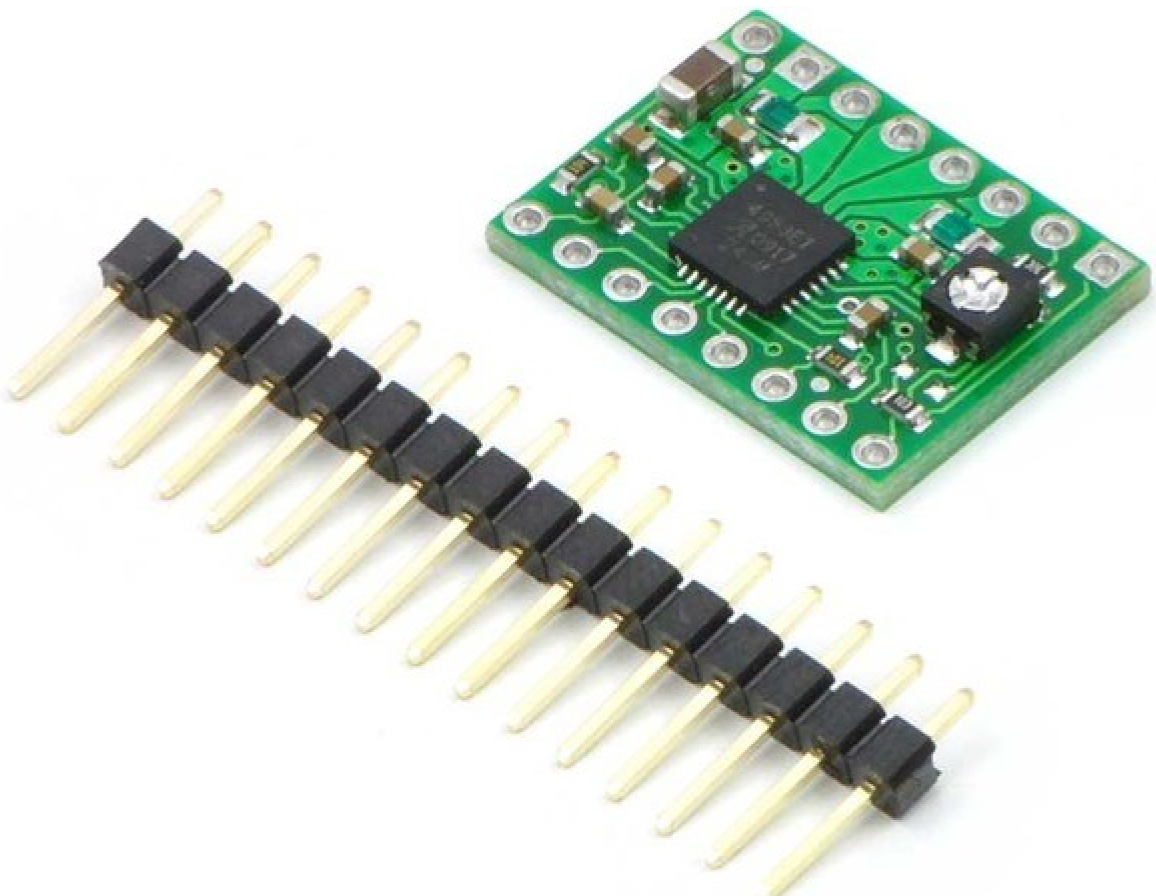
SIZE	CAGE CODE	DRAWING NO
A3	00779	C-1735446

SCALE	SHEET	REV
5:1	2 OF 2	C1

AMP 1470-19 REV 09MAY94

RB-Pol-176

Pololu 8-35V 2A Single Bipolar Stepper Motor Driver A4988



A4988

Stepper Motor Driver Carrier

The A4988 stepper motor driver carrier is a breakout board for Allegro's easy-to-use A4988 microstepping bipolar stepper motor driver and is a drop-in replacement for the A4983 stepper motor driver carrier. The driver features adjustable current limiting, overcurrent protection, and five different microstep resolutions. It operates from 8 – 35 V and can deliver up to 2 A per coil.

Note: This board is a drop-in replacement for the original A4983 stepper motor driver carrier. The newer A4988 offers overcurrent protection and has an internal 100k pull-down on the MS1 microstep selection pin, but it is otherwise virtually identical to the A4983.

Description

Overview

This product is a carrier board or breakout board for Allegro's A4988 DMOS Microstepping Driver with Translator and Overcurrent Protection; we therefore recommend careful reading of the A4988 datasheet (380k pdf) before using this product. This stepper motor driver lets you control one bipolar stepper motor at up to 2 A output current per coil (see the Power Dissipation Considerations section below for more information). Here are some of the driver's key features:

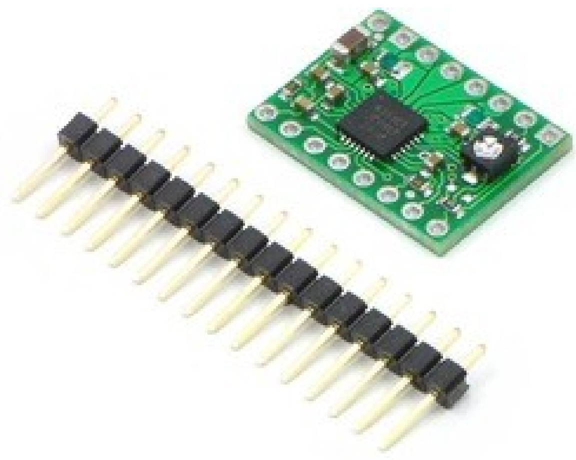
- Simple step and direction control interface
- Five different step resolutions: full-step, half-step, quarter-step, eighth-step, and sixteenth-step
- Adjustable current control lets you set the maximum current output with a potentiometer, which lets you use voltages above your stepper motor's rated voltage to achieve higher step rates
- Intelligent chopping control that automatically selects the correct current decay mode (fast decay or slow decay)
- Over-temperature thermal shutdown, under-voltage lockout, and crossover-current protection
- Short-to-ground and shorted-load protection (this feature is not available on the A4983)

Like nearly all our other carrier boards, this product ships with all surface-mount components —including the A4988 driver IC—installed as shown in the product picture.

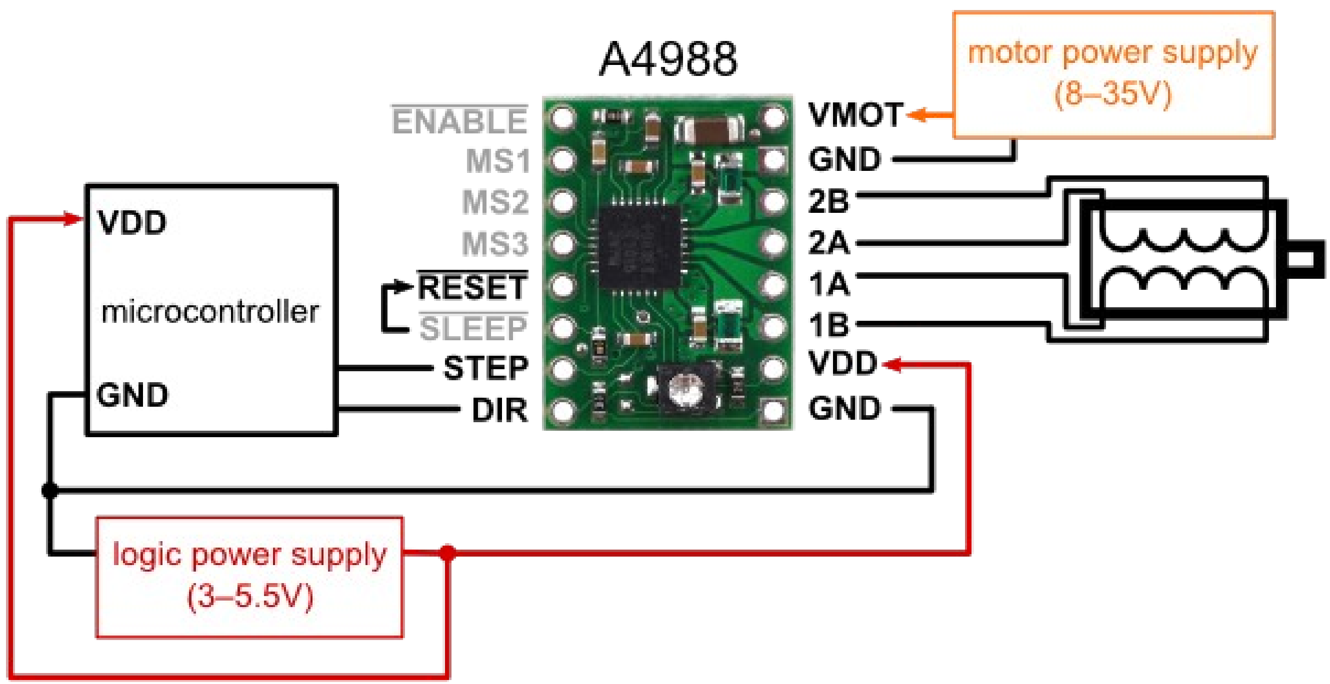
We also sell a larger version of the A4988 carrier that has reverse power protection on the main power input and built-in 5 V and 3.3 V voltage regulators that eliminate the need for separate logic and motor supplies.

Included hardware

The A4988 stepper motor driver carrier comes with one 1×16-pin breakaway 0.1" male header. The headers can be soldered in for use with solderless breadboards or 0.1" female connectors. You can also solder your motor leads and other connections directly to the board.



Using the driver



Minimal wiring diagram for connecting a microcontroller to an A4988 stepper motor driver carrier (full-step mode).

Power connections

The driver requires a logic supply voltage (3 – 5.5 V) to be connected across the VDD and GND pins and a motor supply voltage of (8 – 35 V) to be connected across VMOT and GND. These supplies should have appropriate decoupling capacitors close to the board, and they should be capable of delivering the expected currents (peaks up to 4 A for the motor supply).

Motor connections

Four, six, and eight-wire stepper motors can be driven by the A4988 if they are properly connected; a FAQ answer explains the proper wirings in detail.
Warning: Connecting or disconnecting a stepper motor while the driver is powered can destroy the driver. (More generally, rewiring anything while it is powered is asking for trouble.)

Warning: Connecting or disconnecting a stepper motor while the driver is powered can destroy the driver. (More generally, rewiring anything while it is powered is asking for trouble.)

Step (and microstep) size

Stepper motors typically have a step size specification (e.g. 1.8° or 200 steps per revolution), which applies to full steps. A microstepping driver such as the A4988 allows higher resolutions by allowing intermediate step locations, which are achieved by energizing the coils with intermediate current levels. For instance, driving a motor in quarter-step mode will give the 200-step-per-revolution motor 800 microsteps per revolution by using four different current levels.

The resolution (step size) selector inputs (MS1, MS2, MS3) enable selection from the five step resolutions according to the table below. MS1 and MS3 have internal 100kΩ pull-down resistors and MS2 has an internal 50kΩ pull-down resistor, so leaving these three microstep selection pins disconnected results in full-step mode. For the microstep modes to function correctly, the current limit must be set low enough (see below) so that current limiting gets engaged. Otherwise, the intermediate current levels will not be correctly maintained, and the motor will effectively operate in a full-step mode.

MS1	MS2	MS3	Microstep Resolution
Low	Low	Low	Full step
High	Low	Low	Half step
Low	High	Low	Quarter step
High	High	Low	Eighth step
High	High	High	Sixteenth step

Control inputs

Each pulse to the STEP input corresponds to one microstep of the stepper motor in the direction selected by the DIR pin. Note that the STEP and DIR pins are not pulled to any particular voltage internally, so you should not leave either of these pins floating in your application. If you just want rotation in a single direction, you can tie DIR directly to VCC or

GND. The chip has three different inputs for controlling its many power states: RST, SLP, and EN. For details about these power states, see the datasheet. Please note that the RST pin is floating; if you are not using the pin, you can connect it to the adjacent SLP pin on the PCB.

Current limiting

To achieve high step rates, the motor supply is typically much higher than would be permissible without active current limiting. For instance, a typical stepper motor might have a maximum current rating of 1 A with a 5Ω coil resistance, which would indicate a maximum motor supply of 5 V. Using such a motor with 12 V would allow higher step rates, but the current must actively be limited to under 1 A to prevent damage to the motor.

The A4988 supports such active current limiting, and the trimmer potentiometer on the board can be used to set the current limit. One way to set the current limit is to put the driver into full-step mode and to measure the current running through a single motor coil without clocking the STEP input. The measured current will be 0.7 times the current limit (since both coils are always on and limited to 70% in full-step mode). Please note that the current limit is dependent on the Vdd voltage.

Another way to set the current limit is to measure the voltage on the “ref” pin and to calculate the resulting current limit (the current sense resistors are 0.05Ω). The ref pin voltage is accessible on a via that is circled on the bottom silkscreen of the circuit board. See the A4988 datasheet for more information.

Power dissipation considerations

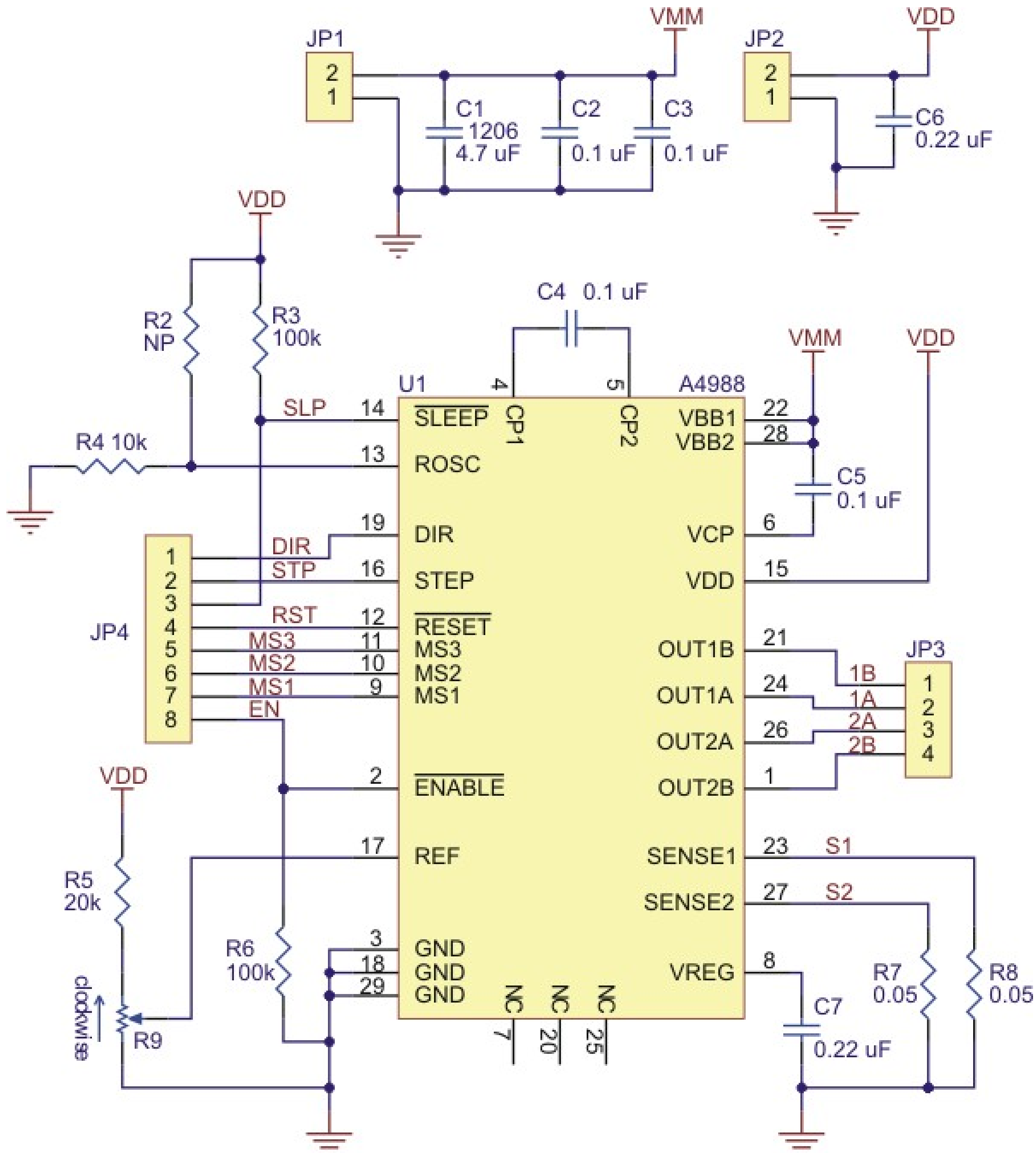
The A4988 driver IC has a maximum current rating of 2 A per coil, but the actual current you can deliver depends on how well you can keep the IC cool. The carrier’s printed circuit board is designed to draw heat out of the IC, but to supply more than approximately 1 A per coil, a heat sink or other cooling method is required.

This product can get hot enough to burn you long before the chip overheats. Take care when handling this product and other components connected to it.

Please note that measuring the current draw at the power supply does not necessarily provide an accurate measure of the coil current. Since the input voltage to the driver can be significantly higher than the coil voltage, the measured current on the power supply can be quite a bit lower than the coil current (the driver and coil basically act like a switching step-down power supply). Also, if the supply voltage is very high compared to what the motor needs to achieve the set current, the duty cycle will be very low, which also leads to significant differences between average and RMS currents.

Schematic diagram

Schematic diagram of the md09b A4988 stepper motor driver carrier.



LM340, LM340A and LM7805 Family Wide V_{IN} 1.5-A Fixed Voltage Regulators

1 Features

- Output Current up to 1.5 A
- Available in Fixed 5-V, 12-V, and 15-V Options
- Output Voltage Tolerances of ±2% at T_J = 25°C (LM340A)
- Line Regulation of 0.01% / V of at 1-A Load (LM340A)
- Load Regulation of 0.3% / A (LM340A)
- Internal Thermal Overload, Short-Circuit and SOA Protection
- Available in Space-Saving SOT-223 Package
- Output Capacitance Not Required for Stability

2 Applications

- Industrial Power Supplies
- SMPS Post Regulation
- HVAC Systems
- AC Inventors
- Test and Measurement Equipment
- Brushed and Brushless DC Motor Drivers
- Solar Energy String Invertors

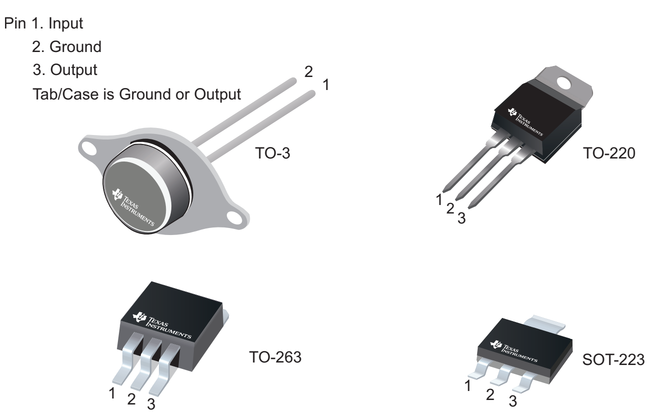
3 Description

The LM340 and LM7805 Family monolithic 3-terminal positive voltage regulators employ internal current-limiting, thermal shutdown and safe-area compensation, making them essentially indestructible. If adequate heat sinking is provided, they can deliver over 1.5-A output current. They are intended as fixed voltage regulators in a wide range of applications including local (on-card) regulation for elimination of noise and distribution problems associated with single-point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents.

Considerable effort was expended to make the entire series of regulators easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

LM7805 is also available in a higher accuracy and better performance version (LM340A). Refer to LM340A specifications in the *LM340A Electrical Characterisitcs* table.

Available Packages

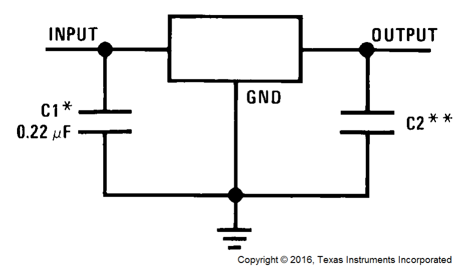


Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM340x LM7805 Family	DDPAK/TO-263 (3)	10.18 mm × 8.41 mm
	SOT-223 (4)	6.50 mm × 3.50 mm
	TO-220 (3)	14.986 mm × 10.16 mm
	TO-3 (2)	38.94 mm x 25.40 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Fixed Output Voltage Regulator



*Required if the regulator is located far from the power supply filter.
**Although no output capacitor is needed for stability, it does help transient response. (If needed, use 0.1-μF, ceramic disc).

Table of Contents

4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

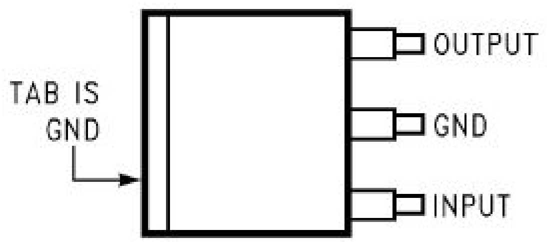
Changes from Revision K (November 2015) to Revision L	Page
• Changed pinout number order for the TO-220 and SOT-223 packages from: 2, 3, 1 to: 1, 2, 3	1

Changes from Revision J (December 2013) to Revision K	Page
• Added *ESD Ratings* table, *Thermal Information* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section	1
• Deleted obsolete LM140 and LM7808C devices from the data sheet	1
• Changed Figure 13 caption from *Line Regulation 140AK-5.0* to *Line Regulation LM340,*	11
• Changed Figure 14 caption from *Line Regulation 140AK-5.0* to *Line Regulation LM340,*	11

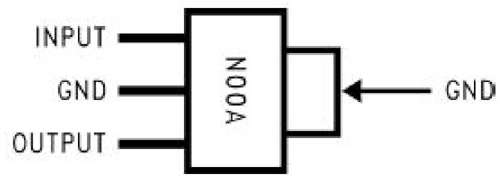
Changes from Revision I (March 2013) to Revision J	Page
• Changed 0.5 from typ to max	5

5 Pin Configuration and Functions

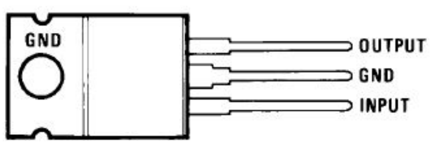
LM7805 and LM7812 KTT Package
3-Pin DDPAK/TO-263
Top View



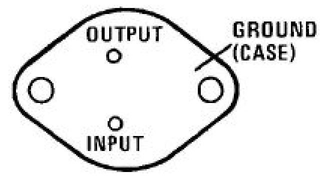
LM7805 DCY Package
4-Pin SOT-223
Side View



LM7805, LM7812, and LM7815 NDE Package
3-Pin TO-220
Top View



LM340K-5.0 NDS Package
2-Pin TO-3
Top View



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
INPUT	1	I	Input voltage pin
GND	2	I/O	Ground pin
OUTPUT	3	O	Output voltage pin

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)(2)

		MIN	MAX	UNIT
DC input voltage			35	V
Internal power dissipation(3)		Internally Limited		
Maximum junction temperature			150	°C
Lead temperature (soldering, 10 sec.)	TO-3 package (NDS)		300	°C
	Lead temperature 1,6 mm (1/16 in) from case for 10 s		230	°C
Storage temperature		−65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/Distributors for availability and specifications.
(3) The maximum allowable power dissipation at any ambient temperature is a function of the maximum junction temperature for operation (T_{JMAX} = 125°C or 150°C), the junction-to-ambient thermal resistance (θ_{JA}), and the ambient temperature (T_A). $P_{DMAX} = (T_{JMAX} - T_A)/\theta_{JA}$. If this dissipation is exceeded, the die temperature rises above T_{JMAX} and the electrical specifications do not apply. If the die temperature rises above 150°C, the device goes into thermal shutdown. For the TO-3 package (NDS), the junction-to-ambient thermal resistance (θ_{JA}) is 39°C/W. When using a heat sink, θ_{JA} is the sum of the 4°C/W junction-to-case thermal resistance (θ_{JC}) of the TO-3 package and the case-to-ambient thermal resistance of the heat sink. For the TO-220 package (NDE), θ_{JA} is 54°C/W and θ_{JC} is 4°C/W. If SOT-223 is used, the junction-to-ambient thermal resistance is 174°C/W and can be reduced by a heat sink (see Applications Hints on heat sinking).If the DDPAK\TO-263 package is used, the thermal resistance can be reduced by increasing the PCB copper area thermally connected to the package: Using 0.5 square inches of copper area, θ_{JA} is 50°C/W; with 1 square inch of copper area, θ_{JA} is 37°C/W; and with 1.6 or more inches of copper area, θ_{JA} is 32°C/W.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM)(1)	±2000	V

(1) ESD rating is based on the human-body model, 100 pF discharged through 1.5 kΩ.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
Temperature (T_A)	LM340A, LM340	0	125	°C

6.4 Thermal Information

THERMAL METRIC(1)		LM340, LM7805 Family				UNIT
		NDE (TO-220)	KTT (DDPAK/TO-263)	DCY (SOT-223)	NDS (TO-3)	
		3 PINS	3 PINS	4 PINS	2 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	23.9	44.8	62.1	39	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	16.7	45.6	44	2	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	5.3	24.4	10.7	—	°C/W
ψ_{JT}	Junction-to-top characterization parameter	3.2	11.2	2.7	—	°C/W
ψ_{JB}	Junction-to-board characterization parameter	5.3	23.4	10.6	—	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	1.7	1.5	—	—	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

6.5 LM340A Electrical Characteristics, V_O = 5 V, V_I = 10 V

I_{OUT} = 1 A, 0°C ≤ T_J ≤ 125°C (LM340A) unless otherwise specified(1)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_O	Output voltage	T_J = 25°C		4.9	5	5.1	V
		P_D ≤ 15 W, 5 mA ≤ I_O ≤ 1 A 7.5 V ≤ V_{IN} ≤ 20 V		4.8		5.2	V
ΔV_O	Line regulation	7.5 V ≤ V_{IN} ≤ 20 V	T_J = 25°C		3	10	mV
			Over temperature, I_O = 500 mA			10	mV
		8 V ≤ V_{IN} ≤ 12 V	T_J = 25°C			4	mV
			Over temperature			12	mV
ΔV_O	Load regulation	T_J = 25°C	5 mA ≤ I_O ≤ 1.5 A		10	25	mV
			250 mA ≤ I_O ≤ 750 mA			15	mV
		Over temperature, 5 mA ≤ I_O ≤ 1 A				25	mV
I_Q	Quiescent current	T_J = 25°C				6	mA
		Over temperature				6.5	mA
ΔI_Q	Quiescent current change	T_J = 25°C, I_O = 1 A 7.5 V ≤ V_{IN} ≤ 20 V				0.8	mA
		Over temperature, 5 mA ≤ I_O ≤ 1 A				0.5	mA
		Over temperature, I_O = 500 mA 8 V ≤ V_{IN} ≤ 25 V				0.8	mA
V_N	Output noise voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			40		µV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple rejection	f = 120 Hz 8 V ≤ V_{IN} ≤ 18 V	T_J = 25°C, , I_O = 1 A	68	80		dB
			Over temperature, I_O = 500 mA	68			dB
R_O	Dropout voltage	T_J = 25°C, I_O = 1 A			2		V
	Output resistance	f = 1 kHz			8		mΩ
	Short-circuit current	T_J = 25°C			2.1		A
	Peak output current	T_J = 25°C			2.4		A
	Average TC of V_O	Min, T_J = 0°C, I_O = 5 mA			−0.6		mV/°C
V_{IN}	Input voltage required to maintain line regulation	T_J = 25°C		7.5			V

(1) All characteristics are measured with a 0.22-µF capacitor from input to ground and a 0.1-µF capacitor from output to ground. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

6.6 LM340 / LM7805 Electrical Characteristics, V_O = 5 V, V_I = 10 V

0°C ≤ T_J ≤ 125°C unless otherwise specified(1)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_O	Output voltage	T_J = 25°C, 5 mA ≤ I_O ≤ 1 A		4.8	5	5.2	V
		P_D ≤ 15 W, 5 mA ≤ I_O ≤ 1 A 7.5 V ≤ V_{IN} ≤ 20 V		4.75		5.25	V
ΔV_O	Line regulation	I_O = 500 mA	T_J = 25°C 7V ≤ V_{IN} ≤ 25V		3	50	mV
			Over temperature 8V ≤ V_{IN} ≤ 20V			50	mV
		I_O ≤ 1 A	T_J = 25°C 7.5V ≤ V_{IN} ≤ 20V			50	mV
			Over temperature 8V ≤ V_{IN} ≤ 12V			25	mV
ΔV_O	Load regulation	T_J = 25°C	5 mA ≤ I_O ≤ 1.5 A		10	50	mV
			250 mA ≤ I_O ≤ 750 mA			25	mV
		Over temperature, 5 mA ≤ I_O ≤ 1 A				50	mV
I_Q	Quiescent current	I_O ≤ 1 A	T_J = 25°C			8	mA
			Over temperature			8.5	mA
ΔI_Q	Quiescent current change	0°C ≤ T_J ≤ 125°C, 5 mA ≤ I_O ≤ 1 A			0.5		mA
		7 V ≤ V_{IN} ≤ 20 V	T_J = 25°C, I_O ≤ 1 A			1	mA
			Over temperature, I_O ≤ 500 mA			1	mA
V_N	Output noise voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			40		µV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple rejection	f = 120 Hz 8 V ≤ V_{IN} ≤ 18 V	T_J = 25°C, I_O ≤ 1 A	62	80		dB
			Over temperature, I_O ≤ 500 mA	62			dB
R_O	Dropout voltage	T_J = 25°C, I_O = 1 A			2		V
	Output resistance	f = 1 kHz			8		mΩ
	Short-circuit current	T_J = 25°C			2.1		A
	Peak output current	T_J = 25°C			2.4		A
	Average TC of V_{OUT}	Over temperature, I_O = 5 mA			−0.6		mV/°C
V_{IN}	Input voltage required to maintain line regulation	T_J = 25°C, I_O ≤ 1 A		7.5			V

