UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Escuela Técnica Superior de Ingeniería del Diseño

DISEÑO DE UN CONVERTIDOR DC/DC PARA ALIMENTAR UN DRON DE HIDRÓGENO

TRABAJO FINAL DEL
Grado en Ingeniería Electrónica Industrial y Automática

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CURSO ACADÉMICO: 2020/2021

Resumen

Este trabajo de Fin de Grado consistirá en el diseño y simulación de un convertidor conmutado DC/DC, el cual controlará la corriente media producida por una pila de hidrógeno para alimentar las baterías de un dron.

Se estudiará la opción más viable para este proyecto y se diseñarán las etapas de potencia y control considerando las especificaciones de la pila de hidrógeno y de las baterías del dron.

Palabras clave: dron, bateria, hidrógeno, convertidor DC/DC

Resum

Este treball Fí de Grau consistirá el de disseny i simulació d'un convertidor commutat DC/DC, el qual controlarà la corrent mitja produida per una pila d'hidrògen per a alimentar les bateries d'un dron.

Es va a estudiar les opcions mes viables per aquest projecte i es dissenyaran les etapes de potència i control considerant les especificacions de la pila de hidrògen i de les bateries del dron.

Paraules clau: dron, bateria, hidrògen, convertidor DC/DC

Abstract

This project consists on the design and simulation of a DC/DC switched converter, which will control the average current produced by a hydrogen cell, to power the batteries of a drone..

The most viable option for this project will be studied and the stages of power and control will be designed, always considering the specifications of the hydrogen cell and the drone batteries.

Keywords: drone, battery, hydrogen, DC/DC switched converter

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Documento 1: Memoria

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1. Introducción

A pesar de que el campo de los vehículos aéreos no tripulados está en auge, siguen teniendo problemas con la duración de las baterías, y este trabajo fin de grado viene a diseñar una herramienta necesaria para el desarrollo del proyecto que el Doctor Carlos Sánchez Diaz está investigando.

La necesidad de alimentar la batería del dron con una pila de hidrógeno, viene por el hecho de que los drones no tienen un tiempo de vuelo muy prolongado por la poca duración de las baterías, por lo que, añadiendo la alimentación de la pila de hidrógeno, se consigue alargar la duración de estas baterías, por tanto, el dron se mantiene en vuelo más tiempo.

1.1 Objetivo del proyecto

Este trabajo de fin de grado (TFG) tendrá la finalidad de diseñar un convertidor DC/DC para alimentar la batería de un dron mediante una pila de hidrógeno.

Esto se debe a que los valores de salida de la pila de hidrógeno no son iguales a los de la batería del dron, por lo que necesitamos adaptar la tensión de la pila de hidrógeno a la de la batería del dron.

Para ello se va a plantear los diferentes tipos de convertidores que existen y se elegirá el que mejor se adecue a nuestra situación.

En nuestro caso vamos a usar la pila de hidrógeno que está usando el Doctor Carlos Sánchez Diaz en su proyecto. Según sus especificaciones este proyecto contará con las siguientes características:

Parámetros	**Valor**
Tensión entrada máxima ($V_{i\ max}$)	28 V
Tensión entrada mínima ($V_{i\ min}$)	25 V
Corriente entrada máxima ($I_{i\ max}$)	5 A
Corriente entrada mínima ($I_{i\ min}$)	3 A
Tensión salida (V_o)	11,1 V
Frecuencia de conmutación (F_c)	100 KHz

Tabla 1 Parámetros del proyecto

En la imagen 1 se muestra un diagrama para representar el sistema:

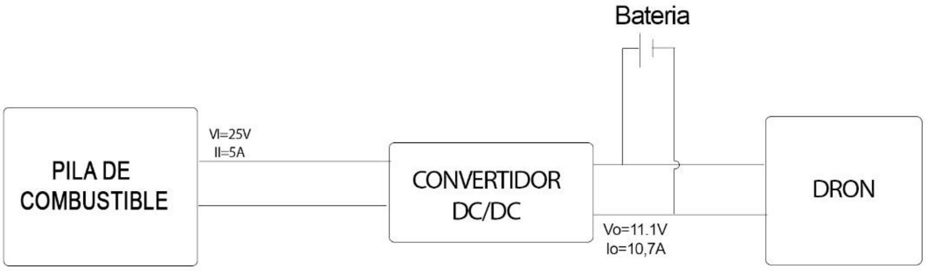


Imagen 1 Diagrama de bloques del sistema

2. Estudio de alternativas

En este apartado vamos a comparar las alternativas que tenemos para este proyecto y veremos cuál se adecua mejor a nuestras necesidades.

Como sabemos las fuentes conmutadas son de pequeño tamaño y tienen bajas pérdidas por tener una frecuencia alta, por lo que serán ideales para este proyecto.