(1) All characteristics are measured with a 0.22-µF capacitor from input to ground and a 0.1-µF capacitor from output to ground. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

6.7 LM340 / LM7812 Electrical Characteristics, V_O = 12 V, V_I = 19 V

0°C ≤ T_J ≤ 125°C unless otherwise specified[(1)]

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_O	Output voltage	T_J = 25°C, 5 mA ≤ I_O ≤ 1 A		11.5	12	12.5	V
		P_D ≤ 15 W, 5 mA ≤ I_O ≤ 1 A 14.5 V ≤ V_{IN} ≤ 27 V		11.4		12.6	V
ΔV_O	Line regulation	I_O = 500 mA	T_J = 25°C 14.5V ≤ V_{IN} ≤ 30V		4	120	mV
			Over temperature 15V ≤ V_{IN} ≤ 27V			120	mV
		I_O ≤ 1 A	T_J = 25°C 14.6V ≤ V_{IN} ≤ 27V			120	mV
			Over temperature 16V ≤ V_{IN} ≤ 22V			60	mV
ΔV_O	Load regulation	T_J = 25°C	5 mA ≤ I_O ≤ 1.5 A		12	120	mV
			250 mA ≤ I_O ≤ 750 mA			60	mV
		Over temperature, 5 mA ≤ I_O ≤ 1 A				120	mV
I_Q	Quiescent current	I_O ≤ 1 A	T_J = 25°C			8	mA
			Over temperature			8.5	mA
ΔI_Q	Quiescent current change	5 mA ≤ I_O ≤ 1 A			0.5		mA
		T_J = 25°C, I_O ≤ 1 A 14.8 V ≤ V_{IN} ≤ 27 V				1	mA
		Over temperature, I_O ≤ 500 mA 14.5 V ≤ V_{IN} ≤ 30 V				1	mA
V_N	Output noise voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			75		µV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple rejection	f = 120 Hz 15 V ≤ V_{IN} ≤ 25 V	T_J = 25°C, I_O ≤ 1 A	55	72		dB
			Over temperature, I_O ≤ 500 mA,	55			dB
R_O	Dropout voltage	T_J = 25°C, I_O = 1 A			2		V
	Output resistance	f = 1 kHz			18		mΩ
	Short-circuit current	T_J = 25°C			1.5		A
	Peak output current	T_J = 25°C			2.4		A
	Average TC of V_{OUT}	Over temperature, I_O = 5 mA			−1.5		mV/°C
V_{IN}	Input voltage required to maintain line regulation	T_J = 25°C, I_O ≤ 1 A		14.6			V

(1) All characteristics are measured with a 0.22-µF capacitor from input to ground and a 0.1-µF capacitor from output to ground. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

6.8 LM340 / LM7815 Electrical Characteristics, V_O = 15 V, V_I = 23 V

0°C ≤ T_J ≤ 125°C unless otherwise specified(1)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_O	Output voltage	T_J = 25°C, 5 mA ≤ I_O ≤ 1 A		14.4	15	15.6	V
		P_D ≤ 15 W, 5 mA ≤ I_O ≤ 1 A 17.5 V ≤ V_{IN} ≤ 30 V		14.25		15.75	V
ΔV_O	Line regulation	I_O = 500 mA	T_J = 25°C 17.5 V ≤ V_{IN} ≤ 30 V		4	150	mV
			Over temperature 18.5 V ≤ V_{IN} ≤ 30 V			150	mV
		I_O ≤ 1 A	T_J = 25°C 17.7 V ≤ V_{IN} ≤ 30 V			150	mV
			Over temperature 20 V ≤ V_{IN} ≤ 26 V			75	mV
ΔV_O	Load regulation	T_J = 25°C	5 mA ≤ I_O ≤ 1.5 A		12	150	mV
			250 mA ≤ I_O ≤ 750 mA			75	mV
		Over temperature, 5 mA ≤ I_O ≤ 1 A,				150	mV
I_Q	Quiescent current	I_O ≤ 1 A	T_J = 25°C			8	mA
			Over temperature			8.5	mA
ΔI_Q	Quiescent current change	5 mA ≤ I_O ≤ 1 A				0.5	mA
		T_J = 25°C, I_O ≤ 1 A 17.9 V ≤ V_{IN} ≤ 30 V				1	mA
		Over temperature, I_O ≤ 500 mA 17.5 V ≤ V_{IN} ≤ 30 V				1	mA
V_N	Output noise voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			90		μV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple rejection	f = 120 Hz 18.5 V ≤ V_{IN} ≤ 28.5 V	T_J = 25°C, I_O ≤ 1 A	54	70		dB
			Over temperature, I_O ≤ 500 mA,	54			dB
R_O	Dropout voltage	T_J = 25°C, I_O = 1 A			2		V
	Output resistance	f = 1 kHz			19		mΩ
	Short-circuit current	T_J = 25°C			1.2		A
	Peak output current	T_J = 25°C			2.4		A
	Average TC of V_{OUT}	Over temperature, I_O = 5 mA			−1.8		mV/°C
V_{IN}	Input voltage required to maintain line regulation	T_J = 25°C, I_O ≤ 1 A		17.7			V

(1) All characteristics are measured with a 0.22-μF capacitor from input to ground and a 0.1-μF capacitor from output to ground. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

6.9 Typical Characteristics

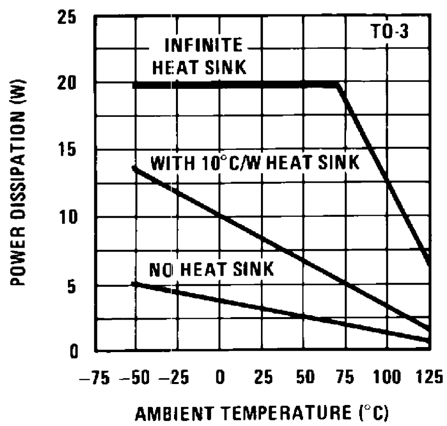


Figure 1. Maximum Average Power Dissipation

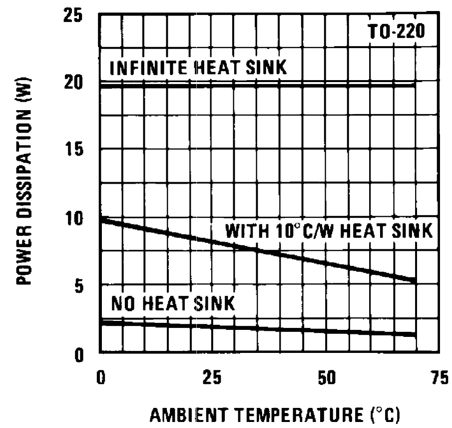


Figure 2. Maximum Average Power Dissipation

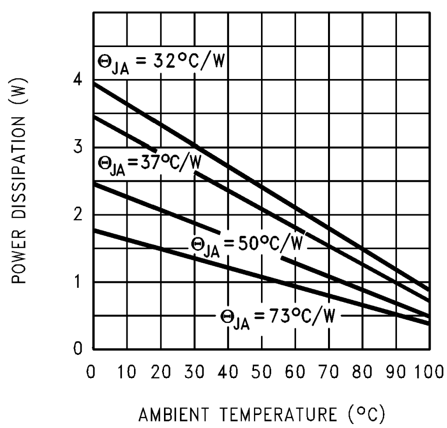
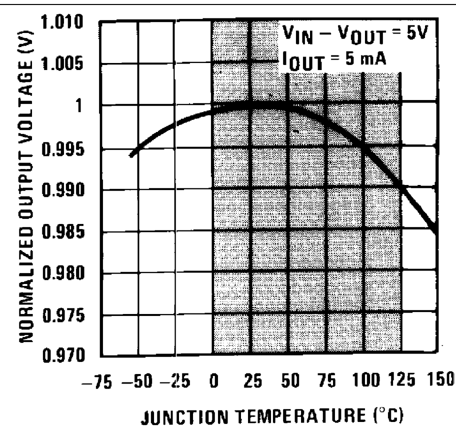


Figure 3. Maximum Power Dissipation (DDPAK/TO-263)



Shaded area refers to LM340A/LM340, LM7805, LM7812 and LM7815.

Figure 4. Output Voltage (Normalized to 1 V at T_J = 25°C)

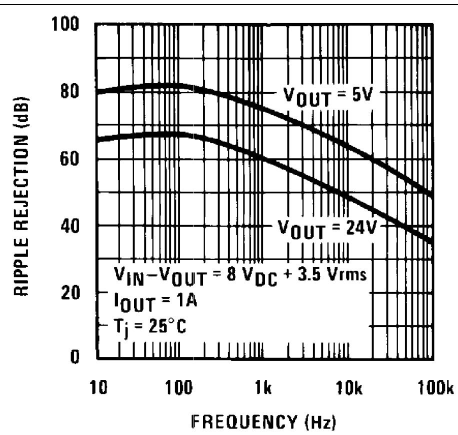


Figure 5. Ripple Rejection

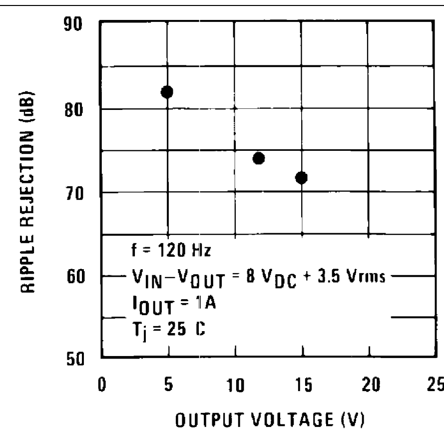


Figure 6. Ripple Rejection

Typical Characteristics (continued)

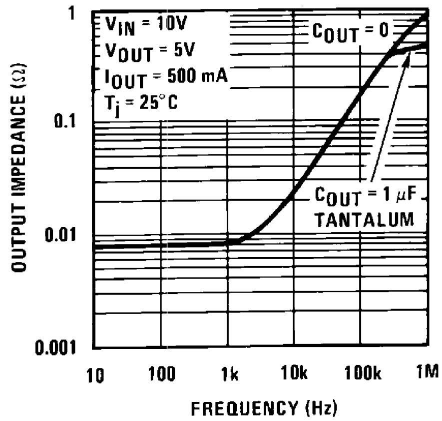


Figure 7. Output Impedance

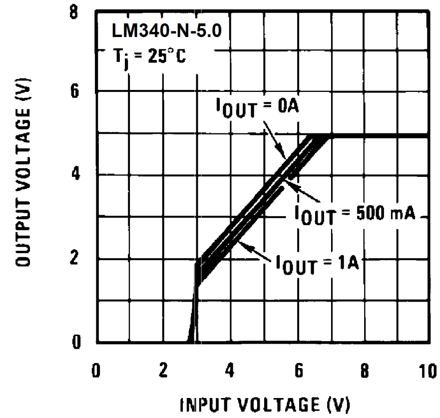
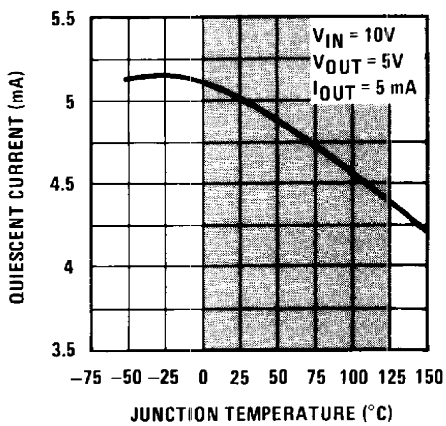


Figure 8. Dropout Characteristics



Shaded area refers to LM340A/LM340, LM7805, LM7812, and LM7815.

Figure 9. Quiescent Current

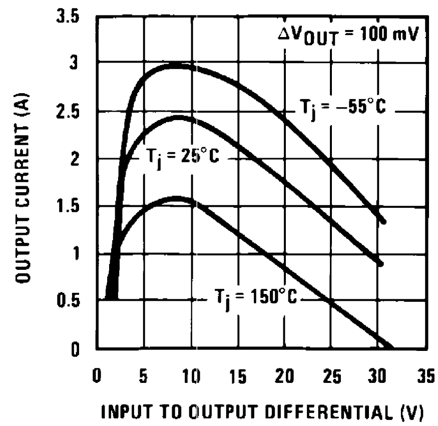
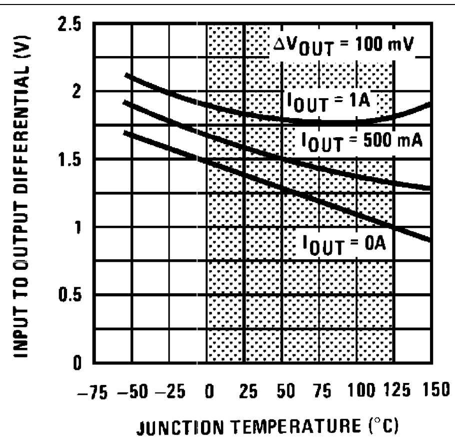


Figure 10. Peak Output Current



Shaded area refers to LM340A/LM340, LM7805, LM7812, and LM7815.

Figure 11. Dropout Voltage

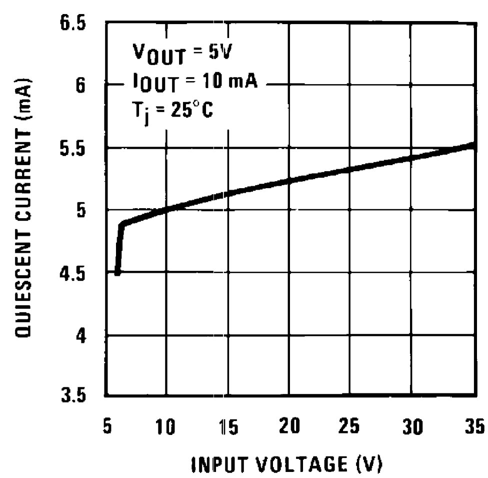
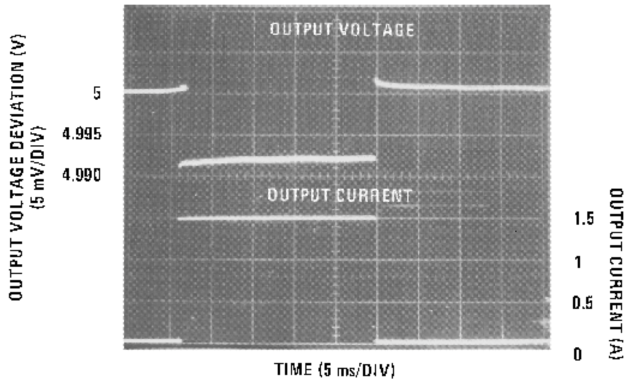


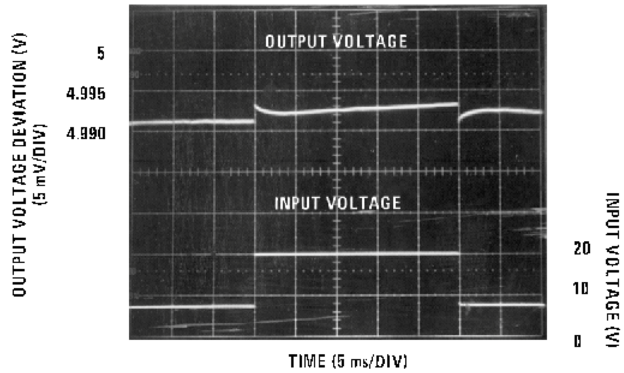
Figure 12. Quiescent Current

Typical Characteristics (continued)



I_{OUT} = 1 A, T_A = 25°C

Figure 13. Line Regulation LM340



V_{IN} = 10 V, T_A = 25°C

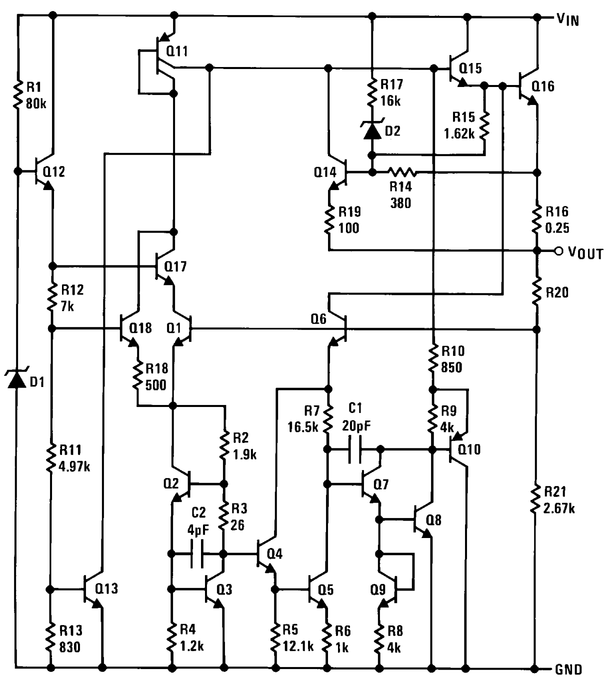
Figure 14. Line Regulation LM340

7 Detailed Description

7.1 Overview

The LM340 and LM7805 devices are a family of fixed output positive voltage regulators with outputs ranging from 3 V to 15 V. They accept up to 35 V of input voltage and with proper heat dissipation can provide over 1.5 A of current. With a combination of current limiting, thermal shutdown, and safe area protection, these regulators eliminate any concern of damage. These features paired with excellent line and load regulation make the LM340 and LM7805 Family versatile solutions to a wide range of power management designs. Although the LM340 and LM7805 Family were designed primarily as fixed-voltage regulators, these devices can be used with external component for adjustable voltage and current.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Output Current

With proper considerations, the LM340 and LM7805 Family can exceed 1.5-A output current. Depending on the desired package option, the effective junction-to-ambient thermal resistance can be reduced through heat sinking, allowing more power to be dissipated in the device.

7.3.2 Current Limiting Feature

In the event of a short circuit at the output of the regulator, each device has an internal current limit to protect it from damage. The typical current limits for the LM340 and LM7805 Family is 2.4 A.

7.3.3 Thermal Shutdown

Each package type employs internal current limiting and thermal shutdown to provide safe operation area protection. If the junction temperature is allowed to rise to 150°C, the device will go into thermal shutdown.

7.4 Device Functional Modes

There are no functional modes for this device.

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The LM340x and LM7805 series is designed with thermal protection, output short-circuit protection, and output transistor safe area protection. However, as with any IC regulator, it becomes necessary to take precautions to assure that the regulator is not inadvertently damaged. The following describes possible misapplications and methods to prevent damage to the regulator.

8.1.1 Shorting the Regulator Input

When using large capacitors at the output of these regulators, a protection diode connected input to output (Figure 15) may be required if the input is shorted to ground. Without the protection diode, an input short causes the input to rapidly approach ground potential, while the output remains near the initial V_{OUT} because of the stored charge in the large output capacitor. The capacitor will then discharge through a large internal input to output diode and parasitic transistors. If the energy released by the capacitor is large enough, this diode, low current metal, and the regulator are destroyed. The fast diode in Figure 15 shunts most of the capacitors discharge current around the regulator. Generally no protection diode is required for values of output capacitance ≤ 10 μF.

8.1.2 Raising the Output Voltage Above the Input Voltage

Because the output of the device does not sink current, forcing the output high can cause damage to internal low current paths in a manner similar to that just described in *Shorting the Regulator Input*.

8.1.3 Regulator Floating Ground

When the ground pin alone becomes disconnected, the output approaches the unregulated input, causing possible damage to other circuits connected to V_{OUT}. If ground is reconnected with power ON, damage may also occur to the regulator. This fault is most likely to occur when plugging in regulators or modules with on card regulators into powered up sockets. The power must be turned off first, the thermal limit ceases operating, or the ground must be connected first if power must be left on. See Figure 16.

8.1.4 Transient Voltages

If transients exceed the maximum rated input voltage of the device, or reach more than 0.8 V below ground and have sufficient energy, they will damage the regulator. The solution is to use a large input capacitor, a series input breakdown diode, a choke, a transient suppressor or a combination of these.

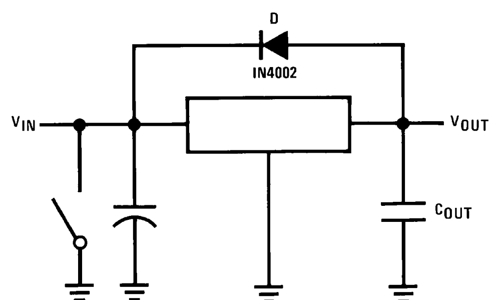


Figure 15. Input Short

Application Information (continued)

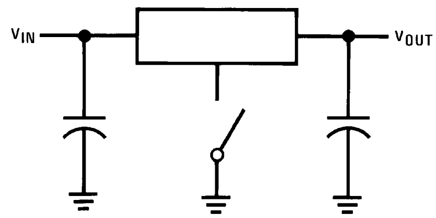


Figure 16. Regulator Floating Ground

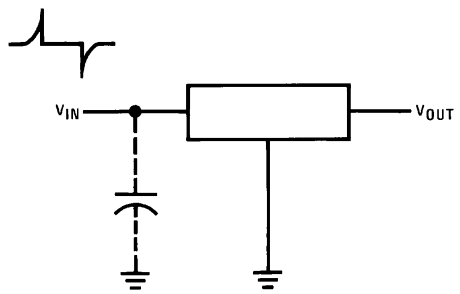


Figure 17. Transients

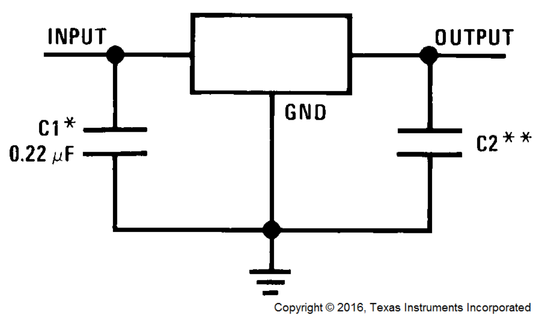
When a value for $\theta_{(H–A)}$ is found, a heat sink must be selected that has *a value that is less than or equal to this number.*

$\theta_{(H–A)}$ is specified numerically by the heat sink manufacturer in this catalog or shown in a curve that plots temperature rise vs power dissipation for the heat sink.

8.2 Typical Applications

8.2.1 Fixed Output Voltage Regulator

The LM340x and LM7805 Family devices are primarily designed to provide fixed output voltage regulation. The simplest implementation of LM340x and LM7805 Family is shown in Figure 18.



*Required if the regulator is located far from the power supply filter.
**Although no output capacitor is needed for stability, it does help transient response. (If needed, use 0.1-μF, ceramic disc).

Figure 18. Fixed Output Voltage Regulator

8.2.1.1 Design Requirements

The device component count is very minimal. Although not required, TI recommends employing bypass capacitors at the output for optimum stability and transient response. These capacitors must be placed as close as possible to the regulator. If the device is located more than 6 inches from the power supply filter, it is required to employ input capacitor.

Typical Applications (continued)

8.2.1.2 Detailed Design Procedure

The output voltage is set based on the device variant. LM340x and LM7805 Family are available in 5-V, 12-V and 15-V regulator options.

8.2.1.3 Application Curve

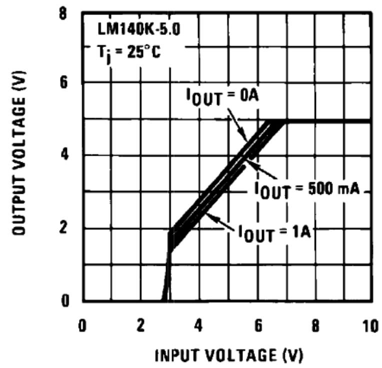
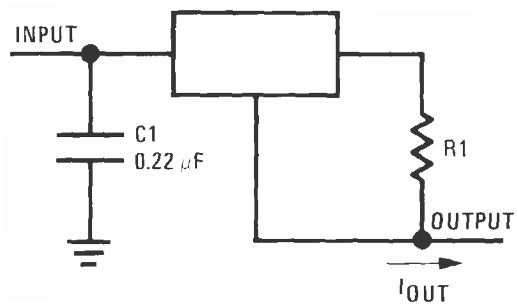


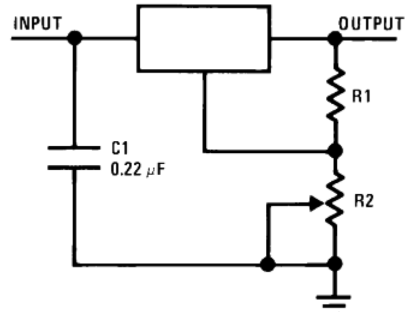
Figure 19. V_{OUT} vs V_{IN}, V_{OUT} = 5 V

8.3 System Examples



I_{OUT} = V2–3 / R1 + I_Q
ΔI_Q = 1.3 mA over line and load changes.

Figure 20. Current Regulator



V_{OUT} = 5 V + (5 V/R1 + I_Q) R2 5 V/R1 > 3 I_Q,
load regulation (L_r) ≈ [(R1 + R2)/R1] (L_r of LM340-5).

Figure 21. Adjustable Output Regulator

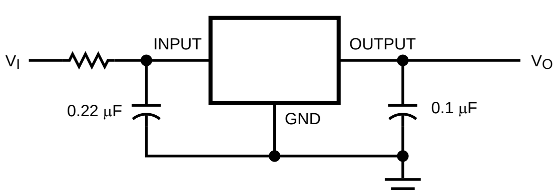


Figure 22. High Input Voltage Circuit With Series Resistor

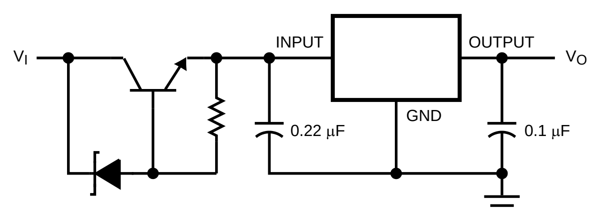
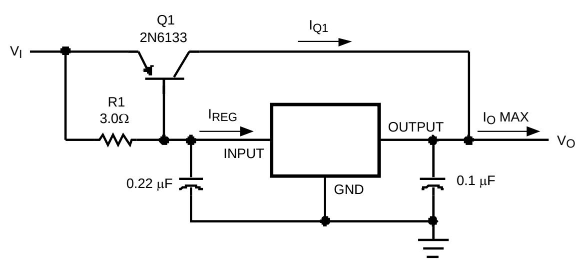


Figure 23. High Input Voltage Circuit implementation With Transistor

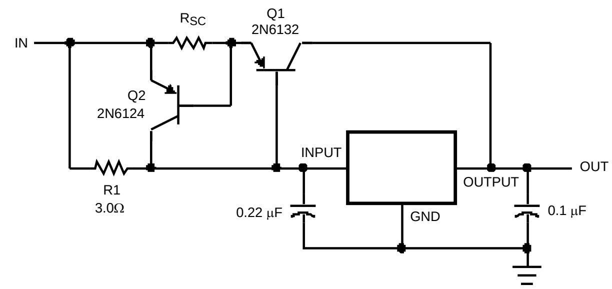
System Examples (continued)



$\beta(Q1) \geq I_{O\ Max} / I_{REG\ Max}$

$R1 = 0.9 / I_{REG} = \beta_{(Q1)} V_{BE(Q1)} / I_{REG\ Max\ (\beta\ +1)} - I_{O\ Max}$

Figure 24. High Current Voltage Regulator



$R_{SC} = 0.8 / I_{SC}$

$R1 = \beta V_{BE(Q1)} / I_{REG\ Max} (\beta +1) - I_{O\ Max}$

Figure 25. High Output Current With Short-Circuit Protection

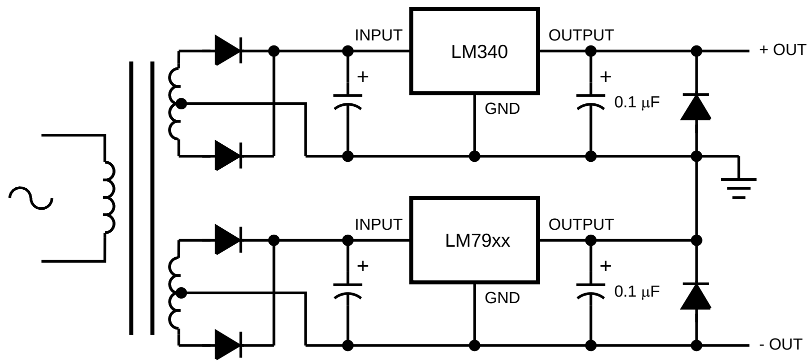


Figure 26. LM340 Used With Negative Regulator LM79xx

9 Power Supply Recommendations

The LM340 is designed to operate from a wide input voltage up to 35 V. Please refer to electrical characteristics tables for the minimum input voltage required for line/load regulation. If the device is more than six inches from the input filter capacitors, an input bypass capacitor, 0.1 μF or greater, of any type is needed for stability.