Entre las fuentes conmutadas tenemos las fuentes con aislamiento, las cuales son más grandes y, por tanto, más pesadas, y las fuentes sin aislamiento, con un menor tamaño y un menor peso. También el hecho de que el rango de valores de tensión entre la pila de combustible y la batería sean tan próximos, hace que no requiera el uso de un aislamiento galvánico.
Por lo que elegiremos una fuente sin aislamiento.

Entre las fuentes sin aislamiento tenemos 3 tipos:

- Buck
- Buck-Boost
- Boost

Pasaremos a explicar brevemente en qué consiste cada una de este tipo de fuentes conmutadas.

2.1. Buck

El convertidor Buck es un tipo de fuente de alimentación conmutada reductora, la cual tiene la finalidad de reducir la tensión de entrada, es decir, el convertidor Buck una tensión de salida menor a la de entrada.

El esquema del circuito es el siguiente:

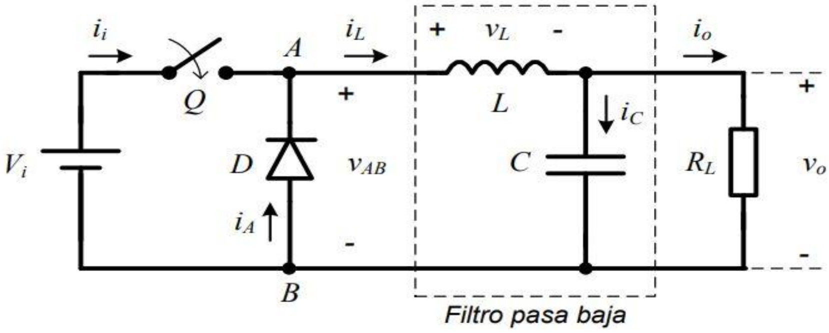


Imagen 2 Esquema circuito Buck

Este convertidor funciona en 2 estados dependiendo del interruptor (Q).
El modo On, el cual su circuito equivalente sería el siguiente:

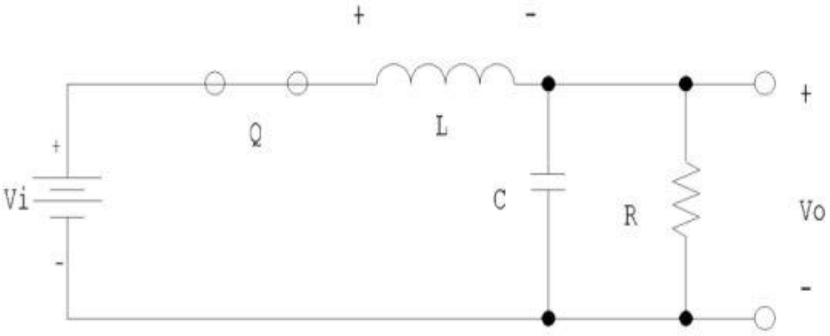


Imagen 3 Esquema circuito Buck On

El modo Off, donde su circuito equivalente sería este:

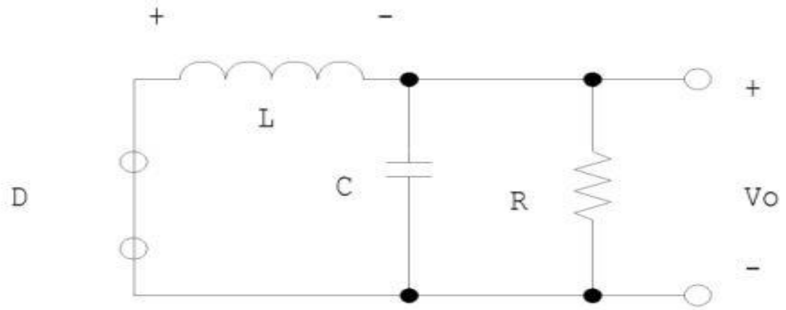


Imagen 4 Esquema circuito Buck Off

2.2 Boost

Este convertidor se considera un elevador, puesto que su función es aumentar el voltaje que entra en el circuito. Por lo que la Vo sería mayor a la Vi.

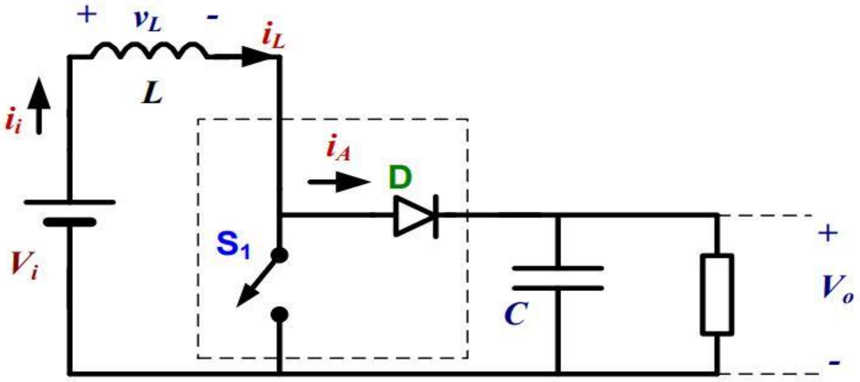


Imagen 5 Esquema circuito Boost

Este al igual que el convertidor Buck funciona mediante 2 estados que dependen si el interruptor (S) está en On o en Off.