10 Layout

10.1 Layout Guidelines

Some layout guidelines must be followed to ensure proper regulation of the output voltage with minimum noise. Traces carrying the load current must be wide to reduce the amount of parasitic trace inductance. To improve PSRR, a bypass capacitor can be placed at the OUTPUT pin and must be placed as close as possible to the IC. All that is required for the typical fixed output regulator application circuit is the LM340x/LM7805 Family IC and a 0.22-µF input capacitor if the regulator is placed far from the power supply filter. A 0.1-µF output capacitor is recommended to help with transient response. In cases when VIN shorts to ground, an external diode must be placed from VOUT to VIN to divert the surge current from the output capacitor and protect the IC.

10.2 Layout Example

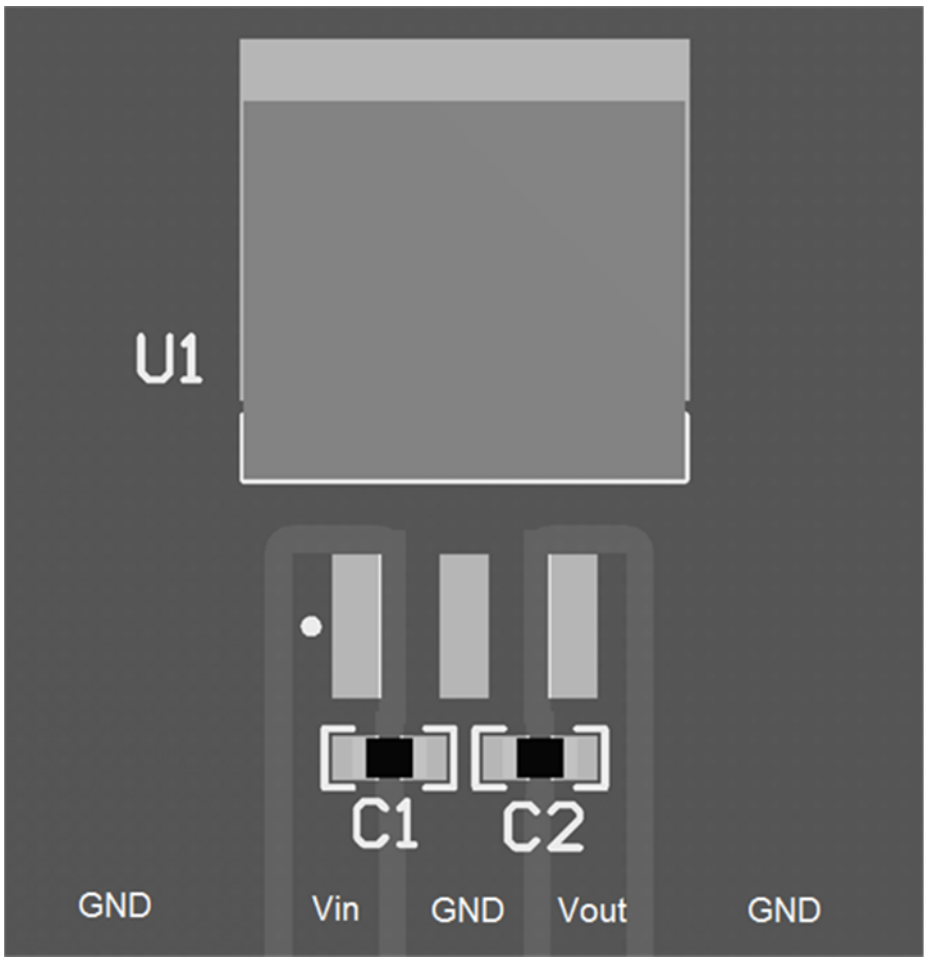


Figure 27. Layout Example DDPAK

Layout Example (continued)

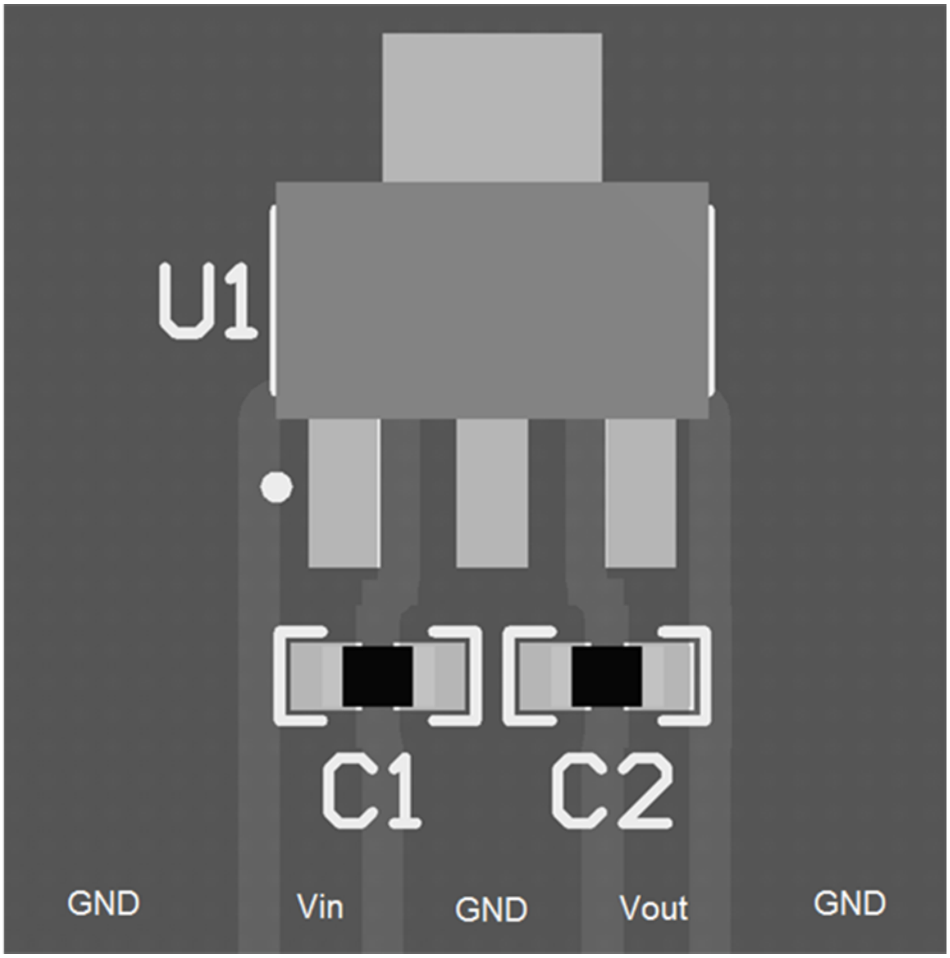


Figure 28. Layout Example SOT-223

10.3 Heat Sinking DDPAK/TO-263 and SOT-223 Package Parts

Both the DDPAK/TO-263 (KTT) and SOT-223 (DCY) packages use a copper plane on the PCB and the PCB itself as a heat sink. To optimize the heat sinking ability of the plane and PCB, solder the tab of the plane.

Figure 29 shows for the DDPAK/TO-263 the measured values of $\theta_{(J-A)}$ for different copper area sizes using a typical PCB with 1-oz copper *and no solder mask over the copper area used for heat sinking*.

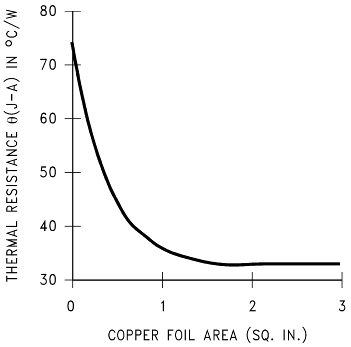


Figure 29. $\theta_{(J-A)}$ vs Copper (1 Ounce) Area for the DDPAK/TO-263 Package

Heat Sinking DDPAK/TO-263 and SOT-223 Package Parts (continued)

As shown in Figure 29, 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 DDPAK/TO-263 package mounted to a PCB is 32°C/W.

As a design aid, Figure 30 shows the maximum allowable power dissipation compared to ambient temperature for the DDPAK/TO-263 device (assuming $\theta_{(J-A)}$ is 35°C/W and the maximum junction temperature is 125°C).

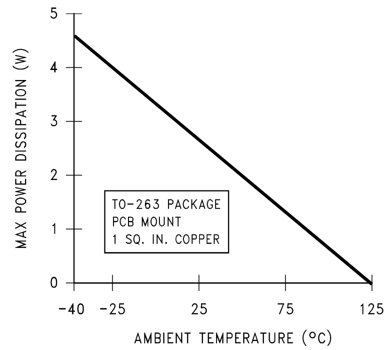


Figure 30. Maximum Power Dissipation vs T_{AMB} for the DDPAK/TO-263 Package

Figure 31 and Figure 32 show the information for the SOT-223 package. Figure 31 assumes a $\theta_{(J-A)}$ of 74°C/W for 1-oz. copper and 51°C/W for 2-oz. copper and a maximum junction temperature of 125°C.

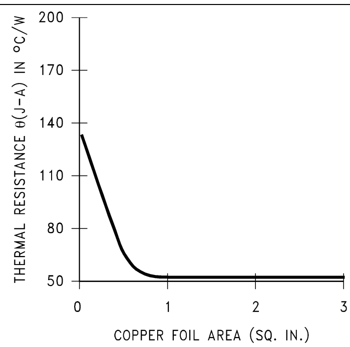


Figure 31. $\theta_{(J-A)}$ vs Copper (2 Ounce) Area for the SOT-223 Package

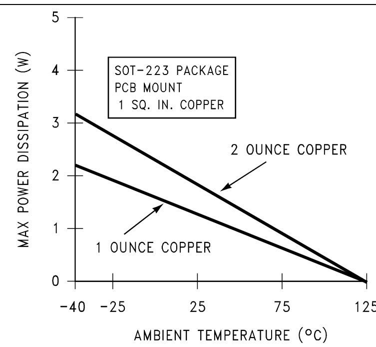


Figure 32. Maximum Power Dissipation vs T_{AMB} for the SOT-223 Package

See *AN-1028 LMX2370 PLLatinum Dual Freq Synth for RF Pers Comm LMX2370 2.5GHz/1.2GHz* (SNVA036) for power enhancement techniques to be used with the SOT-223 package.

11 Device and Documentation Support

11.1 Documentation Support

11.1.1 Related Documentation

For related documentation, see the following:

- *AN-1028 LMX2370 PLLatinum Dual Freq Synth for RF Pers Comm LMX2370 2.5GHz/1.2GHz* (SNVA036)
- *LM140K Series 3-Terminal Positive Regulators* (SNVS994)

11.2 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 1. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
LM340	Click here	Click here	Click here	Click here	Click here
LM340A	Click here	Click here	Click here	Click here	Click here
LM7805	Click here	Click here	Click here	Click here	Click here
LM7812	Click here	Click here	Click here	Click here	Click here
LM7815	Click here	Click here	Click here	Click here	Click here

11.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.4 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.5 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.6 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.7 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM340AT-5.0	NRND	TO-220	NDE	3	45	Non-RoHS & Green	Call TI	Call TI	0 to 70	LM340AT 5.0 P+	
LM340AT-5.0/NOPB	ACTIVE	TO-220	NDE	3	45	RoHS-Exempt & Green	SN	Level-1-NA-UNLIM	0 to 125	LM340AT 5.0 P+	Samples
LM340K-5.0	ACTIVE	TO-3	NDS	2	50	Non-RoHS & Non-Green	Call TI	Call TI	0 to 125	LM340K -5.0 7805P+	Samples
LM340K-5.0/NOPB	ACTIVE	TO-3	NDS	2	50	RoHS & Green	Call TI	Level-1-NA-UNLIM	0 to 125	LM340K -5.0 7805P+	Samples
LM340MP-5.0	NRND	SOT-223	DCY	4	1000	Non-RoHS & Green	Call TI	Call TI	0 to 70	N00A	
LM340MP-5.0/NOPB	ACTIVE	SOT-223	DCY	4	1000	RoHS & Green	SN	Level-1-260C-UNLIM	0 to 125	N00A	Samples
LM340MPX-5.0/NOPB	ACTIVE	SOT-223	DCY	4	2000	RoHS & Green	SN	Level-1-260C-UNLIM	0 to 125	N00A	Samples
LM340S-12/NOPB	ACTIVE	DDPAK/ TO-263	KTT	3	45	RoHS-Exempt & Green	SN	Level-3-245C-168 HR	0 to 125	LM340S -12 P+	Samples
LM340S-5.0	NRND	DDPAK/ TO-263	KTT	3	45	Non-RoHS & Green	Call TI	Call TI	0 to 70	LM340S -5.0 P+	
LM340S-5.0/NOPB	ACTIVE	DDPAK/ TO-263	KTT	3	45	RoHS-Exempt & Green	SN	Level-3-245C-168 HR	0 to 125	LM340S -5.0 P+	Samples
LM340SX-12/NOPB	ACTIVE	DDPAK/ TO-263	KTT	3	500	RoHS-Exempt & Green	SN	Level-3-245C-168 HR	0 to 125	LM340S -12 P+	Samples
LM340SX-5.0	NRND	DDPAK/ TO-263	KTT	3	500	Non-RoHS & Green	Call TI	Call TI	0 to 70	LM340S -5.0 P+	
LM340SX-5.0/NOPB	ACTIVE	DDPAK/ TO-263	KTT	3	500	RoHS-Exempt & Green	SN	Level-3-245C-168 HR	0 to 125	LM340S -5.0 P+	Samples
LM340T-12	NRND	TO-220	NDE	3	45	Non-RoHS & Green	Call TI	Call TI	0 to 70	LM340T12 7812 P+	
LM340T-12/NOPB	ACTIVE	TO-220	NDE	3	45	RoHS & Green	SN	Level-1-NA-UNLIM		LM340T12 7812 P+	Samples
LM340T-15	NRND	TO-220	NDE	3	45	Non-RoHS & Green	Call TI	Call TI	0 to 70	LM340T15 7815 P+	
LM340T-15/NOPB	ACTIVE	TO-220	NDE	3	45	RoHS & Green	SN	Level-1-NA-UNLIM	0 to 125	LM340T15 7815 P+	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM340T-5.0	NRND	TO-220	NDE	3	45	Non-RoHS & Green	Call TI	Call TI	0 to 70	LM340T5 7805 P+	
LM340T-5.0/LF01	ACTIVE	TO-220	NDG	3	45	RoHS-Exempt & Green	SN	Level-4-260C-72 HR	0 to 125	LM340T5 7805 P+	Samples
LM340T-5.0/NOPB	ACTIVE	TO-220	NDE	3	45	RoHS-Exempt & Green	SN	Level-1-NA-UNLIM	0 to 125	LM340T5 7805 P+	Samples
LM7805CT	NRND	TO-220	NDE	3	45	Non-RoHS & Green	Call TI	Call TI	0 to 125	LM340T5 7805 P+	
LM7805CT/NOPB	ACTIVE	TO-220	NDE	3	45	RoHS-Exempt & Green	SN	Level-1-NA-UNLIM	0 to 125	LM340T5 7805 P+	Samples
LM7805MP/NOPB	ACTIVE	SOT-223	DCY	4	1000	RoHS & Green	SN	Level-1-260C-UNLIM	0 to 125	N00A	Samples
LM7805MPX/NOPB	ACTIVE	SOT-223	DCY	4	2000	RoHS & Green	SN	Level-1-260C-UNLIM	0 to 125	N00A	Samples
LM7805S/NOPB	ACTIVE	DDPAK/ TO-263	KTT	3	45	RoHS-Exempt & Green	SN	Level-3-245C-168 HR	0 to 125	LM340S -5.0 P+	Samples
LM7805SX/NOPB	ACTIVE	DDPAK/ TO-263	KTT	3	500	RoHS-Exempt & Green	SN	Level-3-245C-168 HR	0 to 125	LM340S -5.0 P+	Samples
LM7812CT/NOPB	ACTIVE	TO-220	NDE	3	45	RoHS & Green	SN	Level-1-NA-UNLIM	-40 to 125	LM340T12 7812 P+	Samples
LM7812S/NOPB	ACTIVE	DDPAK/ TO-263	KTT	3	45	RoHS-Exempt & Green	SN	Level-3-245C-168 HR	0 to 125	LM340S -12 P+	Samples
LM7812SX/NOPB	ACTIVE	DDPAK/ TO-263	KTT	3	500	RoHS-Exempt & Green	SN	Level-3-245C-168 HR	0 to 125	LM340S -12 P+	Samples
LM7815CT/NOPB	ACTIVE	TO-220	NDE	3	45	RoHS & Green	SN	Level-1-NA-UNLIM	0 to 125	LM340T15 7815 P+	Samples
LM78S40CN/NOPB	ACTIVE	PDIP	NFG	16	25	RoHS & Non-Green	SN	Level-1-NA-UNLIM	0 to 70	LM78S40CN	Samples
LM78S40N/NOPB	LIFEBUY	PDIP	NFG	16	25	RoHS & Green	SN	Level-1-NA-UNLIM	0 to 125	LM78S40N	

[1] The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

[2] **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

[3] MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

[4] There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

[5] Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

[6] Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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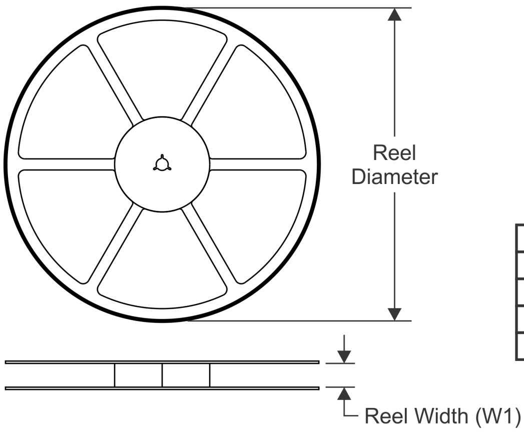
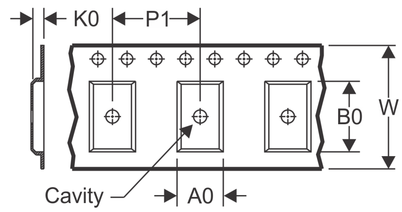
TAPE AND REEL INFORMATION

REEL DIMENSIONS

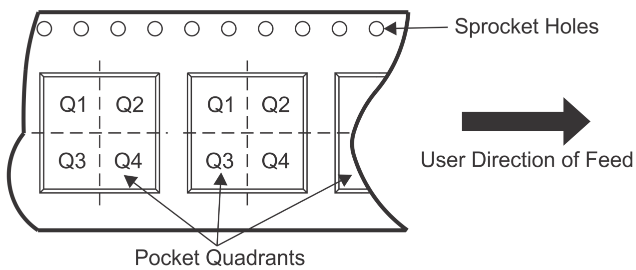


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

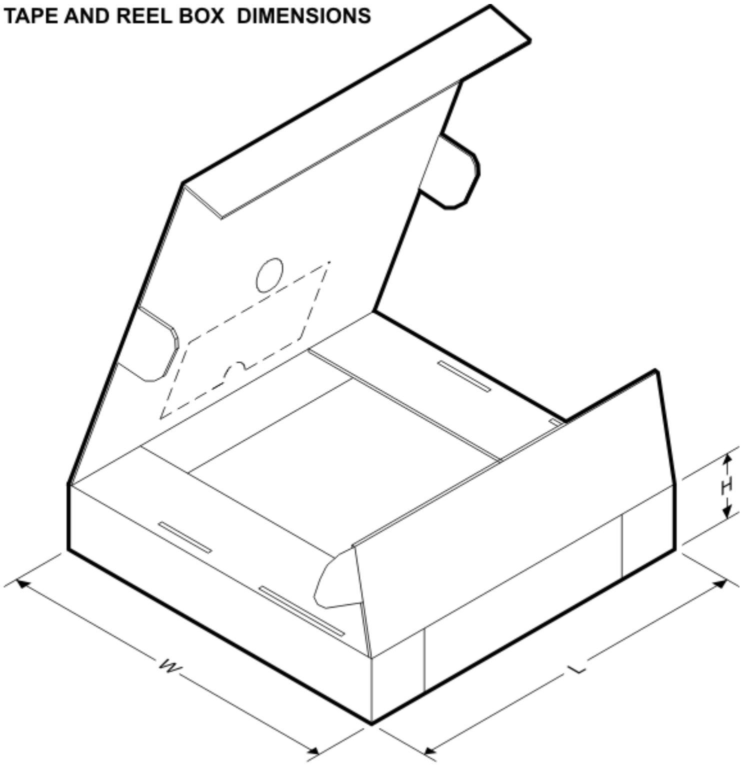
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM340MP-5.0	SOT-223	DCY	4	1000	330.0	16.4	7.0	7.5	2.2	12.0	16.0	Q3
LM340MP-5.0/NOPB	SOT-223	DCY	4	1000	330.0	16.4	7.0	7.5	2.2	12.0	16.0	Q3
LM340MPX-5.0/NOPB	SOT-223	DCY	4	2000	330.0	16.4	7.0	7.5	2.2	12.0	16.0	Q3
LM340SX-12/NOPB	DDPAK/ TO-263	KTT	3	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2
LM340SX-5.0	DDPAK/ TO-263	KTT	3	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2
LM340SX-5.0/NOPB	DDPAK/ TO-263	KTT	3	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2
LM7805MP/NOPB	SOT-223	DCY	4	1000	330.0	16.4	7.0	7.5	2.2	12.0	16.0	Q3
LM7805MPX/NOPB	SOT-223	DCY	4	2000	330.0	16.4	7.0	7.5	2.2	12.0	16.0	Q3
LM7805SX/NOPB	DDPAK/ TO-263	KTT	3	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2
LM7812SX/NOPB	DDPAK/ TO-263	KTT	3	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2

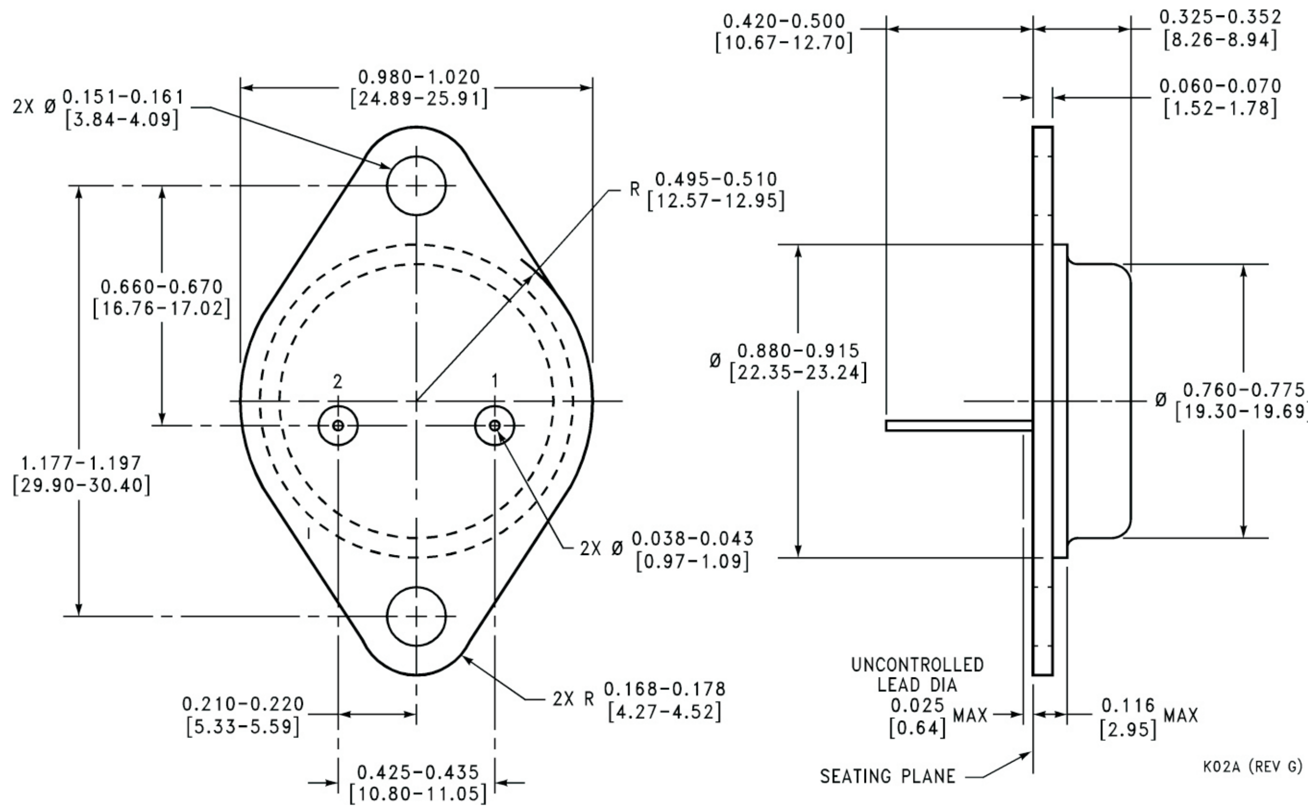
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

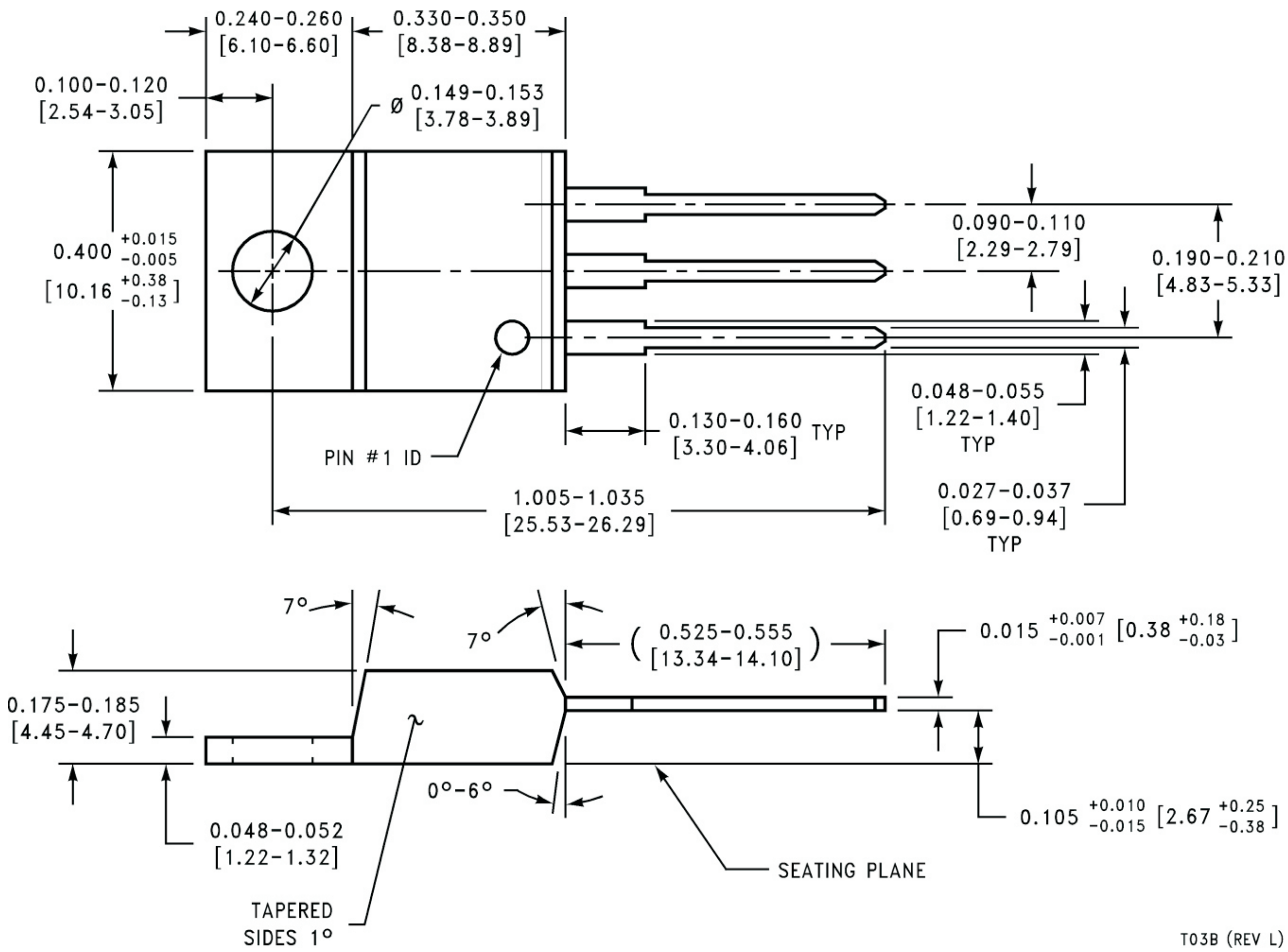
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM340MP-5.0	SOT-223	DCY	4	1000	367.0	367.0	35.0
LM340MP-5.0/NOPB	SOT-223	DCY	4	1000	367.0	367.0	35.0
LM340MPX-5.0/NOPB	SOT-223	DCY	4	2000	367.0	367.0	35.0
LM340SX-12/NOPB	DDPAK/TO-263	KTT	3	500	367.0	367.0	45.0
LM340SX-5.0	DDPAK/TO-263	KTT	3	500	367.0	367.0	45.0
LM340SX-5.0/NOPB	DDPAK/TO-263	KTT	3	500	367.0	367.0	45.0
LM7805MP/NOPB	SOT-223	DCY	4	1000	367.0	367.0	35.0
LM7805MPX/NOPB	SOT-223	DCY	4	2000	367.0	367.0	35.0
LM7805SX/NOPB	DDPAK/TO-263	KTT	3	500	367.0	367.0	45.0
LM7812SX/NOPB	DDPAK/TO-263	KTT	3	500	367.0	367.0	45.0

NDS0002A

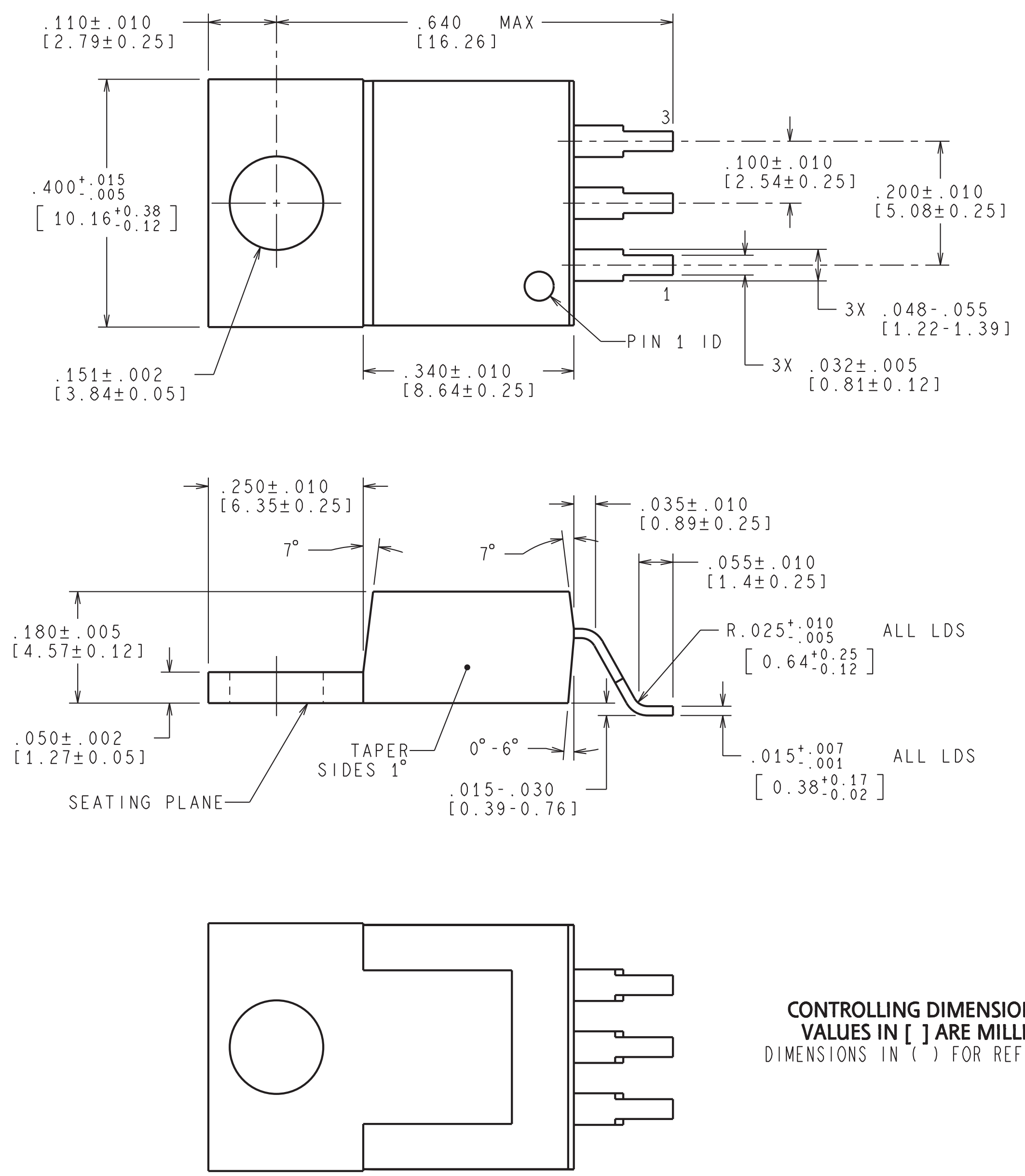


0.420-0.500
[10.67-12.70]
0.325-0.352
[8.26-8.94]
0.980-1.020
[24.89-25.91]
0.060-0.070
[1.52-1.78]
2X Ø 0.151-0.161
[3.84-4.09]
R 0.495-0.510
[12.57-12.95]
0.660-0.670
[16.76-17.02]
Ø 0.880-0.915
[22.35-23.24]
2
1
Ø 0.760-0.775
[19.30-19.69]
1.177-1.197
[29.90-30.40]
2X Ø 0.038-0.043
[0.97-1.09]
UNCONTROLLED
LEAD DIA
0.025
[0.64] MAX
0.116
[2.95] MAX
2X R 0.168-0.178
[4.27-4.52]
0.210-0.220
[5.33-5.59]
0.425-0.435
[10.80-11.05]
SEATING PLANE
K02A (REV G)

NDE0003B


0.240-0.260
[6.10-6.60]
0.330-0.350
[8.38-8.89]
0.100-0.120
[2.54-3.05]
Ø 0.149-0.153
[3.78-3.89]
0.400 +0.015 -0.005
[10.16 +0.38 -0.13]
0.090-0.110
[2.29-2.79]
0.190-0.210
[4.83-5.33]
0.048-0.055
[1.22-1.40]
TYP
0.130-0.160 TYP
[3.30-4.06]
PIN #1 ID
1.005-1.035
[25.53-26.29]
0.027-0.037
[0.69-0.94]
TYP
7°
7°
(0.525-0.555 [13.34-14.10])
0.015 +0.007 -0.001 [0.38 +0.18 -0.03]
0.175-0.185
[4.45-4.70]
0°-6°
0.105 +0.010 -0.015 [2.67 +0.25 -0.38]
0.048-0.052
[1.22-1.32]
SEATING PLANE
TAPERED
SIDES 1°
T03B (REV L)

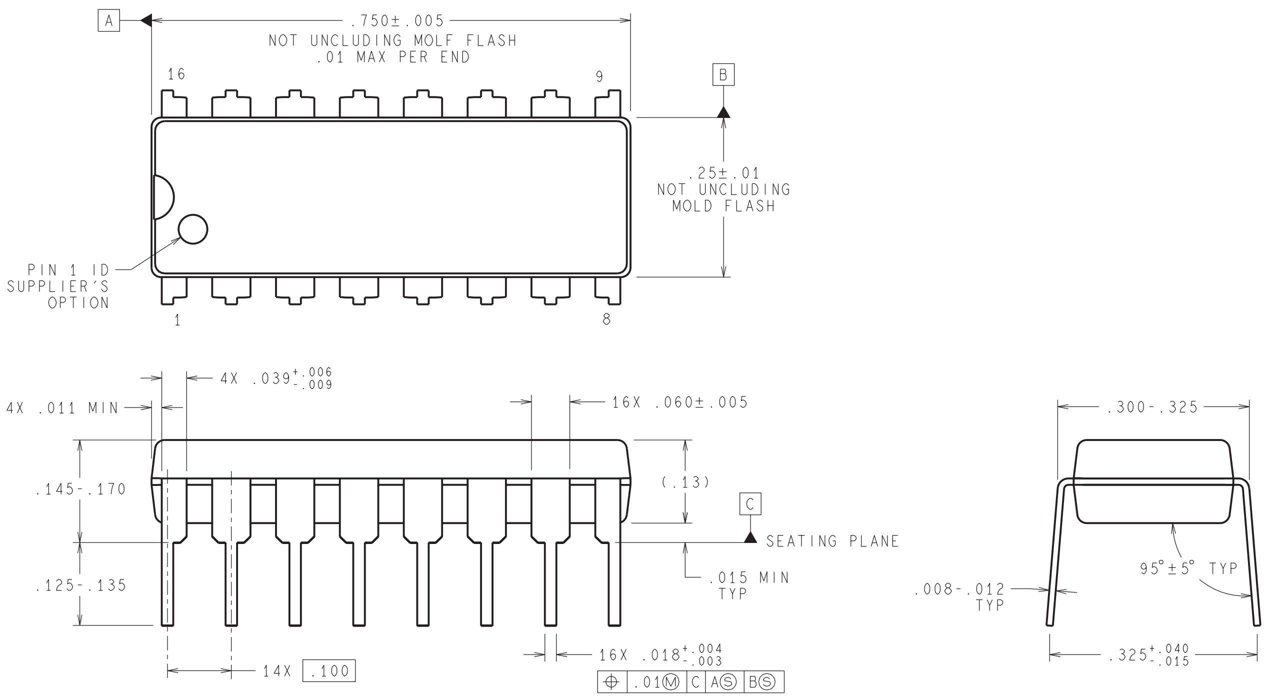
NDG0003F



CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS
DIMENSIONS IN ( ) FOR REFERENCE ONLY

T03F (Rev B)

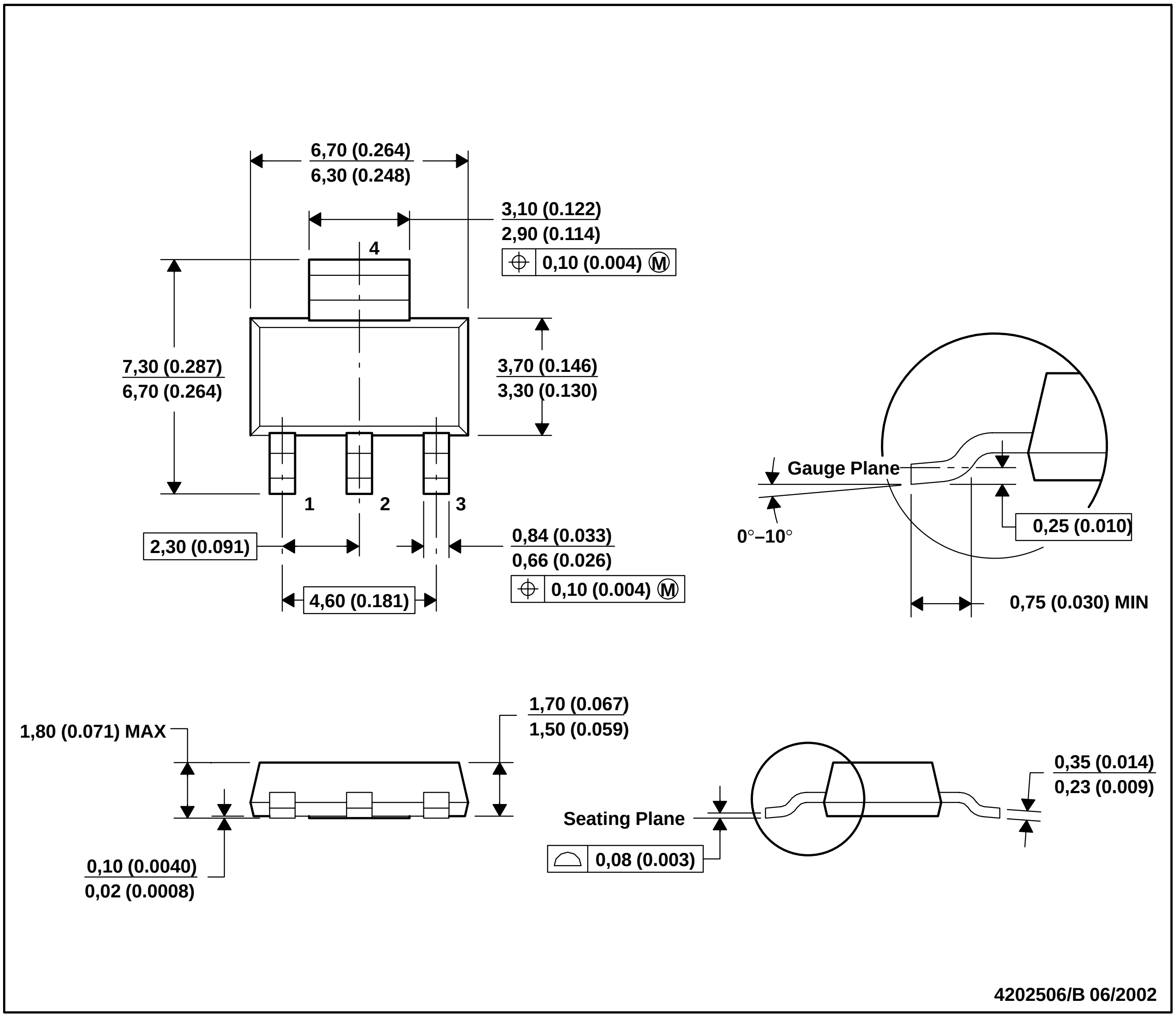
NFG0016E



DIMENSIONS ARE IN INCHES
DIMENSIONS IN ( ) FOR REFERENCE ONLY

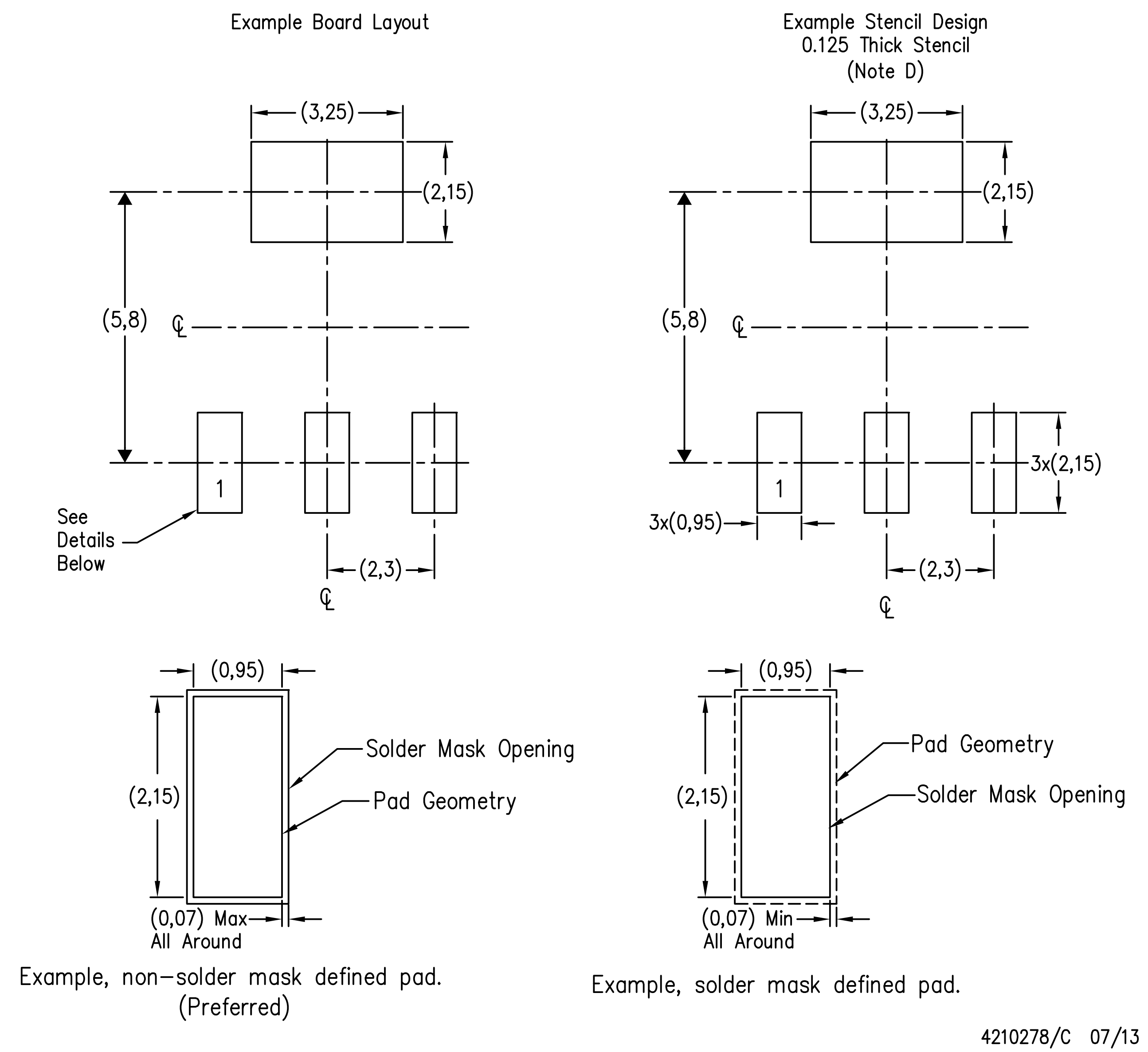
N16E (Rev G)

DCY (R-PDSO-G4) **PLASTIC SMALL-OUTLINE**



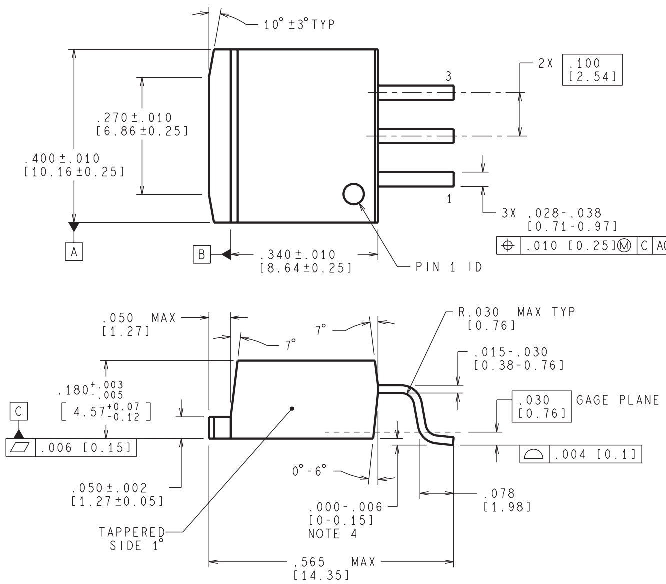
NOTES: A. All linear dimensions are in millimeters (inches).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC TO-261 Variation AA.

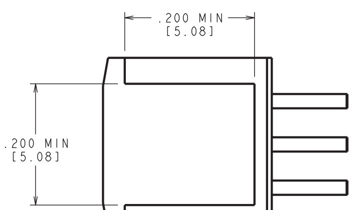
DCY (R–PDSO–G4) PLASTIC SMALL OUTLINE



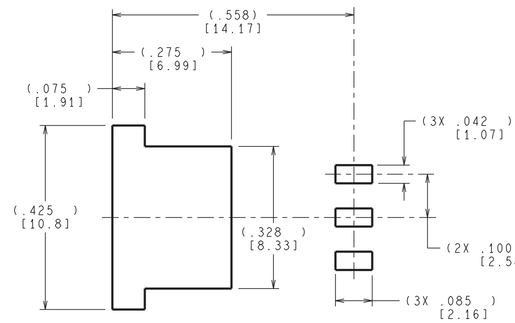
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil recommendations. Refer to IPC 7525 for stencil design considerations.

KTT0003B





BOTTOM SIDE OF PACKAGE



LAND PATTERN RECOMMENDATION

CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS
DIMENSIONS IN ( ) FOR REFERENCE ONLY

TS3B (Rev F)

IMPORTANT NOTICE AND DISCLAIMER

BATTERY PROTECTION IC FOR 3-SERIAL- OR 4-SERIAL-CELL PACK

Rev.5.3_00

The S-8254A Series is a protection IC for 3-serial- or 4-serial-cell lithium-ion / lithium polymer rechargeable batteries and includes a high-accuracy voltage detector and delay circuit.
The S-8254A Series protects both 3-serial or 4-serial cells using the SEL pin for switching.

■ Features

(1) High-accuracy voltage detection for each cell

• Overcharge detection voltage n (n = 1 to 4)	3.90 V to 4.45 V (50 mV step)	Accuracy ±25 mV
• Overcharge release voltage n (n = 1 to 4)	3.80 V to 4.45 V*1	Accuracy ±50 mV
• Overdischarge detection voltage n (n = 1 to 4)	2.0 V to 3.0 V (100 mV step)	Accuracy ±80 mV
• Overdischarge release voltage n (n = 1 to 4)	2.0 V to 3.4 V*2	Accuracy ±100 mV

(2) Three-level overcurrent protection

• Overcurrent detection voltage 1	0.05 V to 0.30 V (50 mV step)	Accuracy ±25 mV
• Overcurrent detection voltage 2	0.5 V	Accuracy ±100 mV
• Overcurrent detection voltage 3	V_{VC1} – 1.2 V	Accuracy ±300 mV

(3) Delay times for overcharge detection, overdischarge detection and overcurrent detection 1 can be set by external capacitors (delay times for overcurrent detection 2 and 3 are fixed internally).
(4) Switchable between a 3-serial cell and 4-serial cell using the SEL pin
(5) Charge/discharge operation can be controlled via the control pins.
(6) 0 V battery charge — Enabled, inhibited
(7) Power-down function — Available
(8) High-withstand voltage — Absolute maximum rating : 26 V
(9) Wide operating voltage range — 2 V to 24 V
(10) Wide operating temperature range — −40°C to + 85°C
(11) Low current consumption
- During operation — 30 μA max. (+25°C)
- During power-down — 0.1 μA max. (+25°C)

(12) Lead-free, Sn100%, halogen-free*3

***1.** Overcharge hysteresis voltage n (n = 1 to 4) can be selected as 0 V or from a range of 0.1 V to 0.4 V in 50 mV steps.
(Overcharge hysteresis voltage = Overcharge detection voltage − Overcharge release voltage)
***2.** Overdischarge hysteresis voltage n (n = 1 to 4) can be selected as 0 V or from a range of 0.2 V to 0.7 V in 100 mV steps.
(Overdischarge hysteresis voltage = Overdischarge release voltage − Overdischarge detection voltage)
***3.** Refer to "■ **Product Name Structure**" for details.

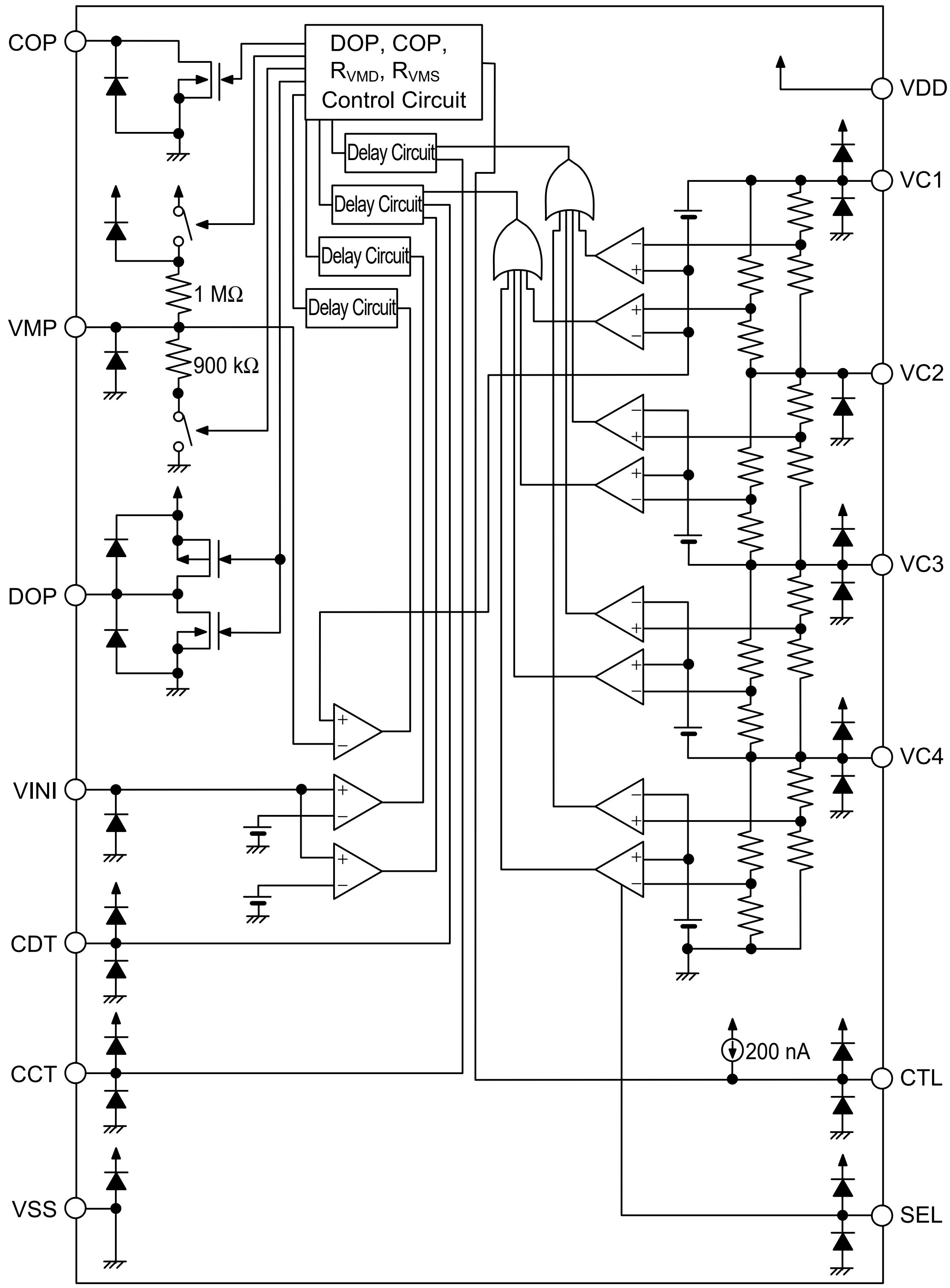
■ Applications

- Lithium-ion rechargeable battery packs
- Lithium polymer rechargeable battery packs

■ Package

- 16-Pin TSSOP

■ Block Diagram



Remark **1.** Diodes in the figure are parasitic diodes.