En modo On su circuito equivalente sería el siguiente:

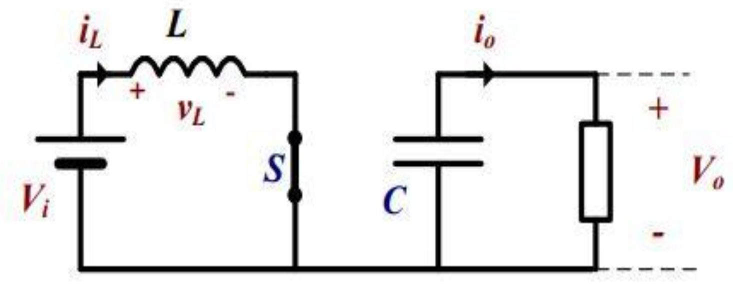


Imagen 6 Esquema circuito Boost On

Y en estado Off sería este:

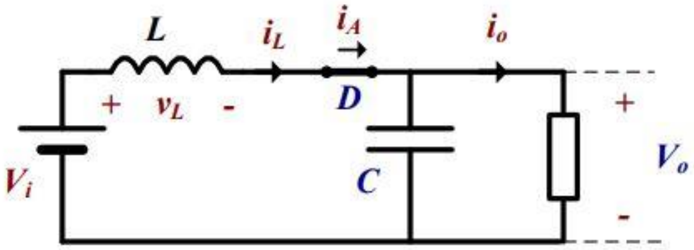


Imagen 7 Esquema circuito Boost Off

2.3 Buck-Boost

Este convertidor es una mezcla entre los 2 anteriores, ya que puede usarse tanto como para elevar el voltaje de entrada, como para reducirlo.

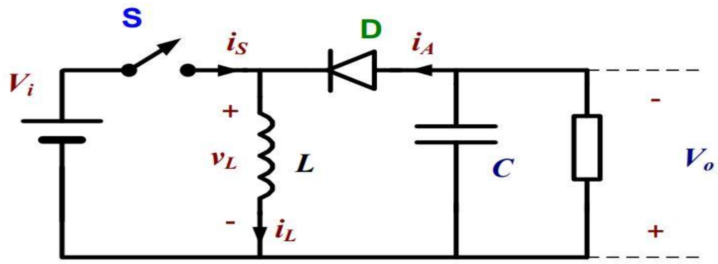


Imagen 8 Esquema circuito Buck-Boost

Y al igual que los dos convertidores anteriores, tiene 2 estados que dependen el interruptor S.

Estado On:

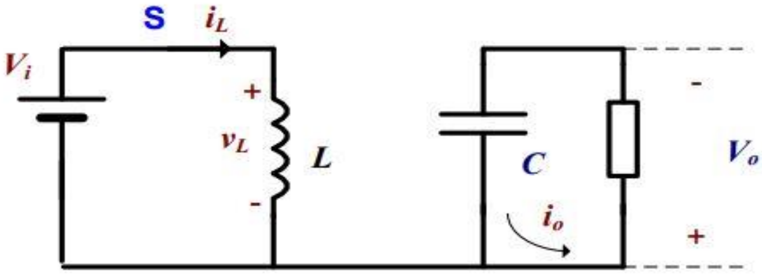


Imagen 9 Esquema circuito Buck-Boost On

Y el estado Off:

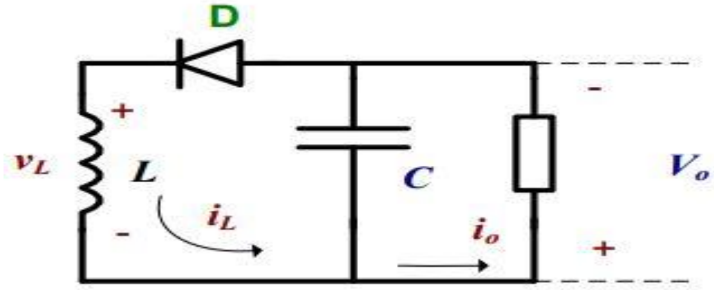


Imagen 10 Esquema circuito Buck-Boost Off

3. Solución adoptada

Como se ha explicado en el punto anterior, el convertidor Buck es el convertidor ideal para usar en este proyecto, por lo que será el seleccionado.

Como se ha explicado anteriormente el convertidor Buck funciona en 2 estados dependiendo del estado del transistor, el modo On y el modo Off.
También hay que destacar que tiene 2 modos de funcionamiento dependiendo de la corriente de la bobina, si la corriente en la bobina nunca llega a ser cero, se considera modo de conducción continua. En cambio, si la corriente de la bobina llega a cero en una parte del ciclo de conmutación, se considera conducción discontinua.

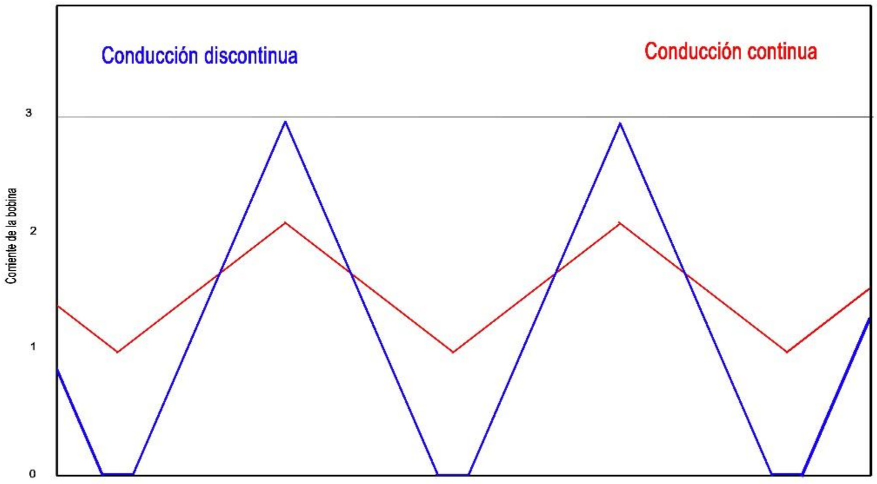


Imagen 11 Gráfica comparativa de la conducción continua y discontinua

En este proyecto trabajaremos en conducción continua, por lo que pasaremos a explicar cómo se comporta el circuito en este modo de conducción.

En el modo On el interruptor Q estará cerrado, de modo que dejará pasar la corriente a través de él.

Si consideramos las caídas de tensión en los componentes, el circuito quedaría de este modo:

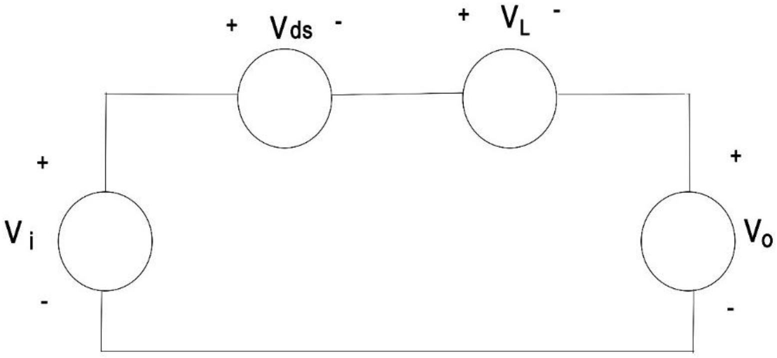


Imagen 12 Caída tensiones en modo Q_{on}

De esto podemos sacar las siguientes ecuaciones:

$$Vi = Vds + V_L + Vo$$

$$Vi = L\frac{di}{dt} + Vds + Vo$$

Despejando di y dt y integrando nos queda la siguiente ecuación:

$$i_{1(o)} = I_{min} = K$$

$$i_{(ton)} = I_{max} = \frac{Vi - Vds - Vo}{L} t_{on} + I_{min}$$

Por otro lado, está el funcionamiento en Off, donde el interruptor Q está abierto, por el que no circula corriente a través de él. Y considerando la caída de tensiones en los componentes el circuito quedaría así:

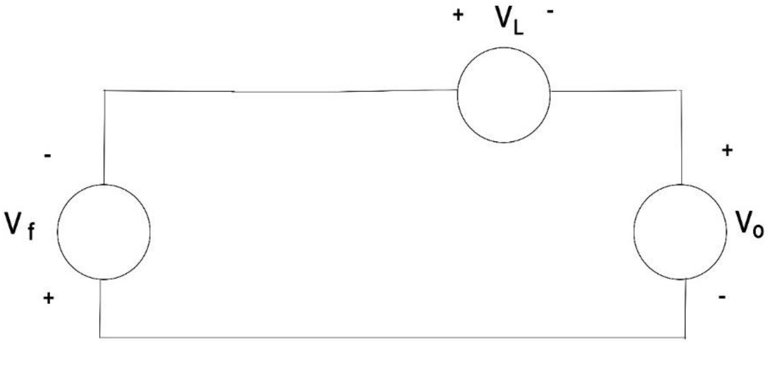


Imagen 13 Caída tensiones en modo Q_{Off}

De este esquema podemos sacar las siguientes ecuaciones:

$$0 = V_f + V_L + Vo$$

$$0 = V_f + L\frac{di}{dt} + Vo$$

Donde al despejar e integrar di y dt, nos queda las siguientes ecuaciones:

$$i_{2(t)} = I_{max} - \frac{V_f\ +\ Vo}{L}(t - t_{on})$$

$$i_{2(T)} = I_{min} = I_{max} - \frac{V_f\ +\ Vo}{L}(T - t_{on})$$

Calculamos el rizado de la corriente sustituyendo I_{max} y I_{min} por las ecuaciones anteriores y obtenemos la siguiente expresión:

$$Vo = -V_f\,(1 - \delta) + Vi \cdot \delta - Vds \cdot \delta \rightarrow Vo = (Vi - Vds_{on})\delta - V_f\,(1 - \delta)$$

De la cual podemos calcular si conocemos todos los valores, podemos calcular el ciclo de trabajo.