2. Numerical values are typical values.

Figure 1

■ Product Name Structure

1. Product Name

S-8254A xx FT - TB - x

- x: Environmental code
  - U: Lead-free (Sn 100%), halogen-free
  - S: Lead-free, halogen-free
  - G: Lead-free (for details, please contact our sales representatives)
- TB: IC direction in tape specifications *1
- FT: Package code
  - FT: 16-Pin TSSOP
- xx: Serial code *2
  - Sequentially set from AA to ZZ

***1.** Refer to the tape drawing.
***2.** Refer to "**3. Product Name List**".

2. Package

Package name		Package	Tape	Reel
16-Pin TSSOP	Environmental code = G, S	FT016-A-P-SD	FT016-A-C-SD	FT016-A-R-SD
	Environmental code = U	FT016-A-P-SD	FT016-A-C-SD	FT016-A-R-S1

3. Product Name List

Table 1

Product name / Item	Overcharge detection voltage [V_{CU}]	Overcharge release voltage [V_{CL}]	Overdischarge detection voltage [V_{DL}]	Overdischarge release voltage [V_{DU}]	Overcurrent detection voltage 1 [V_{IOV1}]	0 V battery charge
S-8254AAAFT-TB-x	4.350 ± 0.025 V	4.150 ± 0.050 V	2.00 ± 0.080 V	2.70 ± 0.100 V	0.30 ± 0.025 V	Enabled
S-8254AABFT-TB-x	4.250 ± 0.025 V	4.250 ± 0.025 V	2.00 ± 0.080 V	2.70 ± 0.100 V	0.30 ± 0.025 V	Enabled
S-8254AAEFT-TB-x	4.350 ± 0.025 V	4.150 ± 0.050 V	2.00 ± 0.080 V	2.70 ± 0.100 V	0.20 ± 0.025 V	Enabled
S-8254AAFFT-TB-x	4.350 ± 0.025 V	4.150 ± 0.050 V	2.40 ± 0.080 V	3.00 ± 0.100 V	0.20 ± 0.025 V	Enabled
S-8254AAGFT-TB-x	4.275 ± 0.025 V	4.075 ± 0.050 V	2.30 ± 0.080 V	2.70 ± 0.100 V	0.13 ± 0.025 V	Enabled
S-8254AAHFT-TB-x	4.350 ± 0.025 V	4.150 ± 0.050 V	2.40 ± 0.080 V	2.70 ± 0.100 V	0.10 ± 0.025 V	Enabled
S-8254AAJFT-TB-x	4.350 ± 0.025 V	4.150 ± 0.050 V	2.40 ± 0.080 V	3.00 ± 0.100 V	0.15 ± 0.025 V	Enabled
S-8254AAKFT-TB-x	4.350 ± 0.025 V	4.150 ± 0.050 V	2.70 ± 0.080 V	3.00 ± 0.100 V	0.20 ± 0.025 V	Enabled
S-8254AALFT-TB-x	4.300 ± 0.025 V	4.150 ± 0.050 V	2.40 ± 0.080 V	3.00 ± 0.100 V	0.20 ± 0.025 V	Enabled
S-8254AAMFT-TB-x	4.200 ± 0.025 V	4.100 ± 0.050 V	2.50 ± 0.080 V	2.70 ± 0.100 V	0.30 ± 0.025 V	Enabled
S-8254AANFT-TB-x	4.250 ± 0.025 V	4.150 ± 0.050 V	2.50 ± 0.080 V	3.00 ± 0.100 V	0.10 ± 0.025 V	Enabled
S-8254AAOFT-TB-x	4.300 ± 0.025 V	4.080 ± 0.050 V	2.50 ± 0.080 V	3.00 ± 0.100 V	0.10 ± 0.025 V	Enabled
S-8254AAPFT-TB-x	4.280 ± 0.025 V	4.130 ± 0.050 V	3.00 ± 0.080 V	3.00 ± 0.080 V	0.15 ± 0.025 V	Enabled
S-8254AAQFT-TB-x	3.900 ± 0.025 V	3.800 ± 0.050 V	2.30 ± 0.080 V	2.70 ± 0.100 V	0.30 ± 0.025 V	Enabled
S-8254AARFT-TB-x	4.350 ± 0.025 V	4.150 ± 0.050 V	2.80 ± 0.080 V	3.00 ± 0.100 V	0.20 ± 0.025 V	Enabled
S-8254AASFT-TB-x	4.290 ± 0.025 V	4.090 ± 0.050 V	2.30 ± 0.080 V	3.00 ± 0.100 V	0.075 ± 0.025 V	Enabled
S-8254AATFT-TB-x	4.200 ± 0.025 V	4.200 ± 0.025 V	2.00 ± 0.080 V	2.70 ± 0.100 V	0.30 ± 0.025 V	Enabled
S-8254AAUFT-TB-x	4.350 ± 0.025 V	4.150 ± 0.050 V	2.40 ± 0.080 V	3.00 ± 0.100 V	0.20 ± 0.025 V	Inhibited
S-8254AAVFT-TB-x	4.250 ± 0.025 V	4.150 ± 0.050 V	2.70 ± 0.080 V	3.00 ± 0.100 V	0.20 ± 0.025 V	Enabled
S-8254AAWFT-TB-x	4.250 ± 0.025 V	4.100 ± 0.050 V	3.00 ± 0.080 V	3.20 ± 0.100 V	0.10 ± 0.025 V	Inhibited
S-8254AAYFT-TB-x	4.275 ± 0.025 V	4.125 ± 0.050 V	2.40 ± 0.080 V	2.70 ± 0.100 V	0.10 ± 0.025 V	Enabled
S-8254AAZFT-TB-x	4.250 ± 0.025 V	4.150 ± 0.050 V	2.00 ± 0.080 V	2.70 ± 0.100 V	0.13 ± 0.025 V	Enabled
S-8254ABAFT-TB-x	3.900 ± 0.025 V	3.800 ± 0.050 V	2.00 ± 0.080 V	2.50 ± 0.100 V	0.15 ± 0.025 V	Enabled
S-8254ABCFT-TB-x	4.175 ± 0.025 V	3.975 ± 0.050 V	2.75 ± 0.080 V	3.05 ± 0.100 V	0.10 ± 0.025 V	Enabled
S-8254ABDFT-TB-y	4.300 ± 0.025 V	4.100 ± 0.050 V	2.00 ± 0.080 V	2.00 ± 0.080 V	0.13 ± 0.025 V	Enabled
S-8254ABEFT-TB-y	4.200 ± 0.025 V	4.150 ± 0.050 V	2.50 ± 0.080 V	3.00 ± 0.100 V	0.15 ± 0.025 V	Enabled
S-8254ABFFT-TB-x	4.150 ± 0.025 V	4.050 ± 0.050 V	2.00 ± 0.080 V	2.70 ± 0.100 V	0.13 ± 0.025 V	Enabled
S-8254ABGFT-TB-x	4.180 ± 0.025 V	4.080 ± 0.050 V	2.00 ± 0.080 V	2.70 ± 0.100 V	0.13 ± 0.025 V	Enabled
S-8254ABHFT-TB-y	4.150 ± 0.025 V	4.050 ± 0.050 V	2.50 ± 0.080 V	2.80 ± 0.100 V	0.10 ± 0.025 V	Enabled
S-8254ABIFT-TB-x	4.215 ± 0.025 V	4.115 ± 0.050 V	2.40 ± 0.080 V	3.00 ± 0.100 V	0.20 ± 0.025 V	Inhibited
S-8254ABJFT-TB-U	4.225 ± 0.025 V	4.125 ± 0.050 V	2.50 ± 0.080 V	2.70 ± 0.100 V	0.10 ± 0.025 V	Enabled
S-8254ABKFT-TB-U	4.150 ± 0.025 V	4.150 ± 0.025 V	2.00 ± 0.080 V	2.70 ± 0.100 V	0.30 ± 0.025 V	Enabled
S-8254ABLFT-TB-U	4.250 ± 0.025 V	4.100 ± 0.050 V	2.40 ± 0.080 V	3.00 ± 0.100 V	0.20 ± 0.025 V	Inhibited
S-8254ABMFT-TB-U	4.425 ± 0.025 V	4.225 ± 0.050 V	2.50 ± 0.080 V	2.90 ± 0.100 V	0.15 ± 0.025 V	Enabled
S-8254ABNFT-TB-U	4.215 ± 0.025 V	4.115 ± 0.050 V	2.80 ± 0.080 V	3.00 ± 0.100 V	0.20 ± 0.025 V	Inhibited

Remark **1.** Please contact our sales representatives for products other than the above.
2. x: G or U
y: S or U
3. Please select products of environmental code = U for Sn 100%, halogen-free products.

■ Pin Configuration

16-Pin TSSOP
Top view

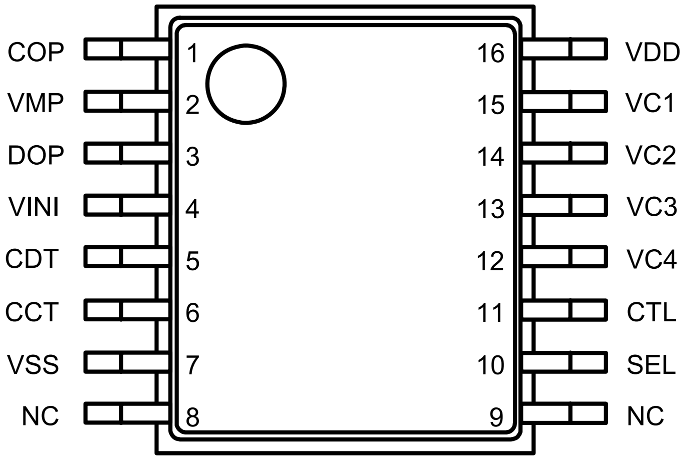


Figure 2

Table 2

Pin No.	Symbol	Description
1	COP	FET gate connection pin for charge control (Nch open drain output)
2	VMP	Pin for voltage detection between VC1 and VMP (Pin for overcurrent 3 detection)
3	DOP	FET gate connection pin for discharge control FET (CMOS output)
4	VINI	Pin for voltage detection between VSS and VINI (Pin for overcurrent detection 1,2)
5	CDT	Capacitor connection pin for delay for overdischarge detection, delay for overcurrent detection 1
6	CCT	Capacitor connection pin for delay for overcharge current
7	VSS	Input pin for negative power supply, Connection pin for battery 4's negative voltage
8	NC [*1]	No connection
9	NC [*1]	No connection
10	SEL	Pin for switching 3-series or 4-series cell V_{SS} level: 3-series cell, V_{DD} level : 4-series cell
11	CTL	Control of charge FET and discharge FET
12	VC4	Connection pin for battery 3's negative voltage, Connection pin for battery 4's positive voltage
13	VC3	Connection pin for battery 2's negative voltage, Connection pin for battery 3's positive voltage
14	VC2	Connection pin for battery 1's negative voltage, Connection pin for battery 2's positive voltage
15	VC1	Connection pin for battery 1's positive voltage
16	VDD	Input pin for positive power supply, Connection pin for battery 1's positive voltage

***1.** The NC pin is electrically open. The NC pin can be connected to VDD or VSS.

■ Absolute Maximum Ratings

Table 3

(Ta = 25°C unless otherwise specified)

Item	Symbol	Applied pin	Absolute Maximum Ratings	Unit
Input voltage between VDD and VSS	V_{DS}	—	V_{SS} − 0.3 to V_{SS} + 26	V
Input pin voltage	V_{IN}	VC1, VC2, VC3, VC4, CTL, SEL, CCT, CDT, VINI	V_{SS} − 0.3 to V_{DD} + 0.3	V
VMP pin input voltage	V_{VMP}	VMP	V_{SS} − 0.3 to V_{SS} + 26	V
DOP pin output voltage	V_{DOP}	DOP	V_{SS} − 0.3 to V_{DD} + 0.3	V
COP pin output voltage	V_{COP}	COP	V_{SS} − 0.3 to V_{SS} + 26	V
Power dissipation	P_D	—	400 (When not mounted on board)	mW
		—	1100*1	mW
Operating ambient temperature	T_{opr}	—	− 40 to + 85	°C
Storage temperature	T_{stg}	—	− 40 to + 125	°C

***1.** When mounted on board
[Mounted board]
(1) Board size : 114.3 mm × 76.2 mm × t1.6 mm
(2) Board name : JEDEC STANDARD51-7

Caution The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any conditions.

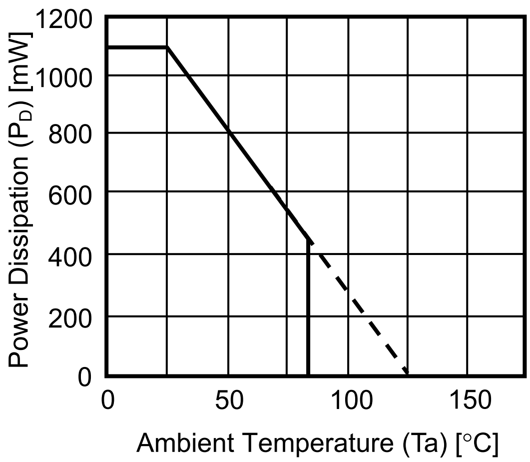


Figure 3 Power Dissipation of Package (When Mounted on Board)

Electrical Characteristics

Table 4 (1 / 2)

(Ta = 25°C unless otherwise specified)

Item	Symbol	Conditions		Min.	Typ.	Max.	Unit	Test circuit
[DETECTION VOLTAGE]								
Overcharge detection voltage n (n = 1, 2, 3, 4)	V_{CUn}	3.90 V to 4.45 V, Adjustable		V_{CUn} − 0.025	V_{CUn}	V_{CUn} + 0.025	V	2
Overcharge release voltage n (n = 1, 2, 3, 4)	V_{CLn}	3.80 V to 4.45 V, Adjustable	$V_{CL} \neq V_{CU}$	V_{CLn} − 0.05	V_{CLn}	V_{CLn} + 0.05	V	2
			$V_{CL} = V_{CU}$	V_{CLn} − 0.025	V_{CLn}	V_{CLn} + 0.025	V	2
Overdischarge detection voltage n (n = 1, 2, 3, 4)	V_{DLn}	2.0 V to 3.0 V, Adjustable		V_{DLn} − 0.08	V_{DLn}	V_{DLn} + 0.08	V	2
Overdischarge release voltage n (n = 1, 2, 3, 4)	V_{DUn}	2.0 V to 3.4 V, Adjustable	$V_{DL} \neq V_{DU}$	V_{DUn} − 0.10	V_{DUn}	V_{DUn} + 0.10	V	2
			$V_{DL} = V_{DU}$	V_{DUn} − 0.08	V_{DUn}	V_{DUn} + 0.08	V	2
Overcurrent detection voltage 1	V_{IOV1}	0.05 V to 0.3 V, Adjustable		V_{IOV1} − 0.025	V_{IOV1}	V_{IOV1} + 0.025	V	2
Overcurrent detection voltage 2	V_{IOV2}	—		0.4	0.5	0.6	V	2
Overcurrent detection voltage 3	V_{IOV3}	—		V_{VC1} − 1.5	V_{VC1} − 1.2	V_{VC1} − 0.9	V	2
Temperature coefficient 1 *1	T_{COE1}	Ta = 0°C to 50°C *3		− 1.0	0	1.0	mV / °C	2
Temperature coefficient 2 *2	T_{COE2}	Ta = 0°C to 50°C *3		− 0.5	0	0.5	mV / °C	2
[DELAY TIME]								
Overcharge detection delay time	t_{CU}	CCT pin capacitance = 0.1 μF		0.5	1.0	1.5	s	3
Overdischarge detection delay time	t_{DL}	CDT pin capacitance = 0.1 μF		50	100	150	ms	3
Overcurrent detection delay time 1	t_{IOV1}	CDT pin capacitance = 0.1 μF		5	10	15	ms	3
Overcurrent detection delay time 2	t_{IOV2}	—		0.4	1	1.6	ms	3
Overcurrent detection delay time 3	t_{IOV3}	FET gate capacitance = 2000 pF		100	300	600	μs	3
[0 V BATTERY CHARGE]								
0 V battery charge starting charger voltage	V_{0CHA}	0 V battery charge enabled		—	0.8	1.5	V	4
0 V battery charge inhibition battery voltage	V_{0INH}	0 V battery charge inhibited		0.4	0.7	1.1	V	4
[INTERNAL RESISTANCE]								
Resistance between VMP and VDD	R_{VMD}	—		0.5	1	1.5	MΩ	5
Resistance between VMP and VSS	R_{VMS}	—		450	900	1800	kΩ	5

Table 4 (2 / 2)

(Ta = 25°C unless otherwise specified)

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit	Test circuit
[INPUT VOLTAGE]							
Operating voltage between VDD and VSS	V_{DSOP}	Output voltage of DOP and COP fixed	2	—	24	V	2
CTL input voltage "H"	V_{CTLH}	—	$V_{DD} \times 0.8$	—	—	V	2
CTL input voltage "L"	V_{CTLL}	—	—	—	$V_{DD} \times 0.2$	V	2
SEL input voltage "H"	V_{SELH}	—	$V_{DD} \times 0.8$	—	—	V	2
SEL input voltage "L"	V_{SELL}	—	—	—	$V_{DD} \times 0.2$	V	2
[INPUT CURRENT]							
Current consumption during operation	I_{OPE}	V1 = V2 = V3 = V4 = 3.5 V	—	12	30	μA	1
Current consumption during power-down	I_{PDN}	V1 = V2 = V3 = V4 = 1.5 V	—	—	0.1	μA	1
VC1 pin current	I_{VC1}	V1 = V2 = V3 = V4 = 3.5 V	—	1.5	3	μA	5
VC2 pin current	I_{VC2}	V1 = V2 = V3 = V4 = 3.5 V	− 0.3	0	0.3	μA	5
VC3 pin current	I_{VC3}	V1 = V2 = V3 = V4 = 3.5 V	− 0.3	0	0.3	μA	5
VC4 pin current	I_{VC4}	V1 = V2 = V3 = V4 = 3.5 V	− 0.3	0	0.3	μA	5
CTL pin current "H"	I_{CTLH}	V1 = V2 = V3 = V4 = 3.5 V, $V_{CTL} = V_{DD}$	—	—	0.1	μA	5
CTL pin current "L"	I_{CTLL}	V1 = V2 = V3 = V4 = 3.5 V, $V_{CTL} = V_{SS}$	− 0.4	− 0.2	—	μA	5
SEL pin current "H"	I_{SELH}	V1 = V2 = V3 = V4 = 3.5 V, $V_{SEL} = V_{DD}$	—	—	0.1	μA	5
SEL pin current "L"	I_{SELL}	V1 = V2 = V3 = V4 = 3.5 V, $V_{SEL} = V_{SS}$	− 0.1	—	—	μA	5
[OUTPUT CURRENT]							
COP pin leakage current	I_{COH}	V_{COP} = 24 V	—	—	0.1	μA	5
COP pin sink current	I_{COL}	$V_{COP} = V_{SS} + 0.5$ V	10	—	—	μA	5
DOP pin source current	I_{DOH}	$V_{DOP} = V_{DD} - 0.5$ V	10	—	—	μA	5
DOP pin sink current	I_{DOL}	$V_{DOP} = V_{SS} + 0.5$ V	10	—	—	μA	5

***1.** Voltage temperature coefficient 1 : Overcharge detection voltage
***2.** Voltage temperature coefficient 2 : Overcurrent detection voltage 1
***3.** Since products are not screened at high and low temperature, the specification for this temperature range is guaranteed by design, not tested in production.

■ Test Circuits

This chapter describes how to test the S-8254A Series when a 4-serial cell is selected by setting the SEL pin to the VDD level. When a 3-serial cell is selected by setting the SEL pin to the VSS level, short the power supply V4.

1. Current Consumption during Operation, Current Consumption during Power-down (Test circuit 1)

1. 1 Current Consumption during operation (I_{OPE})

The current at the VSS pin when V1 = V2 = V3 = V4 = 3.5 V and V_{VMP} = V_{DD} is the current consumption during operation (I_{OPE}).

1. 2 Current Consumption during power-down (I_{PDN})

The current at the VSS pin when V1 = V2 = V3 = V4 = 1.5 V and V_{VMP} = V_{SS} is the current consumption during power-down (I_{PDN}).

2. Overcharge Detection Voltage, Overcharge Release Voltage, Overdischarge Detection Voltage, Overdischarge Release Voltage, Overcurrent Detection Voltage 1, Overcurrent Detection Voltage 2, Overcurrent Detection Voltage 3, CTL Input Voltage "H", CTL Input Voltage "L", SEL Input Voltage "H", SEL Input Voltage "L" (Test circuit 2)

Confirm that the COP pin and DOP pin are low (V_{DD} × 0.1 V or lower) when V_{VMP} = V_{SEL} = V_{DD}, V_{INI} = V_{CTL} = V_{SS}, the CCT pin is open, the CDT pin is open, and V1 = V2 = V3 = V4 = 3.5 V (this status is referred to as the initial status).

2. 1 Overcharge Detection Voltage (V_{CU1}), Overcharge Release Voltage (V_{CL1})

The overcharge detection voltage (V_{CU1}) is the voltage of V1 when the voltage of the COP pin is "H" (V_{DD} × 0.9 V or more) after the V1 voltage has been gradually increased starting at the initial status. The overcharge release voltage (V_{CL1}) is the voltage of V1 when the voltage at the COP pin is "L" after the V1 voltage has been gradually decreased.

2. 2 Overdischarge Detection Voltage (V_{DL1}), Overdischarge Release Voltage (V_{DU1})

The overdischarge detection voltage (V_{DL1}) is the voltage of V1 when the voltage of the DOP pin is "H" after the V1 voltage has been gradually decreased starting at the initial status. The overdischarge release voltage (V_{DU1}) is the voltage of V1 when the voltage at the DOP pin is "L" after the V1 voltage has been gradually increased.
When the voltage of Vn (n = 2 to 4) is changed, the overcharge detection voltage (V_{CUn}), overcharge release voltage (V_{CLn}), overdischarge detection voltage (V_{DLn}), and overdischarge release voltage (V_{DUn}) can be determined in the same way as when n = 1.

2. 3 Overcurrent Detection Voltage 1 (V_{IOV1})

Overcurrent detection voltage 1 (V_{IOV1}) is the voltage of the VINI pin when the voltage of the DOP pin is "H" after the VINI pin voltage has been gradually increased starting at the initial status.

2. 4 Overcurrent Detection Voltage 2 (V_{IOV2})

Overcurrent detection voltage 2 (V_{IOV2}) is the voltage of the VINI pin when the voltage of the DOP pin is "H" after the voltage of the CDT pin was set to V_{SS} following the initial status and the voltage of the VINI pin has been gradually decreased.

2. 5 Overcurrent Detection Voltage 3 (V_{IOV3})

Overcurrent detection voltage 3 (V_{IOV3}) is the voltage difference between V_{VC1} and V_{VMP} (V_{VC1} – V_{VMP}) when the voltage of the DOP pin is "H" after the VMP voltage has been gradually decreased starting at the initial status.

2. 6 CTL Input Voltage "H" (V_{CTLH}), CTL Input Voltage "L" (V_{CTLL})

The CTL input voltage "H" (V_{CTLH}) is the voltage of CTL when the voltages at the COP and DOP pins are "H" after the CTL voltage has been gradually increased starting at the initial status. The CTL input voltage "L" (V_{CTLL}) is the voltage of CTL when the voltages at the COP and DOP pins are "L" after the CTL voltage has been gradually decreased.

2. 7 SEL Input Voltage "H" (V_{SELH}), SEL Input Voltage "L" (V_{SELL})

Apply 0 V to V4 in the initial status and confirm that the DOP pin is "H". The SEL input voltage "L" (V_{SELL}) is the voltage of the SEL pin when the voltage at the DOP pin is "L" after the SEL voltage has been gradually decreased. The SEL input voltage "H" (V_{SELH}) is the voltage of the SEL pin when the voltage of the DOP pin is "H" after the SEL voltage has been gradually increased.

3. Overcharge Detection Delay Time, Overdischarge Detection Delay Time, Overcurrent Detection Delay Time 1, Overcurrent Detection Delay Time 2, Overcurrent Detection Delay Time 3 (Test circuit 3)

Confirm that the COP pin and DOP pin are "L" when $V_{VMP} = V_{DD}$, $V_{INI} = V_{SS}$, and V1 = V2 = V3 = V4 = 3.5 V (this status is referred to as the initial status).

3. 1 Overcharge Detection Delay Time (t_{CU})

The overcharge detection delay time (t_{CU}) is the time it takes for the voltage of the COP pin to change from "L" to "H" after the voltage of V1 is instantaneously changed to 4.5 V from the initial status.

3. 2 Overdischarge Detection Delay Time (t_{DL})

The overdischarge detection delay time (t_{DL}) is the time it takes for the voltage of the DOP pin to change from "L" to "H" after the voltage of V1 is instantaneously changed to 1.5 V from the initial status

3. 3 Overcurrent Detection Delay Time 1 (t_{IOV1})

Overcurrent detection delay time 1 (t_{IOV1}) is the time it takes for the voltage of the DOP pin to change from "L" to "H" after the voltage of the VINI pin is instantaneously changed to 0.4 V from the initial status.

3. 4 Overcurrent Detection Delay Time 2 (t_{IOV2})

Overcurrent detection delay time 2 (t_{IOV2}) is the time it takes for the voltage of the DOP pin to change from "L" to "H" after the voltage of the VINI pin is instantaneously changed to V_{IOV2} max. + 0.2 V from the initial status.

3. 5 Overcurrent Detection Delay Time 3 (t_{IOV3})

Overcurrent detection delay time 3 (t_{IOV3}) is the time it takes for the voltage of the DOP pin to change from "L" to "H" after the voltage of the VMP pin is instantaneously changed to V_{IOV3} min. − 0.2 V from the initial status.

4. 0 V Battery Charge Starting Charger Voltage (0 V Battery Charge Enabled), 0 V Battery Charge Inhibition Battery Voltage (0 V Battery Charge Inhibited) (Test circuit 4)

Either the 0 V battery charge starting charger voltage or the 0 V battery charge inhibition battery voltage is applied to each product according to the 0 V battery charge function.

4. 1 0 V Battery Charge Starting Charger Voltage (V_{0CHA}) (0 V Battery Charge Enabled)

The starting condition is V1 = V2 = V3 = V4 = 0 V for a product in which 0 V battery charging is available. The COP pin voltage should be lower than V_{0CHA} max. − 1 V when the VMP pin voltage $V_{VMP} = V_{0CHA}$ max.

4. 2 0 V Battery Charge Inhibition Battery Voltage (V_{0INH}) (0 V Battery Charge Inhibited)

The starting condition is V1 = V2 = V3 = V4 = V_{0INH} for a product in which 0 V battery charging is inhibited. The COP pin voltage should be higher than V_{VMP} − 1 V when the VMP pin voltage V_{VMP} = 24 V.

5. Resistance between VMP and VDD, Resistance between VMP and VSS, VC1 Pin Current, VC2 Pin Current, VC3 Pin Current, VC4 Pin Current, CTL pin Current "H", CTL Pin Current "L", SEL Pin Current "H", SEL Pin Current "L", COP Pin Leakage Current, COP Pin Sink Current, DOP Pin Source Current, DOP Pin Sink Current (Test circuit 5)

$V_{VMP} = V_{SEL} = V_{DD}$, $V_{INI} = V_{CTL} = V_{SS}$, V1 = V2 = V3 = V4 = 3.5 V, and other pins left "open" (this status is referred to as the initial status).

5. 1 Resistance between VMP and VDD (R_{VMD})

The resistance between VMP and VDD (R_{VMD}) is obtained from $R_{VMD} = V_{DD} / I_{VMD}$ using the current value of the VMP pin (I_{VMD}) when V_{VMP} is V_{SS} after the initial status.

5. 2 Resistance between VMP and VSS (R_{VMS})

The resistance between VMP and VSS (R_{VMS}) is obtained from $R_{VMS} = V_{DD} / I_{VMS}$ using the current value of the VMP pin (I_{VMS}) when V1 = V2 = V3 = V4 = 1.8 V after the initial status.

5. 3 VC1 Pin Current (I_{VC1}), VC2 Pin Current (I_{VC2}), VC3 Pin Current (I_{VC3}), VC4 Pin Current (I_{VC4})

At the initial status, the current that flows through the VC1 pin is the VC1 pin current (I_{VC1}), the current that flows through the VC2 pin is the VC2 pin current (I_{VC2}), the current that flows through the VC3 pin is the VC3 pin current (I_{VC3}), and the current that flows through the VC4 pin is the VC4 pin current (I_{VC4}).

5. 4 CTL pin Current "H" (I_{CTLH}), CTL Pin Current "L" (I_{CTLL})

In the initial status, the current that flows through the CTL pin is the CTL pin current "L" (I_{CTLL}), after that, when $V_{CTL} = V_{DD}$, the current that flows through the CTL pin is the CTL pin current "H" (I_{CTLH}).

5. 5 SEL Pin Current "H" (I_{SELH}), SEL Pin Current "L" (I_{SELL})

In the initial status, the current that flows through the SEL pin is the SEL pin current "H" (I_{SELH}), after that, when $V_{SEL} = V_{SS}$, the current that flows through the SEL pin is the SEL pin current "L" (I_{SELL}).

5. 6 COP Pin Leakage Current (I_{COH}), COP Pin Sink Current (I_{COL})

The COP pin sink current (I_{COL}) is the current that flows through the COP pin when $V_{COP} = V_{SS} + 0.5$ V after the initial status. After that, the current that flows through the COP pin when V1 = V2 = V3 = V4 = 6 V and $V_{COP} = V_{DD}$ is the COP pin leakage current (I_{COH}).

5. 7 DOP Pin Source Current (I_{DOH}), DOP Pin Sink Current (I_{DOL})

The DOP pin sink current (I_{DOL}) is the current that flows through the DOP pin when $V_{DOP} = V_{SS} + 0.5$ V after the initial status. After that, the current that flows through the DOP pin when $V_{VMP} = V_{DD} - 2$ V and $V_{DOP} = V_{DD} - 0.5$ V is the DOP pin source current (I_{DOH}).