En cuanto al funcionamiento de la bobina será el que se muestra en las imágenes 14 y 15.

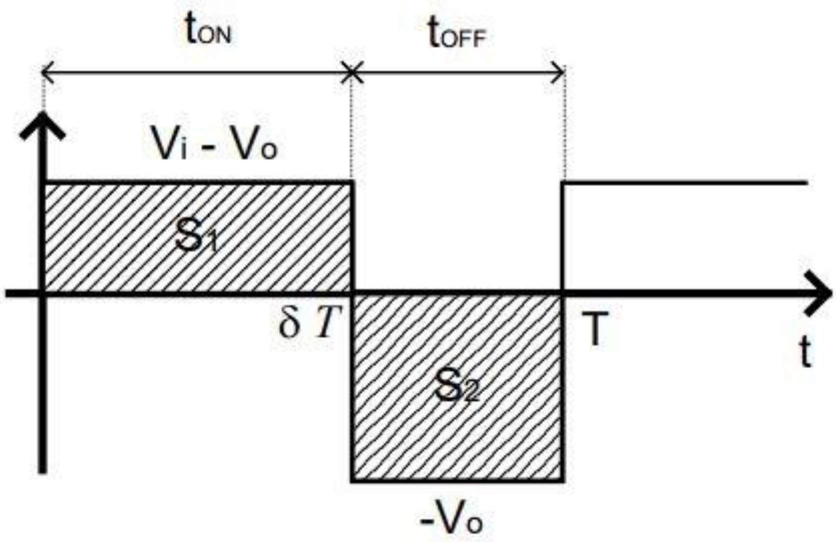


Imagen 14 Gráfica de V_L en conducción continua

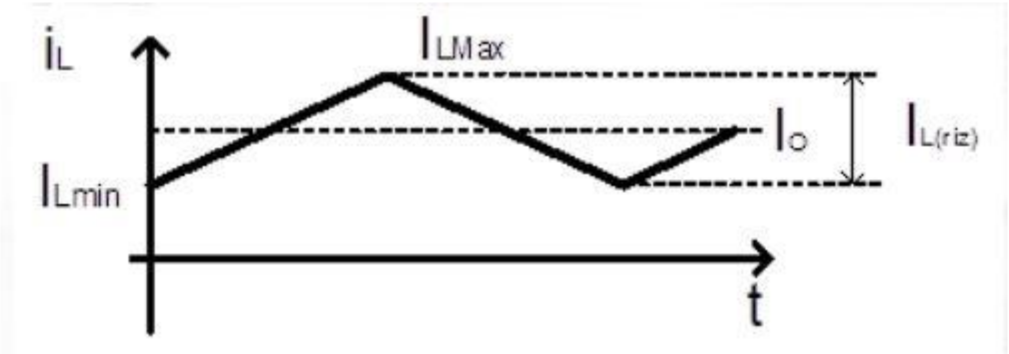


Imagen 15 gráfico I_L en conducción continua

En estas gráficas se observa como la corriente de la bobina no llega a cero, por lo que se cumple la condición de condición continua y podemos calcular la I_{max} y la I_{min} que tendrá.

$$I_{max} = I_o + \frac{\Delta I_o}{2}$$

$$I_{min} = I_o - \frac{\Delta I_o}{2}$$

El funcionamiento del condensador será el mostrado en la imagen 16.

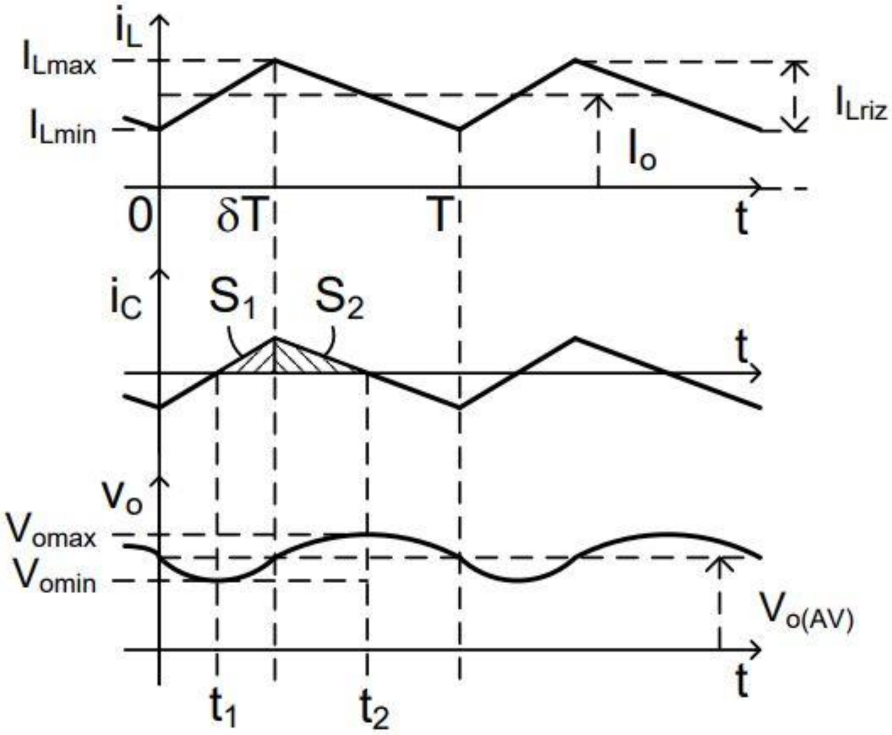


Imagen 16 Gráfico de funcionamiento del condensador en conducción continua

De este gráfico podemos sacar la ecuación para calcular el valor del condensador.

$$V_{o(riz)} = \frac{1}{C}\int_{t_1}^{t_2} i_c dt$$

Al integrar esta ecuación conseguimos la siguiente expresión:

$$C = \frac{\Delta I_{Lriz}}{8 \cdot Vo_{riz} \cdot f}$$

4. Diseño del convertidor

Para el diseño del convertidor usaremos el programa Matlab para los cálculos y para la simulación del circuito se usará el programa LTspice.
En el proceso de control usaremos un control por lazo cerrado ya que necesitaremos una realimentación para reducir el error y que la salida tenga los valores deseados.

4.1 Diseño etapa potencia

La etapa de potencia será la que se encargue de transformar los 25V de la pila de hidrógeno en los 11,1V necesarios para alimentar la batería del dron.

Esta etapa de potencia estará formada por una bobina (L), un condensador (C), un transistor MOSFET (Q) y un diodo (D).

Como el voltaje de entrada variará entre 25V y 28V, calcularemos todo para ambas situaciones y veremos qué ciclo de trabajo (δ) es mayor, puesto que el ciclo de trabajo mayor será más crítico, por lo que sí lo cumple para el ciclo mayor, lo cumplirá en el ciclo menor. Todos los cálculos se podrán comprobar en el anexo.

Para 28V	Para 25V
$Pi_{min} = 84\text{W}$	$Pi_{max} = 125\text{W}$
$Po_{min} = 79{,}8\text{W}$	$Po_{max} = 118{,}75\text{W}$
$Io_{min} = 7{,}189\text{A}$	$Io_{max} = 10{,}7\text{A}$
$Ro_{max} = 1{,}544\Omega$	$Ro_{min} = 1{,}037\Omega$

Como queremos un rizado de corriente bajo, pondremos que sea menor al 5% de la corriente de salida y un rizado de la tensión menor al 1%.

$$\Delta Io_{min} = 0{,}359A \qquad \Delta Io_{max} = 0{,}535A$$

$$I_{max} = 10{,}965A \qquad I_{2max} = 7{,}368A$$

$$Vo_{riz} = 0{,}111V$$

$$\delta_{25V} = 0{,}454 \qquad \delta_{28V} = 0{,}4059$$

Como el ciclo de trabajo de 25V es mayor, trabajaremos sobre ese ciclo de trabajo para calcular el resto de componentes.

4.1.1. Cálculo y selección de la bobina y condensador

$$I_{Lriz} = \Delta Io_{max}$$

$$L = \frac{V_f + Vo}{\Delta I_{Lriz}}(1-\delta)\frac{1}{f} = 1{,}174 \cdot 10^{-4}H$$

$$C = \frac{\Delta I_{Lriz}}{8 \cdot Vo_{riz} \cdot f} = 6{,}0238 \cdot 10^{-6}F$$

$$ESR = \frac{Vo_{riz}}{\Delta I_{Lriz}} = 0{,}207\Omega$$

Buscaremos una bobina de 117μH y del menor pero posible y un condensador de 6,8μF puesto que son los valores comercializados más próximos.

La bobina elegida será el modelo R81XXNL de la marca Incore con un peso de 6,2g.

Imagen 17 Bobina modelo R81XXNL de Incore

El condensador elegido es un condensador electrolítico de la serie B43858 del fabricante TDK

Imagen 18 Condensador modelo B43858 de TDK

4.1.2. Selección del transistor

Para la elección del transistor se ha de tener en cuenta las características que tiene el circuito para que sea capaz de funcionar en estos parámetros.