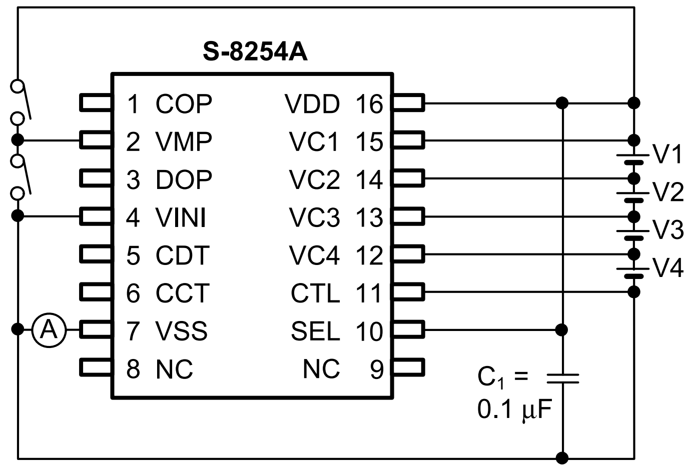


Figure 4 Test Circuit 1

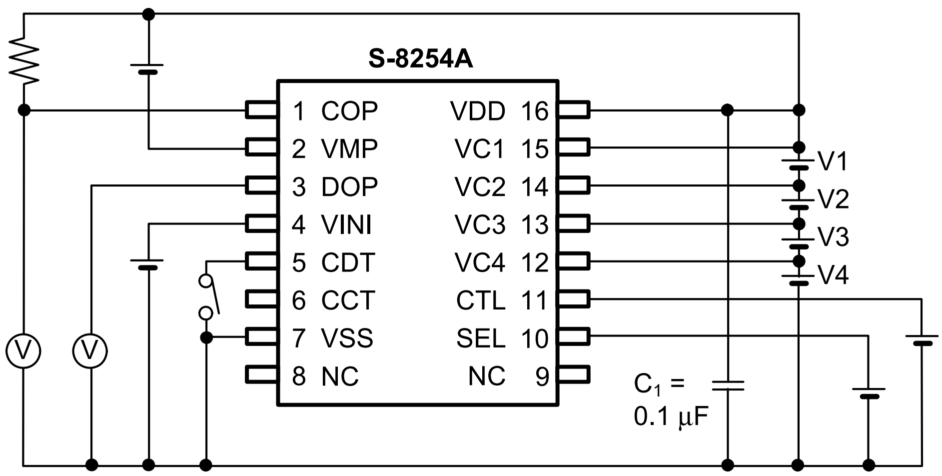


Figure 5 Test Circuit 2

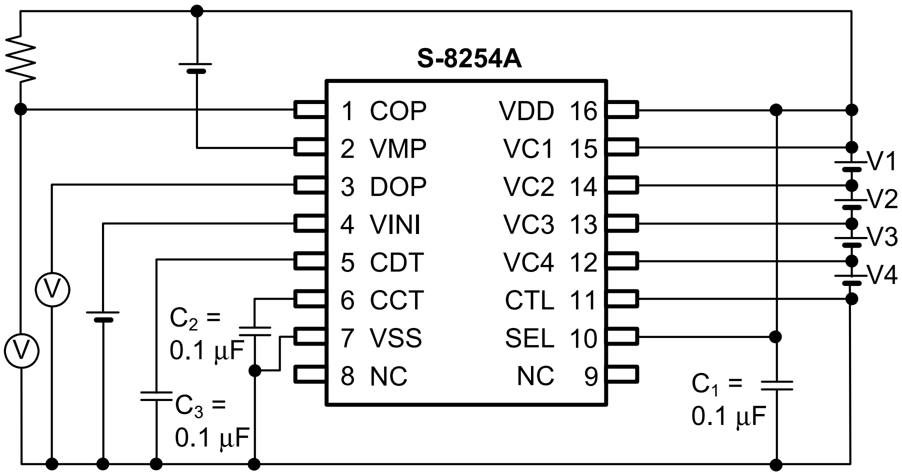


Figure 6 Test Circuit 3

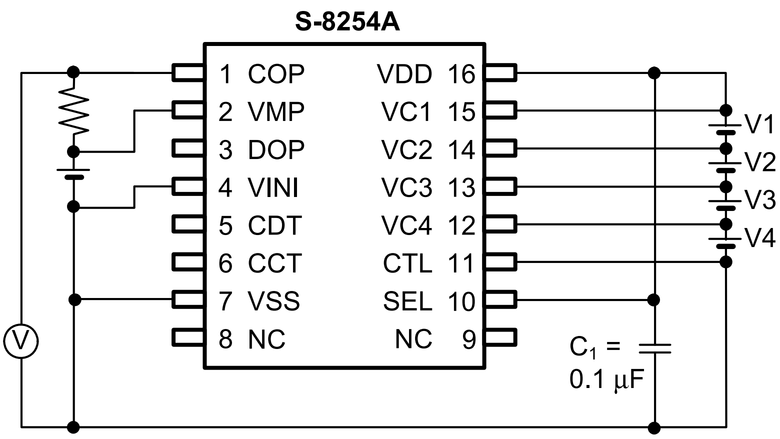


Figure 7 Test Circuit 4

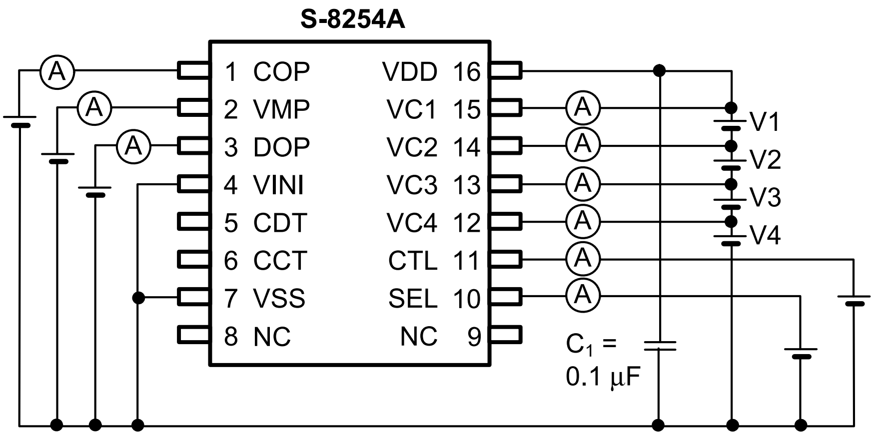


Figure 8 Test Circuit 5

■ Operation

Remark Refer to "**■ Battery Protection IC Connection Example**".

1. Normal Status

When the voltage of each of the batteries is in the range from V_{DLn} to V_{CUn} and the discharge current is lower than the specified value (the VINI pin voltage is lower than V_{IOV1} and V_{IOV2}, and the VMP pin voltage is higher than V_{IOV3}), the charging and discharging FETs are turned on.

2. Overcharge Status

When the voltage of one of the batteries becomes higher than V_{CUn} and the state continues for t_{CU} or longer, the COP pin becomes high impedance. The COP pin is pulled up to the EB_+ pin voltage by an external resistor, and the charging FET is turned off to stop charging. This is called the overcharge status. The overcharge status is released when one of the following two conditions holds.

(1) The voltage of each of the batteries becomes V_{CLn} or lower.

(2) The voltage of each of the batteries is V_{CUn} or lower, and the VMP pin voltage is $39 / 40 \times V_{DD}$ or lower (a load is connected and discharging is started via the body diode of the charging FET).

3. Overdischarge Status

When the voltage of one of the batteries becomes lower than V_{DLn} and the state continues for t_{DL} or longer, the DOP pin voltage becomes V_{DD} level, and the discharging FET is turned off to stop discharging. This is called the overdischarge status.

3. 1 Power-down Function

When the overdischarge status is reached, the VMP pin is pulled down to the V_{SS} level by the internal R_{VMS} resistor of the IC. When the VMP pin voltage is V_{DD} / 2 or lower, the power-down function starts to operate and almost every circuit in the S-8254A Series stops working. The conditions of each output pin are as follows.

(1) COP pin : High-Z

(2) DOP pin : V_{DD}

The power-down function is released when the following condition holds.

(1) The VMP pin voltage is V_{DD} / 2 or higher.

The overdischarge status is released when the following two conditions hold.

(1) In case the VMP pin voltage is V_{DD} / 2 or higher and the VMP pin voltage is lower than V_{DD}, the overdischarge status is released when the voltage of each of the batteries is V_{DUn} or higher.

(2) In case a charger is connected, the overdischarge hysteresis is released. And the overdischarge status is released when the voltage of each of the batteries is V_{DLn} or higher.

4. Overcurrent Status

The S-8254A Series has three overcurrent detection levels (V_{IOV1}, V_{IOV2}, and V_{IOV3}) and three overcurrent detection delay times (t_{IOV1}, t_{IOV2}, and t_{IOV3}) corresponding to each overcurrent detection level. When the discharging current becomes higher than the specified value (the voltage between V_{SS} and V_{INI} is greater than V_{IOV1}) and the state continues for t_{IOV1} or longer, the S-8254A Series enters the overcurrent status, in which the DOP pin voltage becomes V_{DD} level to turn off the discharging FET to stop discharging, the COP pin becomes high impedance and is pulled up to the EB+ pin voltage to turn off the charging FET to stop charging, and the VMP pin is pulled up to the V_{DD} voltage by the internal resistor (R_{VMD}). Operation of overcurrent detection level 2 (V_{IOV2}) and overcurrent detection delay time 2 (t_{IOV2}) is the same as for V_{IOV1} and t_{IOV1}.
In the overcurrent status, the VMP pin is pulled up to the V_{DD} level by the internal resistor in the IC (R_{VMD} resistor). The overcurrent status is released when the following condition holds.

(1) The VMP pin voltage is V_{IOV3} or higher because a charger is connected or the load (30 MΩ or more) is released.

5. 0 V Battery Charge

Regarding the charging of a self-discharged battery (0 V battery), the S-8254A Series has two functions from which one should be selected.

(1) 0 V battery charging is allowed (0 V battery charge enabled)
When the charger voltage is higher than V_{0CHA}, the 0 V battery can be charged.
(2) 0 V battery charging is prohibited (0 V battery charge inhibited)
When the battery voltage is V_{0INH} or lower, the 0 V battery cannot be charged.

Caution When the VDD pin voltage is lower than the minimum value of V_{DSOP}, the operation of the S-8254A Series is not guaranteed.

6. Delay Time Setting

The overcharge detection delay time (t_{CU}) is determined by the external capacitor connected to the CCT pin. The overdischarge detection delay time (t_{DL}) and overcurrent detection delay time 1 (t_{IOV1}) are determined by the external capacitor connected to the CDT pin. Overcurrent detection delay times 2 and 3 (t_{IOV2}, t_{IOV3}) are fixed internally.

	min.	typ.	max.
t_{CU} [s] =	(5.00,	10.0,	15.0) × C_{CCT} [μF]
t_{DL} [s] =	(0.50,	1.00,	1.50) × C_{CDT} [μF]
t_{IOV1} [s] =	(0.05,	0.10,	0.15) × C_{CDT} [μF]

7. CTL Pin

The S-8254A Series has control pins. The CTL pin is used to control the COP and DOP pin output voltages. CTL pin takes precedence over the battery protection circuit.

Table 5 Conditions Set by CTL Pin

CTL Pin	COP Pin	DOP Pin
High	High-Z	V_{DD}
Open	High-Z	V_{DD}
Low	Normal status *1	Normal status *1

***1.** The status is controlled by the voltage detector.

Caution Please note unexpected behavior might occur when electrical potential difference between the CTL pin ('L' level) and VSS is generated through the external filter (R_{VSS} and C_{VSS}) as a result of input voltage fluctuations.

8. SEL pin

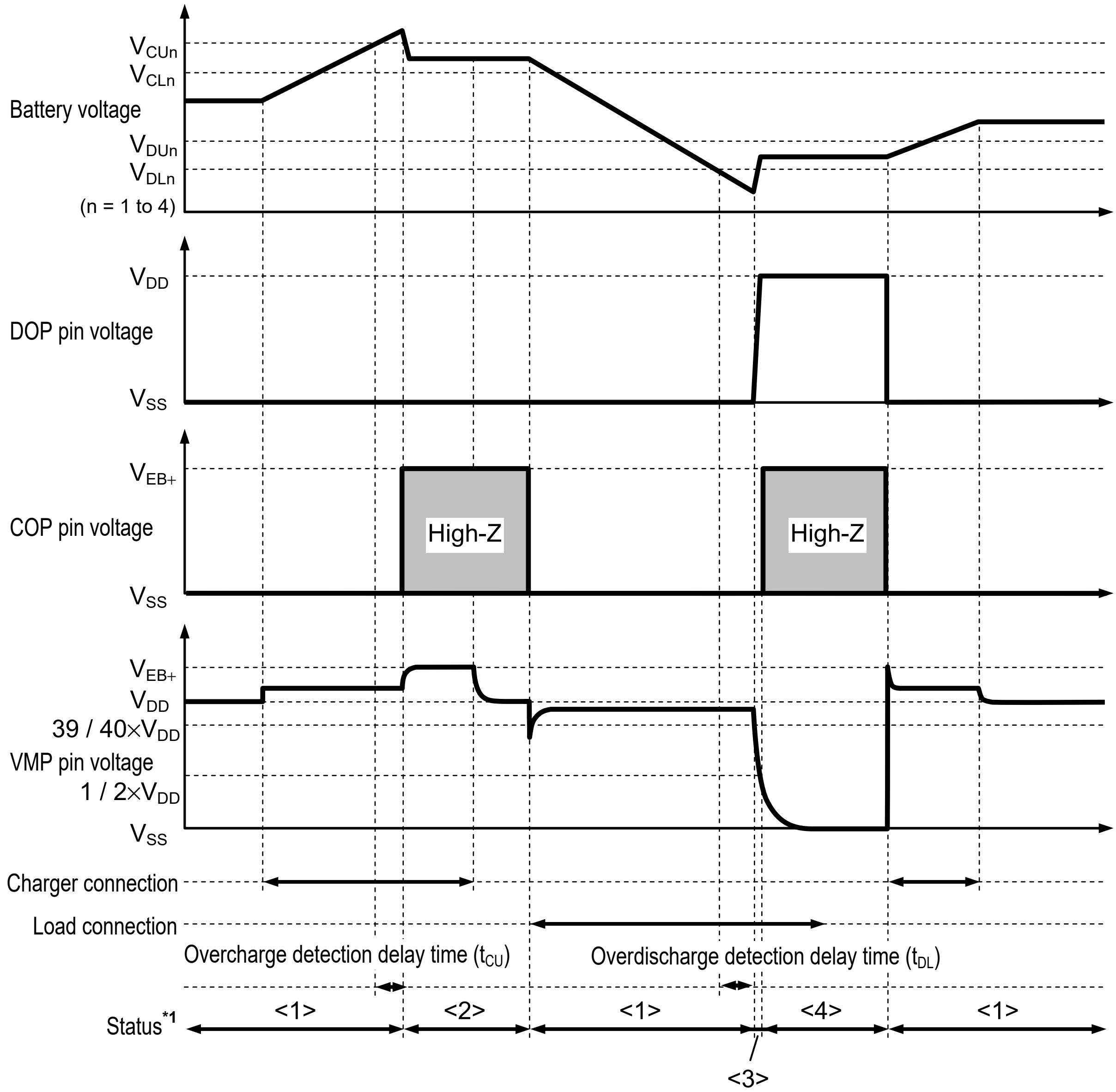
The S-8254A Series has control pins. The SEL pin is used to switch between 3-cell and 4-cell protection. When the SEL pin is low, overdischarge detection of the V4 cell is prohibited and an overdischarge is not detected even if the V4 cell is shorted, therefore, the V4 cell can be used for 3-cell protection. The SEL pin takes precedence over the battery protection circuit. Use the SEL pin at high or low.

Table 6 Conditions Set by SEL Pin

SEL Pin	Condition
High	4-cell protection
Open	Undefined
Low	3-cell protection

■ Timing Chart

1. Overcharge Detection and Overdischarge Detection

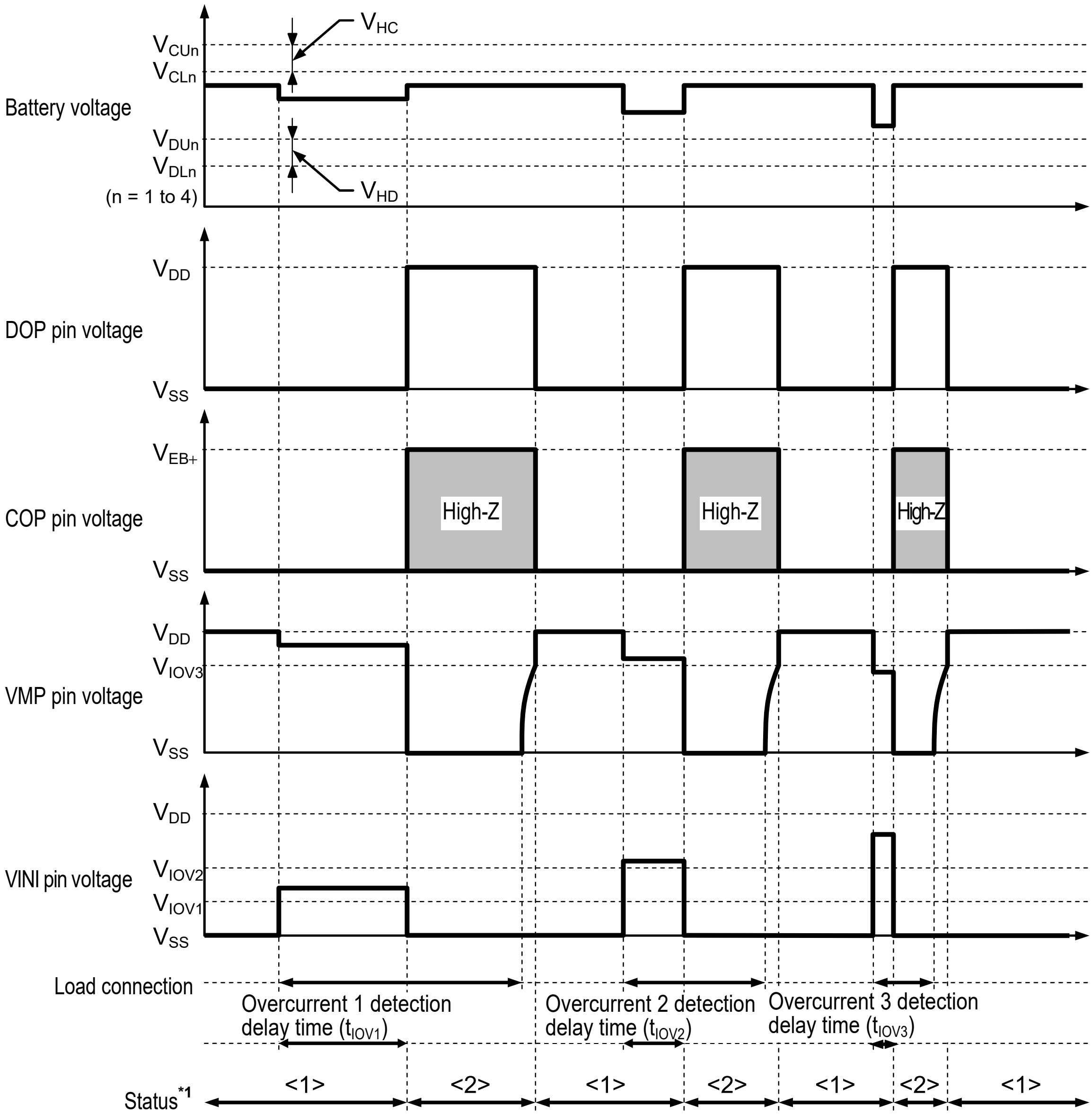


***1.** < 1 > : Normal status
< 2 > : Overcharge status
< 3 > : Overdischarge status
< 4 > : Power-down status

Remark The charger is assumed to charge with a constant current. V_{EB+} indicates the open voltage of the charger.

Figure 9

2. Overcurrent detection



***1.** < 1 > : Normal status
< 2 > : Overcurrent status

Remark The charger is assumed to charge with a constant current. V_{EB+} indicates the open voltage of the charger.

Figure 10

■ Battery Protection IC Connection Example

1. 3-serial Cell

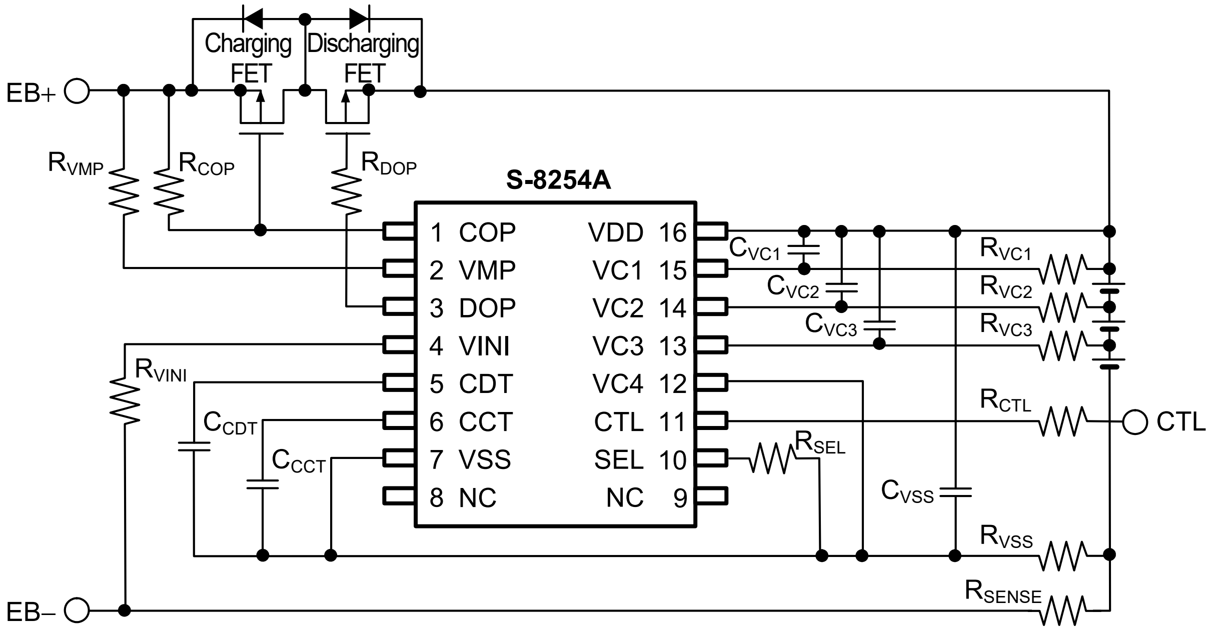


Figure 11

2. 4-serial Cell

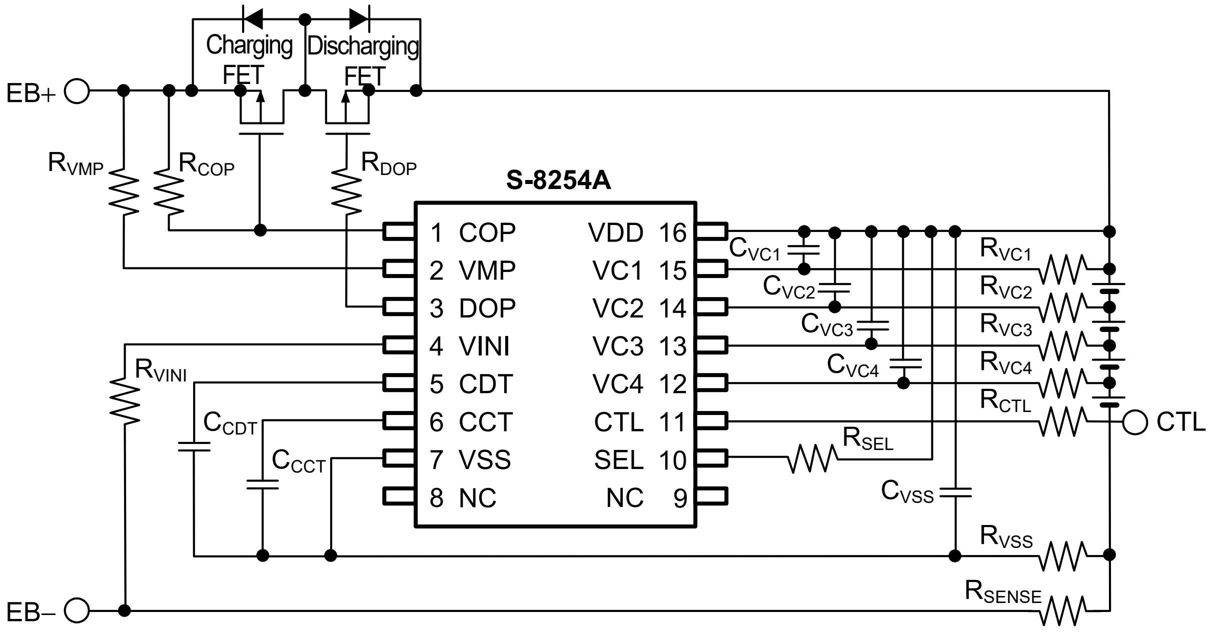


Figure 12

Table 7 Constants for External Components

Symbol	Min.	Typ.	Max.	Unit
R_{VC1}*1	0	1	1	kΩ
R_{VC2}*1	0	1	1	kΩ
R_{VC3}*1	0	1	1	kΩ
R_{VC4}*1	0	1	1	kΩ
R_{DOP}	2	5.1	10	kΩ
R_{COP}	0.1	1	1	MΩ
R_{VMP}	1	5.1	10	kΩ
R_{CTL}	1	1	100	kΩ
R_{VINI}	1	1	100	kΩ
R_{SEL}	1	1	100	kΩ
R_{SENSE}	0	—	—	mΩ
R_{VSS}*1	10	51	51	Ω
C_{VC1}*1	0	0.1	0.33	μF
C_{VC2}*1	0	0.1	0.33	μF
C_{VC3}*1	0	0.1	0.33	μF
C_{VC4}*1	0	0.1	0.33	μF
C_{CCT}	0.01	0.1	—	μF
C_{CDT}	0.07	0.1	—	μF
C_{VSS}*1	2.2	2.2	10	μF

***1.** Please set up a filter constant to be $R_{VSS} \times C_{VSS} \geq 51$ μF • Ω and to be $R_{VC1} \times C_{VC1} = R_{VC2} \times C_{VC2} = R_{VC3} \times C_{VC3} = R_{VC4} \times C_{VC4} = R_{VSS} \times C_{VSS}$.

Caution 1. The constants may be changed without notice.

2. It is recommended that filter constants between VDD and VSS should be set approximately to 112 μF • Ω.

e.g. $C_{VSS} \times R_{VSS}$ = 2.2 μF × 51 Ω = 112 μF • Ω

Enough evaluation of transient power supply variation and overcurrent protection function in the actual application is needed to determine the proper constants. Contact our sales representatives in case the constants should be set to other than 112 μF • Ω or so.

3. It has not been confirmed whether the operation is normal or not in circuits other than the connection examples. In addition, the connection examples and the constants do not guarantee proper operation. Perform thorough evaluation using the actual application to set the constants.

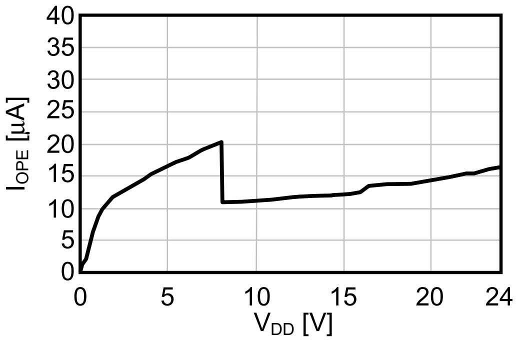
■ Precautions

- The application conditions for the input voltage, output voltage, and load current should not exceed the package power dissipation.
- Batteries can be connected in any order, however, there may be cases when discharging cannot be performed when a battery is connected. In this case, short the VMP pin and VDD pin or connect the battery charger to return to the normal status.
- When an overcharged battery and an overdischarged battery intermix, the circuit is in both the overcharge and overdischarge statuses, so charging and discharging are not possible.
- Do not apply an electrostatic discharge to this IC that exceeds the performance ratings of the built-in electrostatic protection circuit.
- ABLIC Inc. claims no responsibility for any disputes arising out of or in connection with any infringement by products including this IC of patents owned by a third party.