Las características a tener en cuenta para elegir el transistor son:

- La tensión drenador-surtidor debe ser mayor a la tensión de entrada.
- La corriente máxima que debe alcanzar tiene que superar la tensión máxima de la bobina.

Teniendo en cuenta estas 2 características, se ha elegido el Mosfet de canal N, el modelo SQJA88EP de la marca Vishay. El cual tiene una V_{ds}=40V y una I_D=30A.

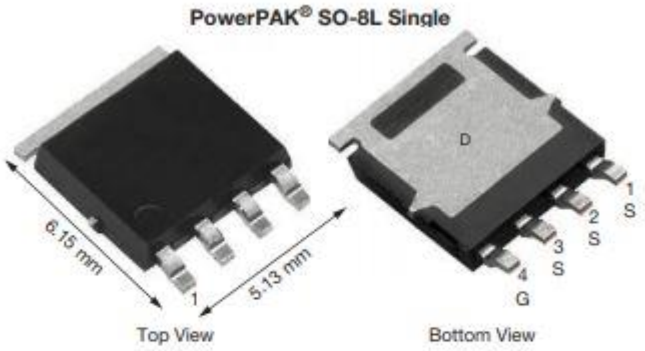


Imagen 19 MOSFET modelo SQJA88EP de Vishay

4.1.3. Selección del diodo

Para la selección del diodo se debe tener en cuenta que lo necesitamos para evitar el paso de la corriente por el circuito.
Al polarizarlo de forma inversa evitará el paso de la corriente, mientras que si lo polarizamos de forma directa, dejará pasar la corriente a través de él.
Como necesitamos un diodo que conmute muy rápidamente, optamos por un diodo tipo Schottky. puesto que estos tienen una velocidad mayor a los diodos convencionales.

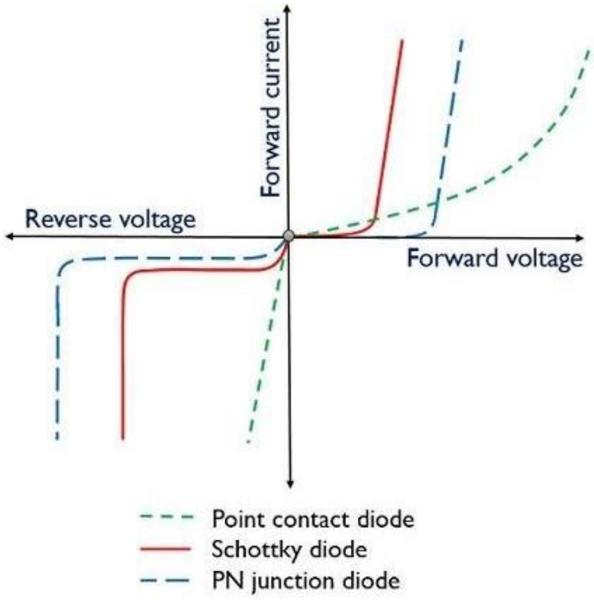


Imagen 20 Gráfico comparación velocidad diodos

Para este proyecto se ha elegido el diodo Schotty modelo STTH3002PI del fabricante STMicroelectronics

Imagen 21 Diodo Schotty modelo STTH3002PI de STMicroelectronics

4.1.4. Selección del sensor

Para este proyecto vamos a usar un sensor de efecto Hall, el cual crea un voltaje proporcional a la corriente media.

Unas de las ventajas de usar este tipo de sensor son:

- Es la capacidad de operar a altas frecuencias, donde otros sensores empiezan a distorsionar.
- Tiene una vida útil más prolongada, por el hecho de no tener un desgaste físico como otro tipo de sensores.
- No se ve afectado por el polvo n el aire, algo muy importante puesto que vamos a estar usándolo en un dron.

El sensor elegido en este caso es el ACS712 del fabricante Allegro, el cual tiene una ganancia de 0,1V/A

Imagen 22 Sensor ACS712 del fabricante Allegro

4.1.5. Seleccionar el modulador PWM

El modulador PWM se encarga de comparar la tensión que genera el compensador con la señal en forma de diente de sierra de la frecuencia, generará la señal de control y permite los mecanismos de protección contra sobrecorrientes.

$$Fm = \frac{1}{V_m} = 0{,}333\frac{1}{V}$$

Teniendo en cuenta las características del proyecto, y del valor Fm, el sensor elegido será el UC3825 del fabricante Texas Instrument

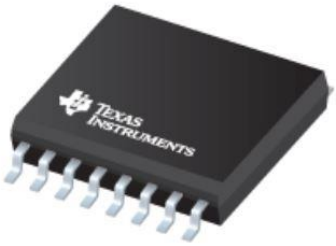


Imagen 23 Modulador PWM UC3825 de Texas Instruments

4.2. Modelado de la etapa de potencia

Para el diseño de la etapa de control, primero debemos modelar la etapa de potencia.
Como necesitamos modelizar oscilaciones de control en modo corriente, vamos a usar el método del modelo linealizado del conmutador PWM.