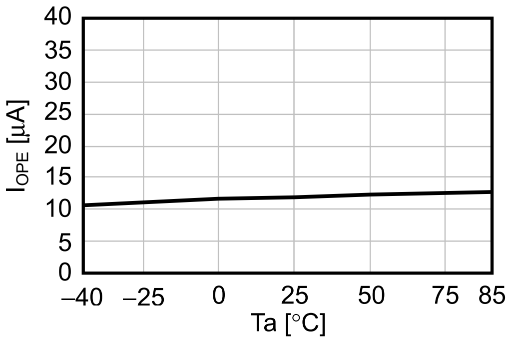
■ Characteristics (Typical Data)

1. Current Consumption

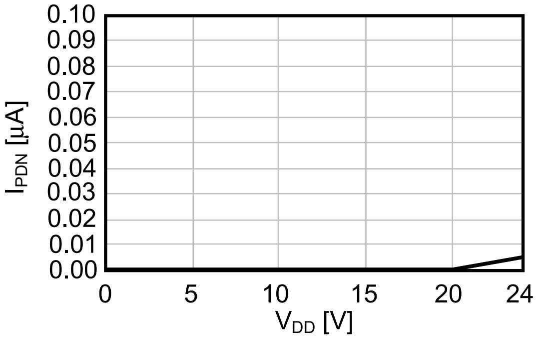
1. 1 I_{OPE} vs. V_{DD}



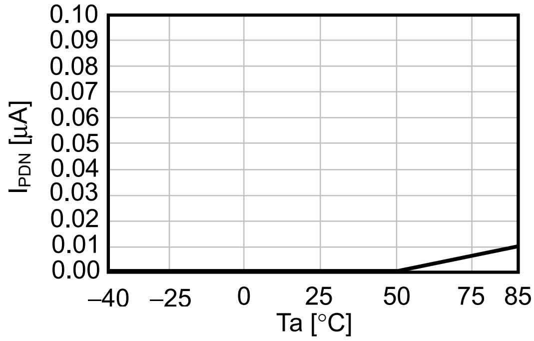
1. 2 I_{OPE} vs. Ta



1. 3 I_{PDN} vs. V_{DD}

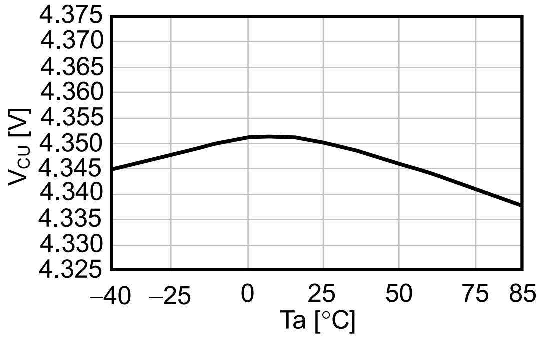


1. 4 I_{PDN} vs. Ta

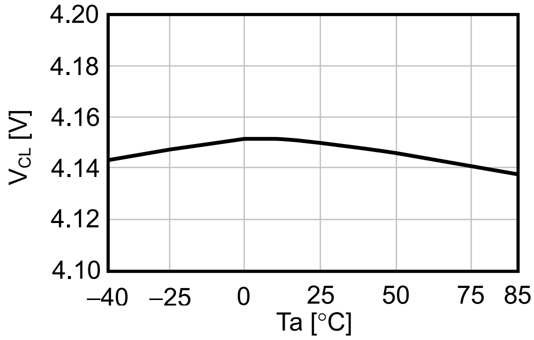


2. Overcharge Detection / Release Voltage, Overdischarge Detection / Release Voltage, Overcurrent Detection Voltage, and Delay Times

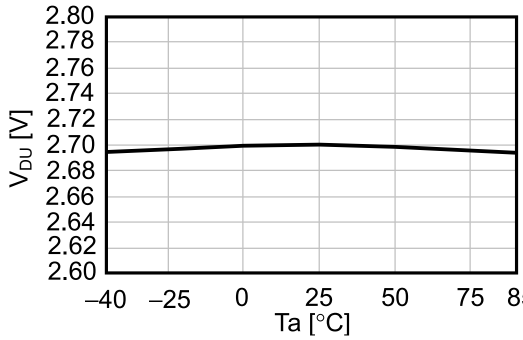
2. 1 V_{CU} vs. Ta



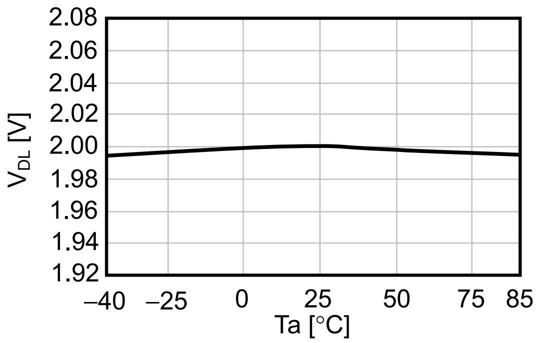
2. 2 V_{CL} vs. Ta



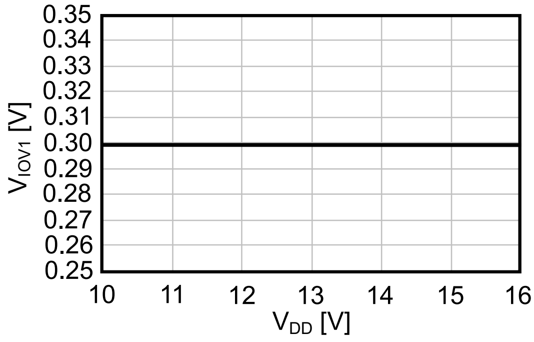
2. 3 V_{DU} vs. Ta



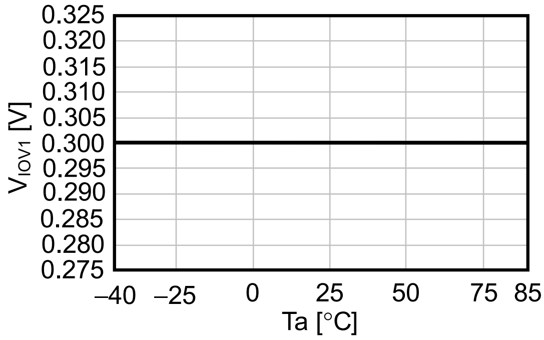
2. 4 V_{DL} vs. Ta



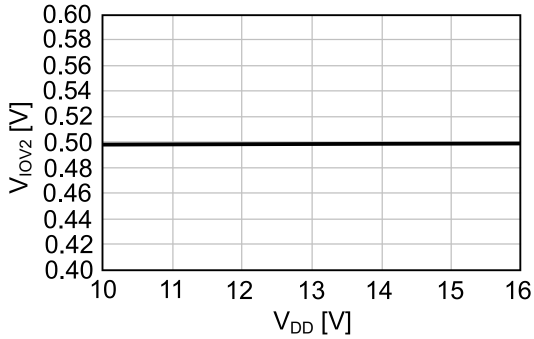
2. 5 V_{IOV1} vs. V_{DD}



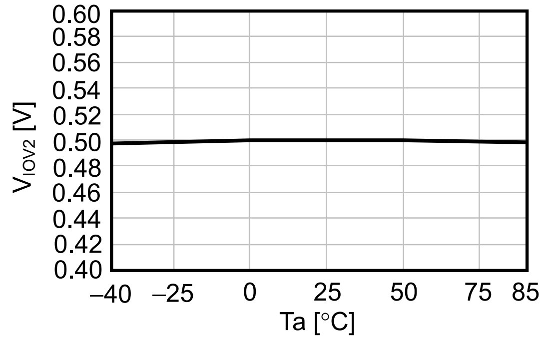
2. 6 V_{IOV1} vs. Ta



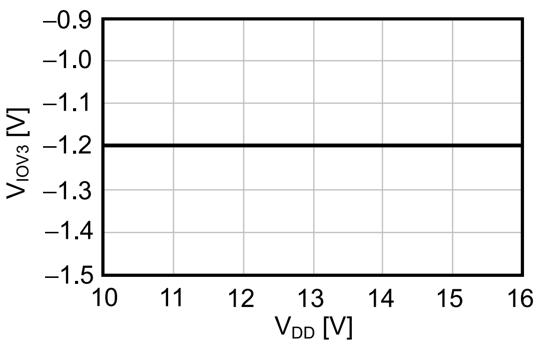
2. 7 V_{IOV2} vs. V_{DD}



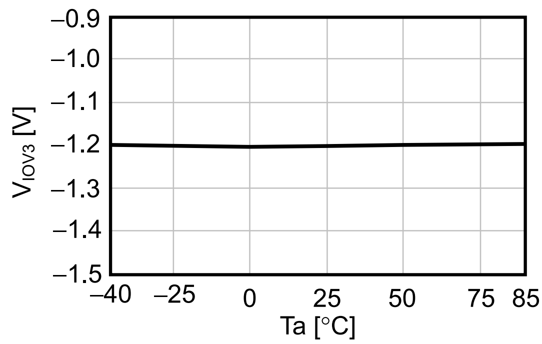
2. 8 V_{IOV2} vs. Ta



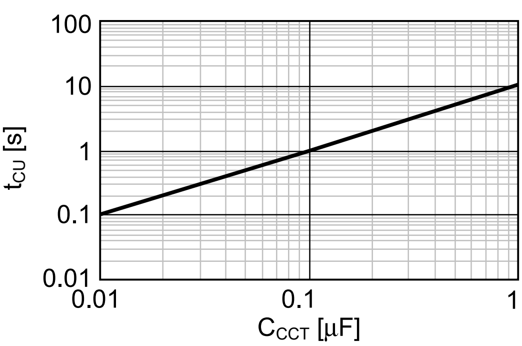
2. 9 V_{IOV3} vs. V_{DD}



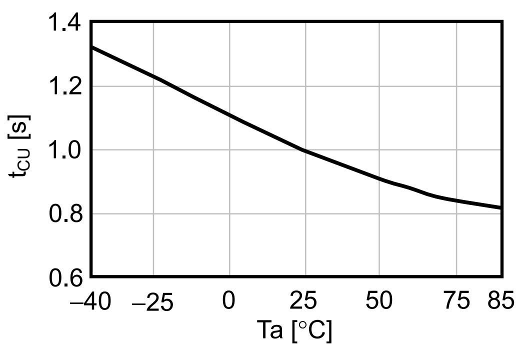
2. 10 V_{IOV3} vs. Ta



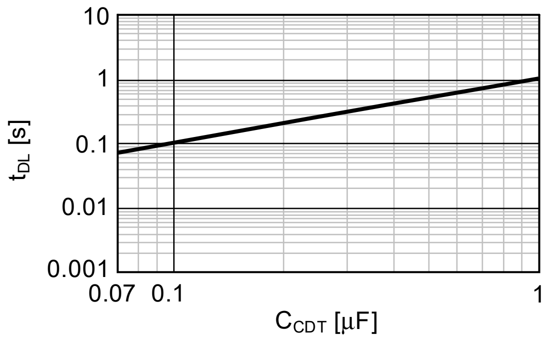
2. 11 t_{CU} vs. C_{CCT}



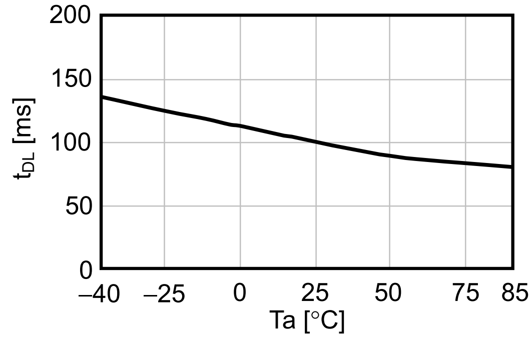
2. 12 t_{CU} vs. Ta



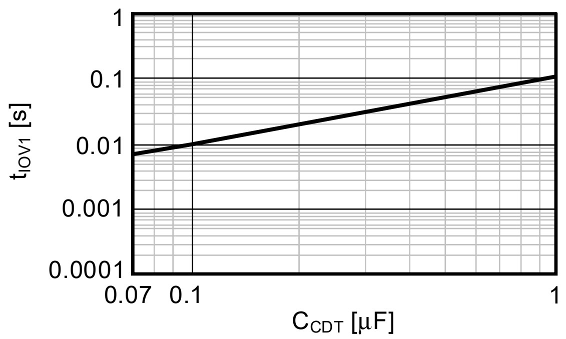
2. 13 t_{DL} vs. C_{CDT}



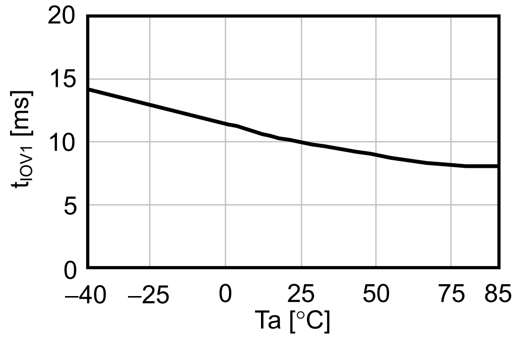
2. 14 t_{DL} vs. Ta



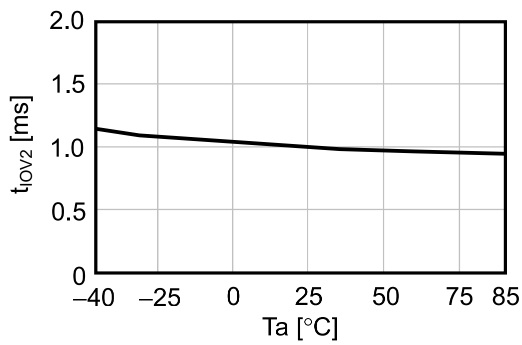
2. 15 t_{IOV1} vs. C_{CDT}



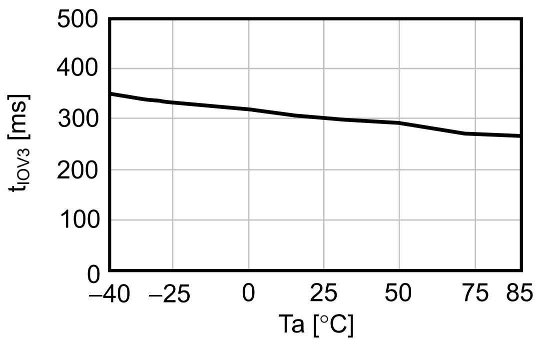
2. 16 t_{IOV1} vs. Ta



2. 17 t_{IOV2} vs. Ta

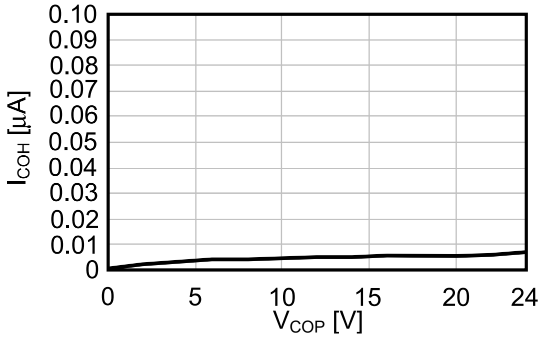


2. 18 t_{IOV3} vs. Ta

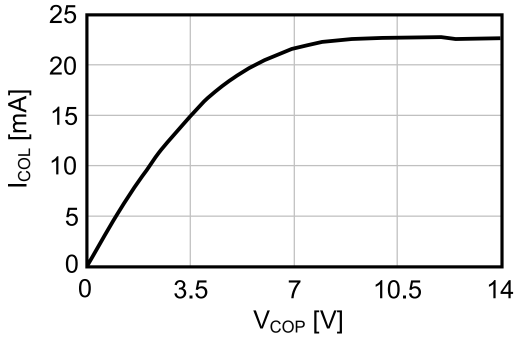


3. COP / DOP Pin

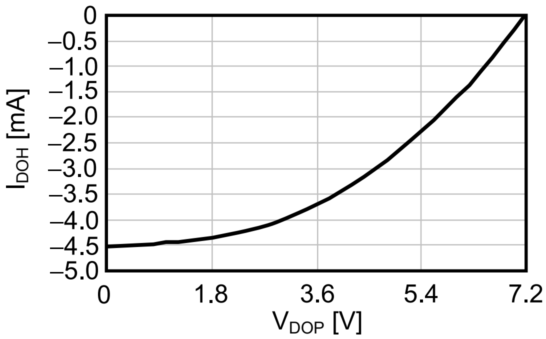
3. 1 I_{COH} vs. V_{COP}



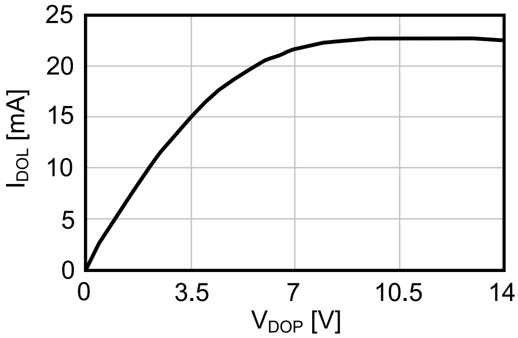
3. 2 I_{COL} vs. V_{COP}

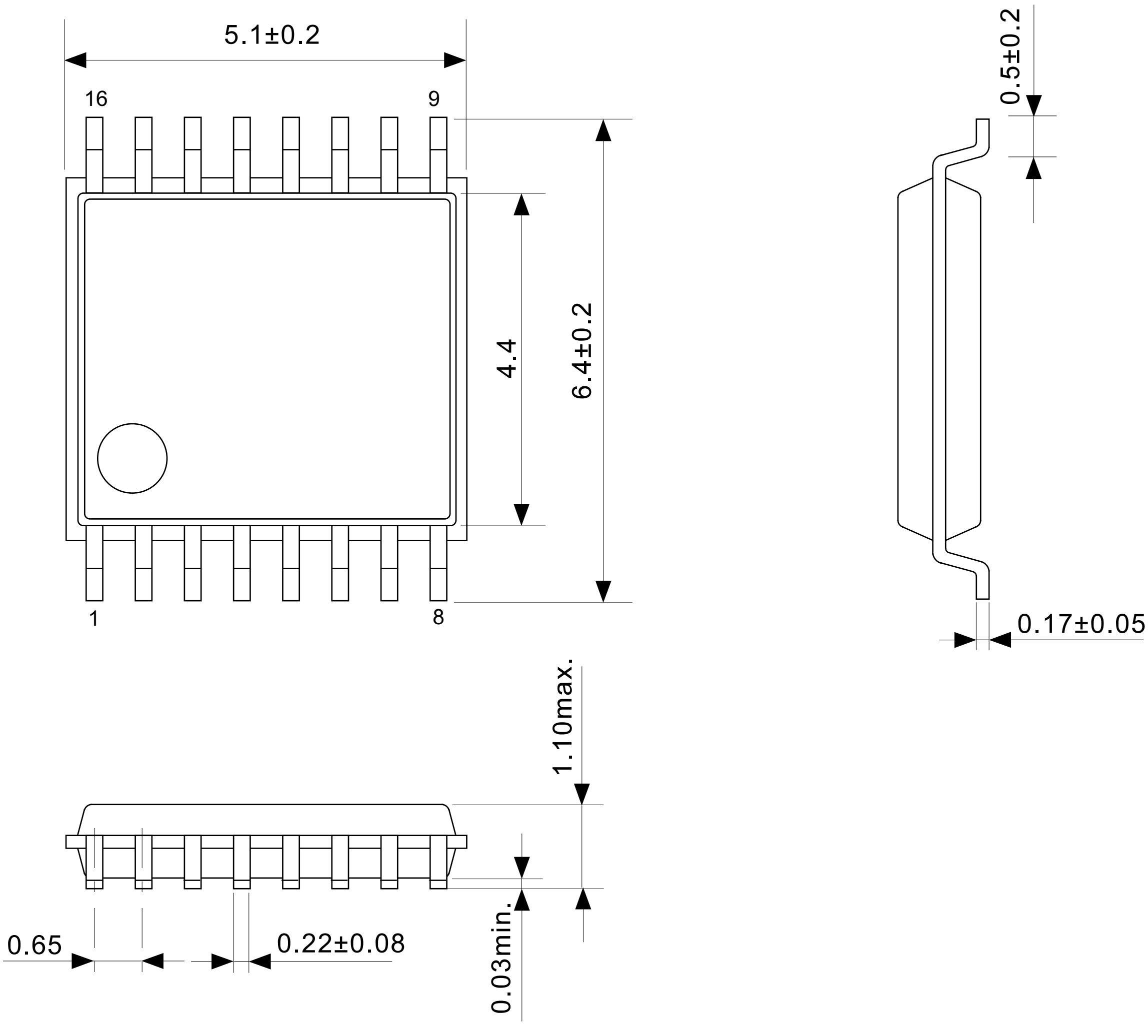


3. 3 I_{DOH} vs. V_{DOP}



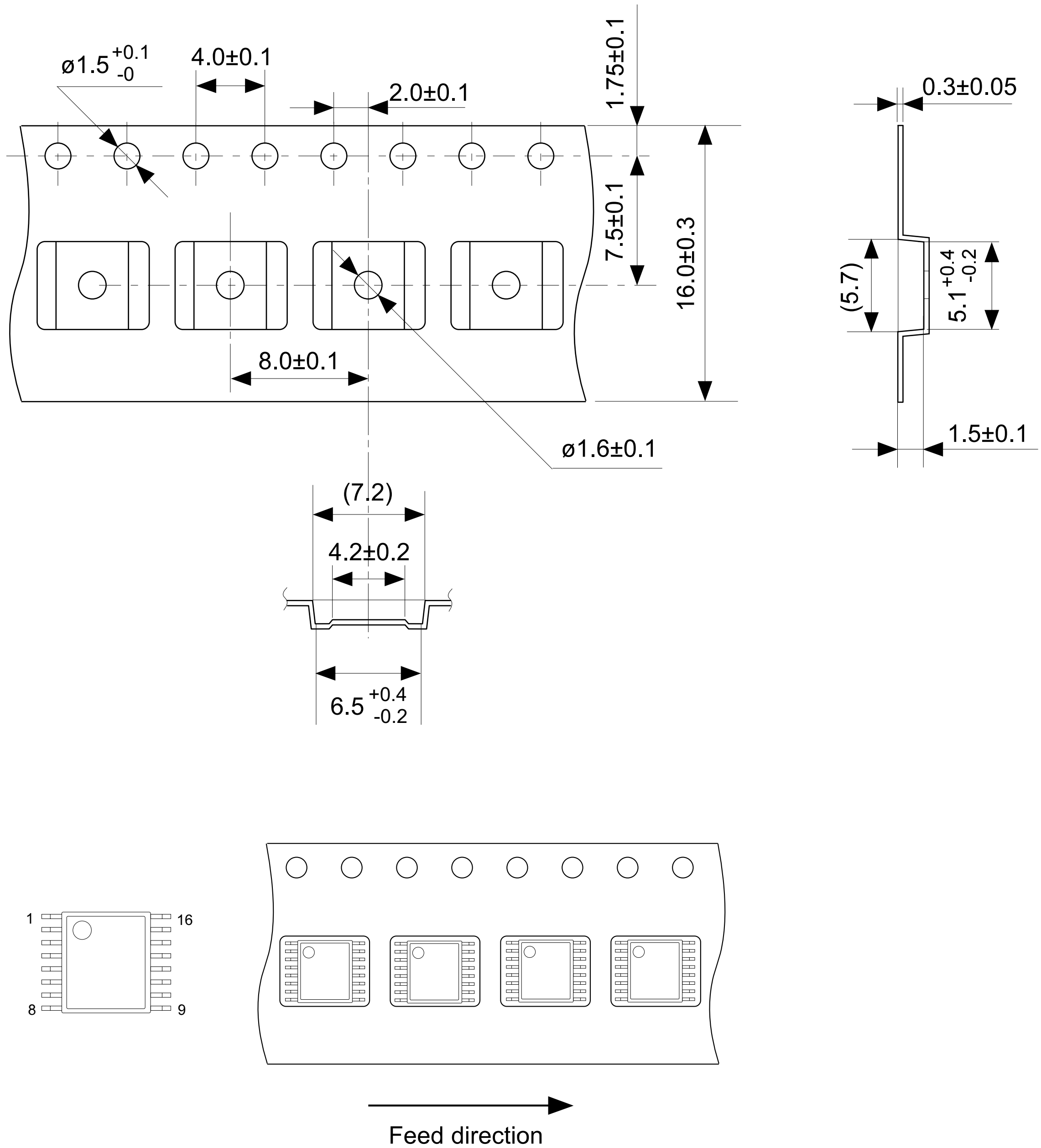
3. 4 I_{DOL} vs. V_{DOP}





No. FT016-A-P-SD-1.2

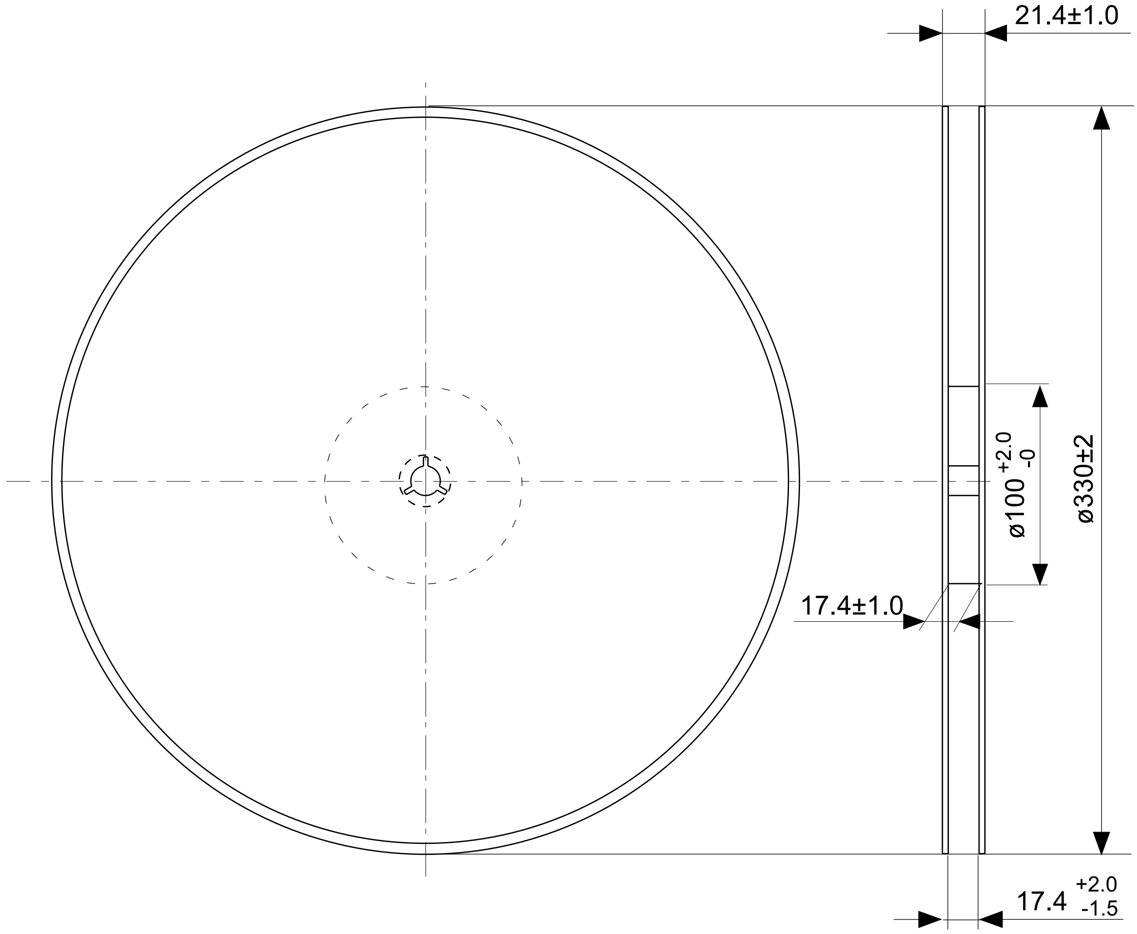
TITLE	TSSOP16-A-PKG Dimensions
No.	FT016-A-P-SD-1.2
ANGLE	
UNIT	mm
ABLIC Inc.	



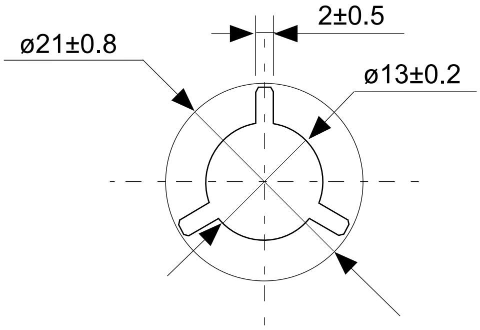
No. FT016-A-C-SD-1.1

TITLE	TSSOP16-A-Carrier Tape
No.	FT016-A-C-SD-1.1
ANGLE	
UNIT	mm

ABLIC Inc.

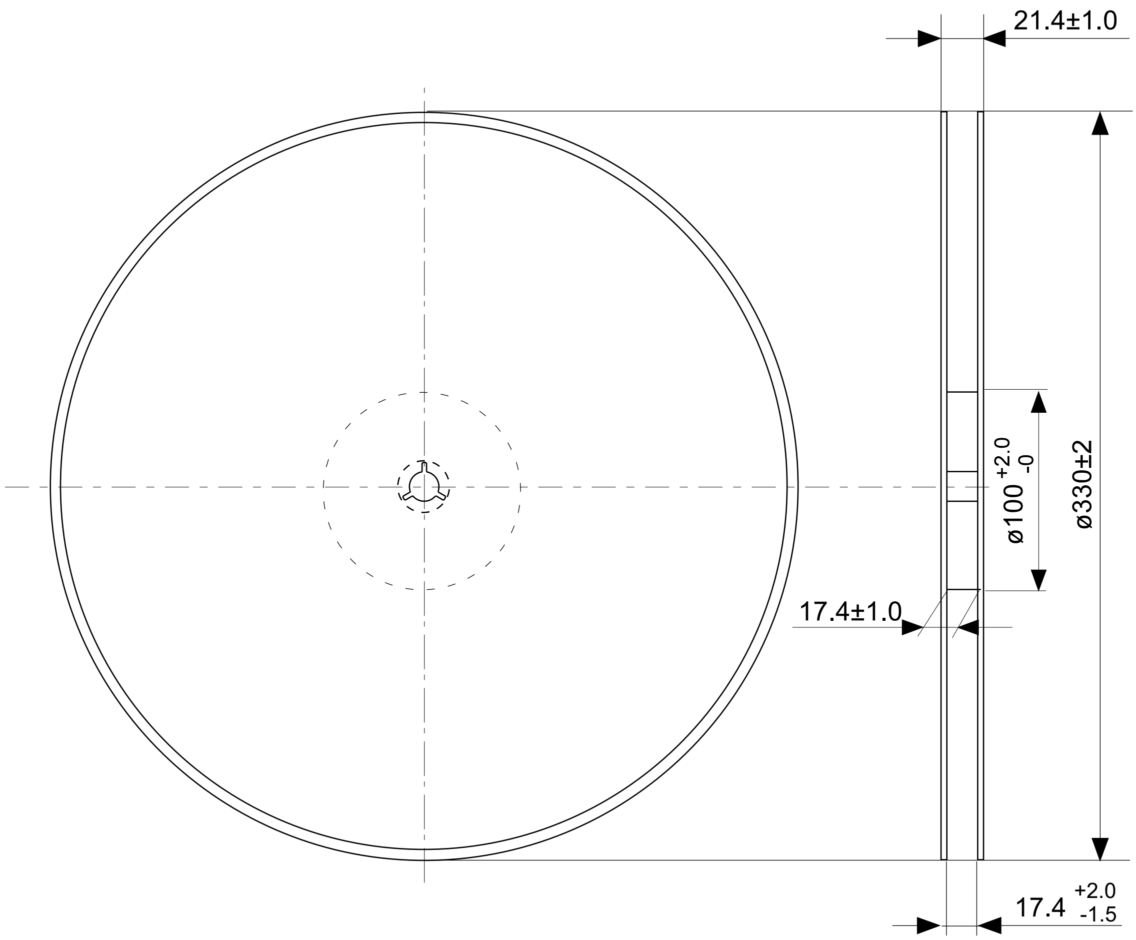


Enlarged drawing in the central part

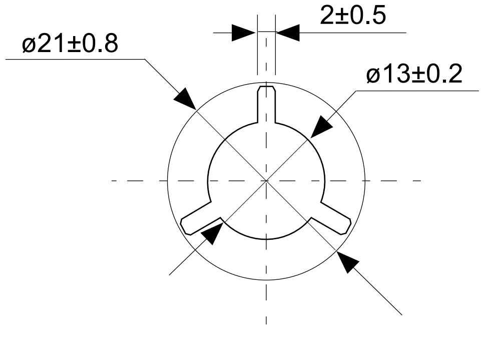


No. FT016-A-R-SD-2.0

TITLE	TSSOP16-A- Reel		
No.	FT016-A-R-SD-2.0		
ANGLE		QTY.	2,000
UNIT	mm		
ABLIC Inc.			



Enlarged drawing in the central part



No. FT016-A-R-S1-1.0

TITLE	TSSOP16-A- Reel		
No.	FT016-A-R-S1-1.0		
ANGLE		QTY.	4,000
UNIT	mm		

ABLIC Inc.

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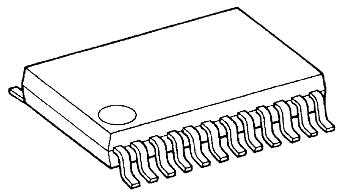
2.4-2019.07

Toshiba Bi-CD Integrated Circuit Silicon Monolithic

TB6612FNG

Driver IC for Dual DC motor

TB6612FNG is a driver IC for DC motor with output transistor in LD MOS structure with low ON-resistor. Two input signals, IN1 and IN2, can choose one of four modes such as CW, CCW, short brake, and stop mode.



SSOP24-P-300-0.65A

質量: 0.14 g (標準)

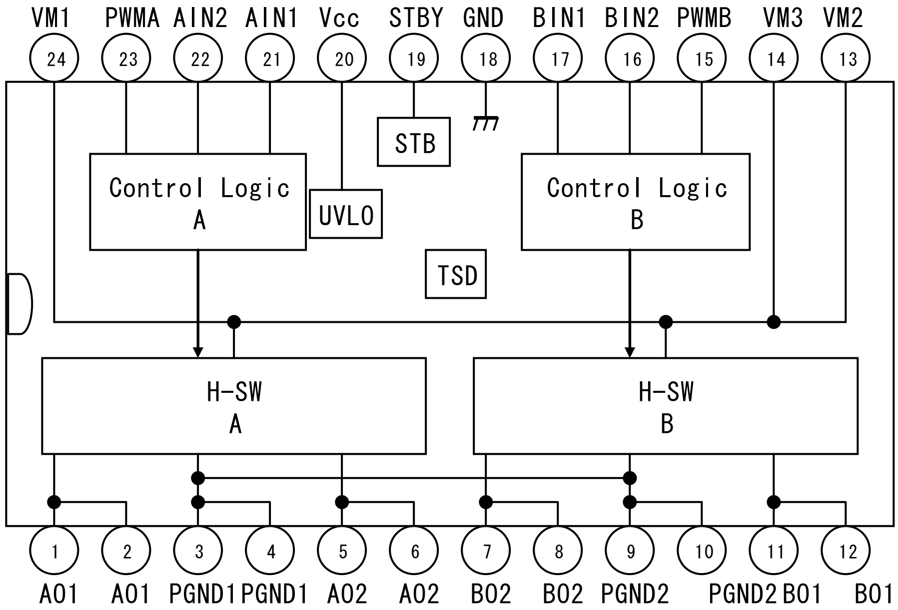
Features

- Power supply voltage; V_M = 15 V(Max)
- Output current; I_{OUT}=1.2 A(ave) / 3.2 A (peak)
- Output low ON resistor; 0.5 Ω (upper+lower Typ. @$V_M \geq$ 5 V)
- Standby (Power save) system
- CW / CCW / short brake / stop function modes
- Built-in thermal shutdown circuit and low voltage detecting circuit
- Small faced package(SSOP24: 0.65 mm Lead pitch)
- Response to Pb free packaging

* This product has a MOS structure and is sensitive to electrostatic discharge. When handling this product, ensure that the environment is protected against electrostatic discharge by using an earth strap, a conductive mat and an ionizer. Ensure also that the ambient temperature and relative humidity are maintained at reasonable levels.

The TB6612FNG is a Pb-free product.
The following conditions apply to solderability:
*Solderability
1. Use of Sn-37Pb solder bath
   *solder bath temperature = 230°C
   *dipping time = 5 seconds
   *number of times = once
   *use of R-type flux
2. Use of Sn-3.0Ag-0.5Cu solder bath
   *solder bath temperature = 245°C
   *dipping time = 5 seconds

Block Diagram



Pin Functions

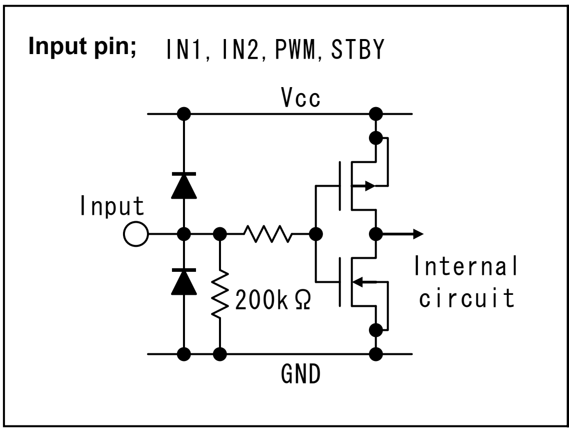
No.	Pin Name	I/O	Function
1	AO1	O	ch A output1
2	AO1		
3	PGND1	—	Power GND 1
4	PGND1		
5	AO2	O	ch A output2
6	AO2		
7	BO2	O	ch B output2
8	BO2		
9	PGND2	—	Power GND 2
10	PGND2		
11	BO1	O	ch B output1
12	BO1		
13	VM2	—	Motor supply (2.5 V to 13.5 V)
14	VM3		
15	PWMB	I	ch B PWM input / 200 kΩ pull-down at internal
16	BIN2	I	ch B input 2 / 200 kΩ pull-down at internal
17	BIN1	I	ch B input 1 / 200 kΩ pull-down at internal
18	GND	—	Small signal GND
19	STBY	I	“L”=standby / 200 kΩ pull-down at internal
20	Vcc	—	Small signal supply
21	AIN1	I	ch A input 1 / 200 kΩ pull-down at internal
22	AIN2	I	ch A input 2 / 200 kΩ pull-down at internal
23	PWMA	I	ch A PWM input / 200 kΩ pull-down at internal
24	VM1	—	Motor supply (2.5 V~13.5 V)

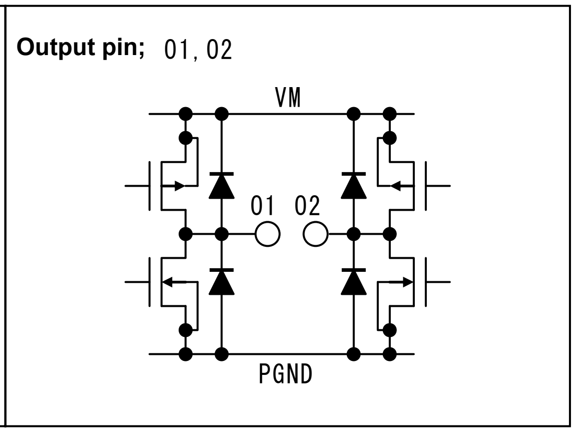
Absolute Maximum Ratings (Ta = 25°C)

Characteristics	Symbol	Rating	Unit	Remarks
Supply voltage	V_M	15	V	
	V_{CC}	6		
Input voltage	V_{IN}	-0.2 to 6	V	IN1,IN2,STBY,PWM pins
Output voltage	V_{OUT}	15	V	O1,O2 pins
Output current	I_{OUT}	1.2	A	Per 1 ch
	I_{OUT} (peak)	2		tw = 20 ms Continuous pulse, Duty ≤ 20%
		3.2		tw = 10 ms Single pulse
Power dissipation	P_D	0.78	W	IC only
		0.89		50 mm × 50 mm t=1.6 mm Cu ≥ 40% in PCB mounting
		1.36		76.2 mm × 114.3 mm t=1.6 mm Cu ≥ 30% in PCB monting
Operating temperature	T_{opr}	-20 to 85	℃	
Storage temperature	T_{stg}	-55 to 150	℃	

Operating Range (Ta=-20～85℃)

Characteristics	Symbol	Min	Typ.	Max	Unit	Remarks
Supply voltage	V_{CC}	2.7	3	5.5	V	
	V_M	2.5	5	13.5	V	
Output current (H-SW)	I_{OUT}	—	—	1.0	A	$V_M \geq 4.5$ V
		—	—	0.4		4.5 V > $V_M \geq 2.5$ V Without PWM Operation
Switching frequency	f_{PWM}	—	—	100	kHz	



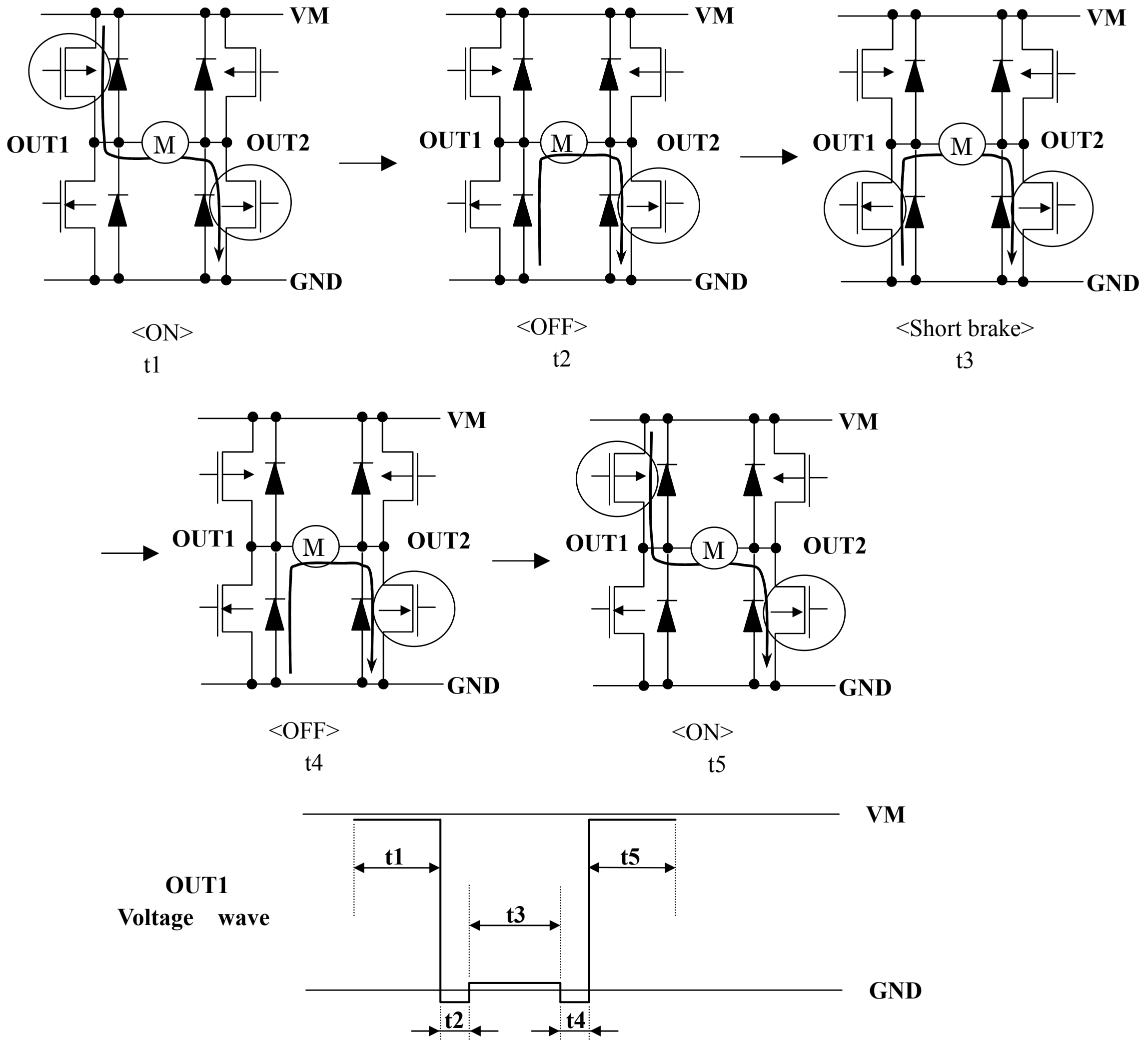


H-SW Control Function

Input				Output		
IN1	IN2	PWM	STBY	OUT1	OUT2	Mode
H	H	H/L	H	L	L	Short brake
L	H	H	H	L	H	CCW
		L	H	L	L	Short brake
H	L	H	H	H	L	CW
		L	H	L	L	Short brake
L	L	H	H	OFF (High impedance)		Stop
H/L	H/L	H/L	L	OFF (High impedance)		Standby

H-SW Operating Description

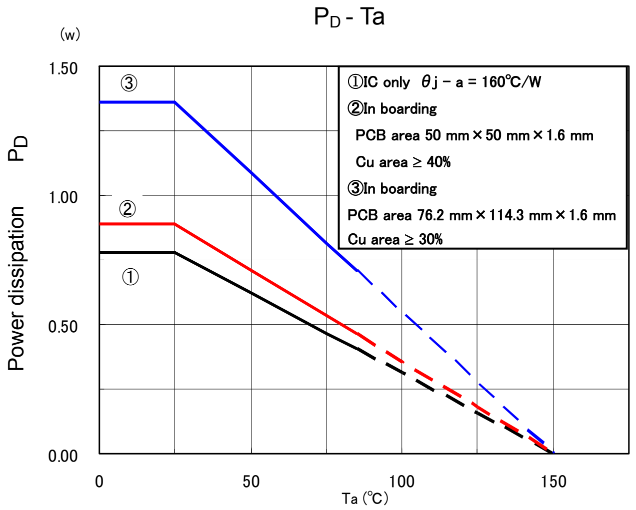
・To prevent penetrating current, dead time t2 and t4 is provided in switching to each mode in the IC.

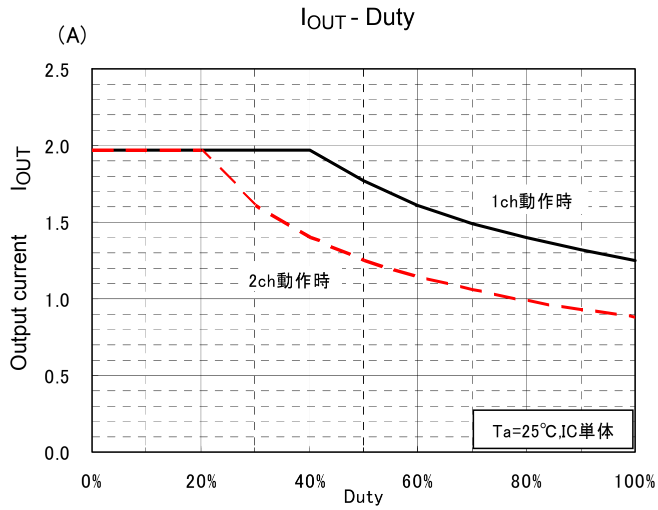


Electrical Characteristics (unless otherwise specified, Ta = 25°C, V_{CC} = 3 V, V_M = 5 V)

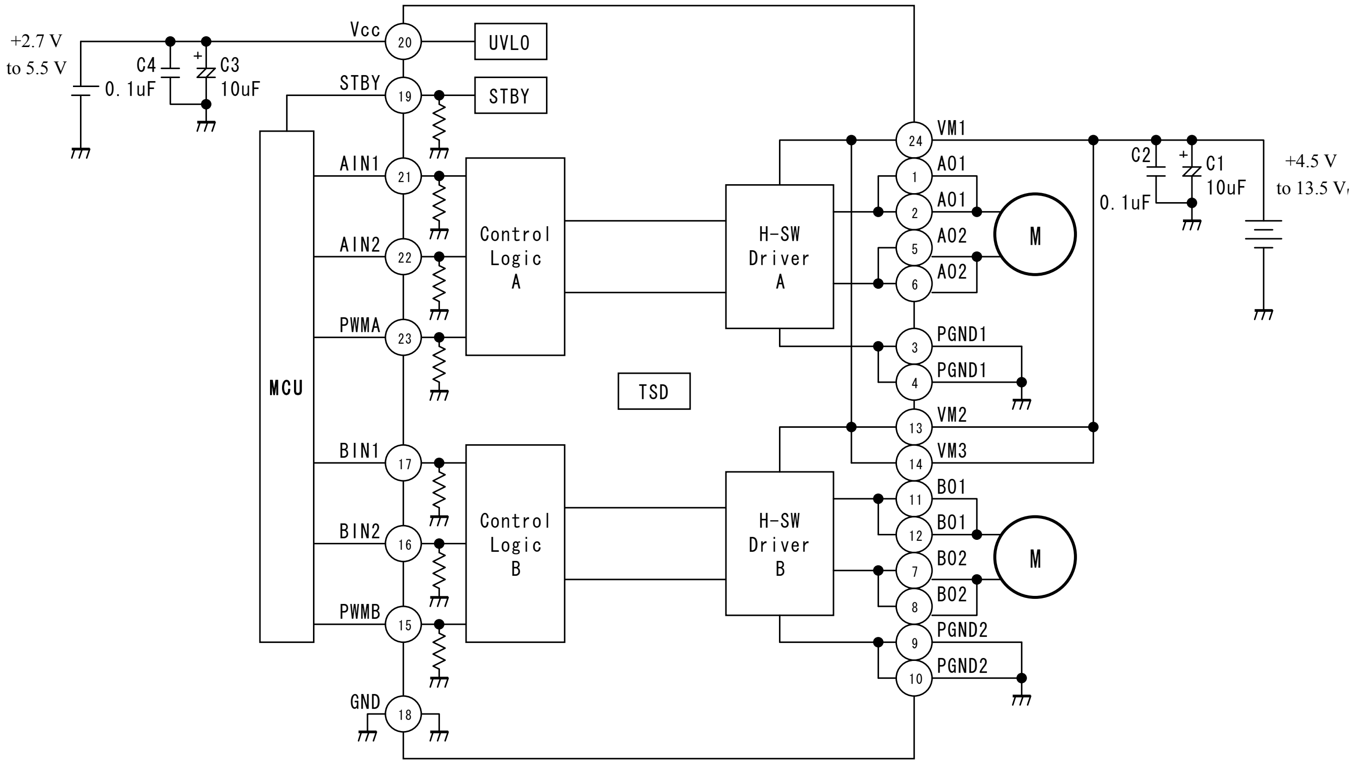
Characteristics	Symbol		Test Condition	Min	Typ.	Max	Unit
Supply current	$I_{CC}(3V)$		STBY = V_{CC} = 3 V, V_M = 5 V	—	1.1	1.8	mA
	$I_{CC}(5.5V)$		STBY = V_{CC} = 5.5 V, V_M = 5 V	—	1.5	2.2	
	$I_{CC(STB)}$		STBY = 0 V	—	—	1	μA
	$I_{M(STB)}$			—	—	1	
Control input voltage	V_{IH}			V_{CC}×0.7	—	V_{CC}+0.2	V
	V_{IL}			-0.2	—	V_{CC}×0.3	
Control input current	I_{IH}		V_{IN} = 3 V	5	15	25	μA
	I_{IL}		V_{IN} = 0 V	—	—	1	
Standby input voltage	$V_{IH(STB)}$			V_{CC}×0.7	—	V_{CC}+0.2	V
	$V_{IL(STB)}$			-0.2	—	V_{CC}×0.3	
Standby input current	$I_{IH(STB)}$		V_{IN} = 3 V	5	15	25	μA
	$I_{IL(STB)}$		V_{IN} = 0 V	—	—	1	
Output saturating voltage	$V_{sat(U+L)1}$		I_O = 1 A, V_{CC} = V_M = 5 V	—	0.5	0.7	V
	$V_{sat(U+L)2}$		I_O = 0.3 A, V_{CC} = V_M = 5 V		0.15	0.21	
Output leakage current	$I_{L(U)}$		V_M = V_{OUT} = 15 V	—	—	1	μA
	$I_{L(L)}$		V_M = 15 V, V_{OUT} = 0 V	-1	—	—	
Regenerative diode VF	$V_{F(U)}$		I_F = 1A	—	1	1.1	V
	$V_{F(L)}$			—	1	1.1	
Low voltage detecting voltage	UVLD		(Designed value)	—	1.9	—	V
Recovering voltage	UVLC			—	2.2	—	
Response speed	t_r		(Designed value)	—	24	—	ns
	t_f			—	41	—	
	Dead time	H to L	Penetration protect time (Designed value)	—	50	—	
		L to H		—	230	—	
Thermal shutdown circuit operating temperature	TSD		(Designed value)	—	175	—	℃
Thermal shutdown hysteresis	△TSD			—	20	—	

Target characteristics



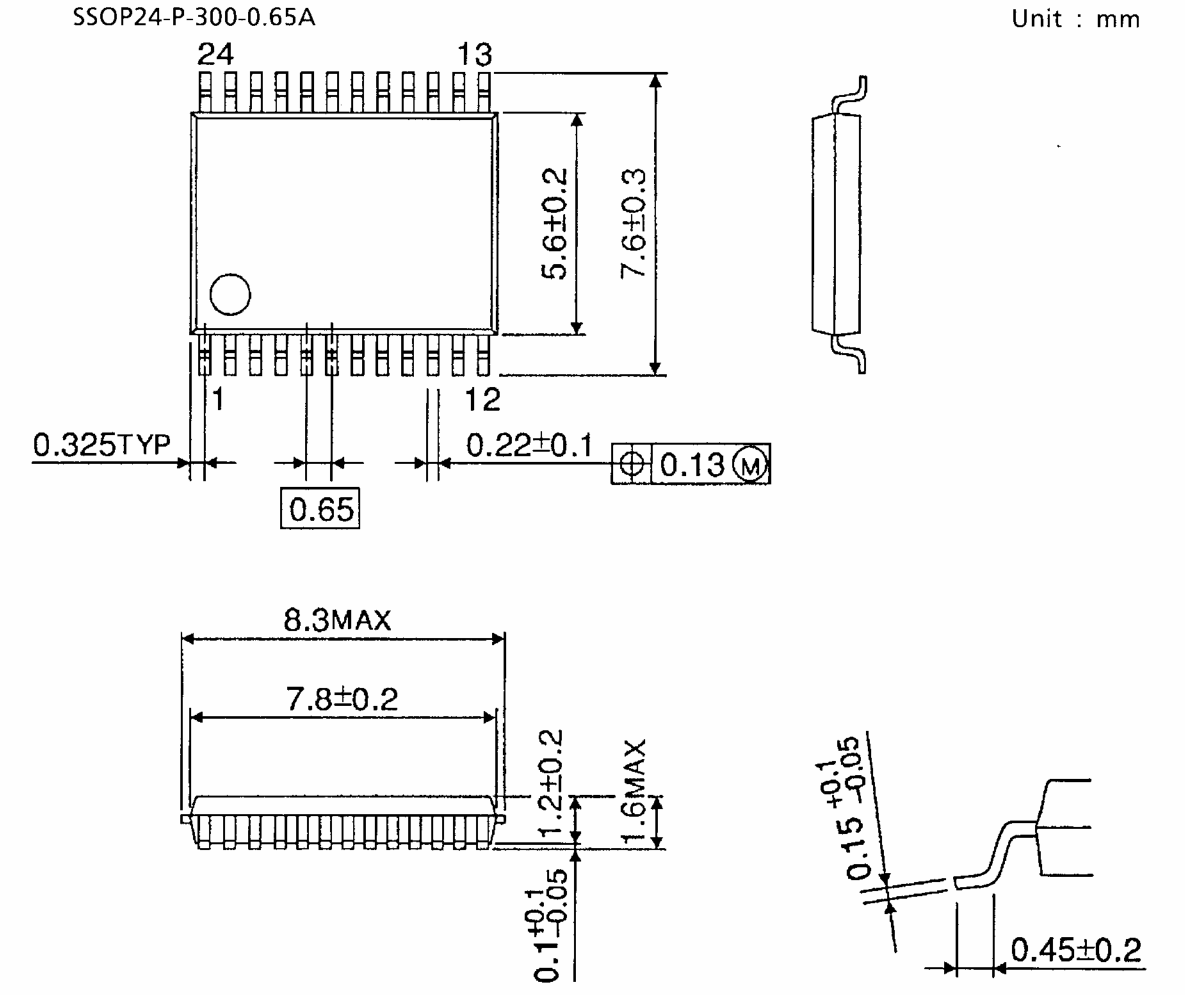


Typical Application Diagram



Note: Condensers for noise absorption (C1, C2, C3, and C4) should be connected as close as possible to the IC.

Package Dimennsions



Weght: 0.14 g (typ)

Notes on Contents

1. Block Diagrams

Some of the functional blocks, circuits, or constants in the block diagram may be omitted or simplified for explanatory purposes.

2. Equivalent Circuits

The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

3. Timing Charts

Timing charts may be simplified for explanatory purposes.

4. Application Circuits

The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required, especially at the mass production design stage.

Toshiba does not grant any license to any industrial property rights by providing these examples of application circuits.

5. Test Circuits

Components in the test circuits are used only to obtain and confirm the device characteristics. These components and circuits are not guaranteed to prevent malfunction or failure from occurring in the application equipment.

IC Usage Considerations

Notes on handling of ICs

[1] The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded, even for a moment. Do not exceed any of these ratings.
Exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.

[2] Use an appropriate power supply fuse to ensure that a large current does not continuously flow in case of over current and/or IC failure. The IC will fully break down when used under conditions that exceed its absolute maximum ratings, when the wiring is routed improperly or when an abnormal pulse noise occurs from the wiring or load, causing a large current to continuously flow and the breakdown can lead smoke or ignition. To minimize the effects of the flow of a large current in case of breakdown, appropriate settings, such as fuse capacity, fusing time and insertion circuit location, are required.

[3] If your design includes an inductive load such as a motor coil, incorporate a protection circuit into the design to prevent device malfunction or breakdown caused by the current resulting from the inrush current at power ON or the negative current resulting from the back electromotive force at power OFF. IC breakdown may cause injury, smoke or ignition.
Use a stable power supply with ICs with built-in protection functions. If the power supply is unstable, the protection function may not operate, causing IC breakdown. IC breakdown may cause injury, smoke or ignition.

[4] Do not insert devices in the wrong orientation or incorrectly.
Make sure that the positive and negative terminals of power supplies are connected properly.
Otherwise, the current or power consumption may exceed the absolute maximum rating, and exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.
In addition, do not use any device that is applied the current with inserting in the wrong orientation or incorrectly even just one time.

Points to remember on handling of ICs

(1) Thermal Shutdown Circuit

Thermal shutdown circuits do not necessarily protect ICs under all circumstances. If the thermal shutdown circuits operate against the over temperature, clear the heat generation status immediately.

Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the thermal shutdown circuit to not operate properly or IC breakdown before operation.

(2) Heat Radiation Design

In using an IC with large current flow such as power amp, regulator or driver, please design the device so that heat is appropriately radiated, not to exceed the specified junction temperature (T_J) at any time and condition. These ICs generate heat even during normal use. An inadequate IC heat radiation design can lead to decrease in IC life, deterioration of IC characteristics or IC breakdown. In addition, please design the device taking into considerate the effect of IC heat radiation with peripheral components.

(3) Back-EMF

When a motor rotates in the reverse direction, stops or slows down abruptly, a current flow back to the motor's power supply due to the effect of back-EMF. If the current sink capability of the power supply is small, the device's motor power supply and output pins might be exposed to conditions beyond maximum ratings. To avoid this problem, take the effect of back-EMF into consideration in system design.

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