Este modelo consiste en sustituir los elementos no lineales por un circuito lineal, para obtener un sistema lineal. De este modo se puede obtener de forma sencilla las funciones de transferencia del sistema.

A continuación, en la imagen 25, se mostrarán los circuitos equivalentes en conducción continua del Buck y de pequeña señal, de los cuales se obtienen las funciones de transferencia que usaremos.

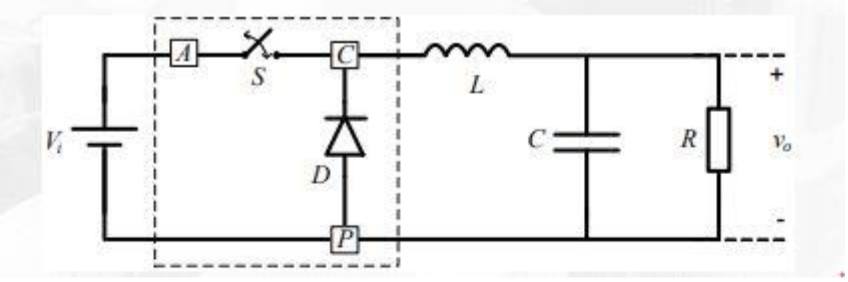


Imagen 24 Convertidor Buck con los terminales señalados

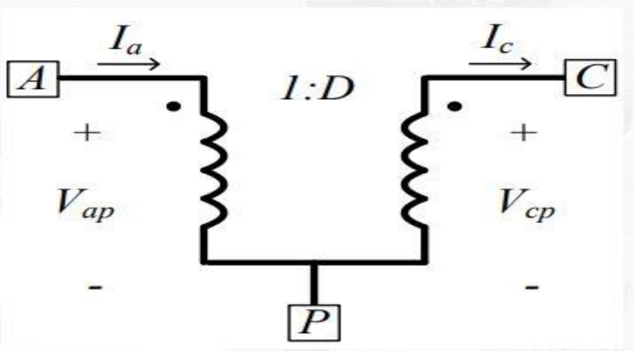


Imagen 25 Circuito equivalente en conducción continua

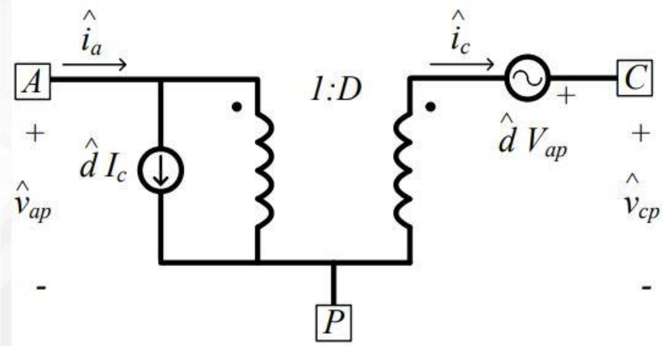


Imagen 26 Circuito equivalente de pequeña señal

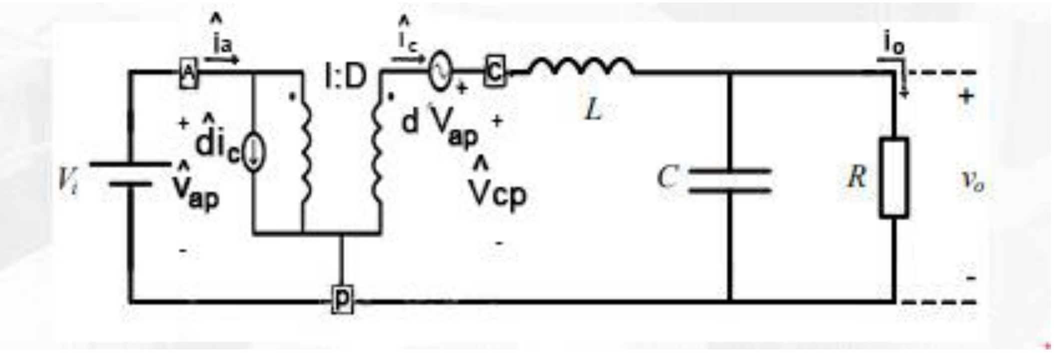


Imagen 27 Buck con circuito equivalente de pequeña señal

De este circuito obtenemos la fórmula para el cálculo de $G_{id}(\omega)$, la cual es la siguiente:

$$G_{Id}(\omega) = Go\,\frac{1 + j \cdot \omega \cdot C \cdot R}{-\omega^2 \cdot C \cdot L + j \cdot \omega \cdot (C \cdot R_c + \frac{L}{R}) + 1}$$

4.3. Diseño etapa de control

Para el control, se ha elegido un control mediante la corriente media, para poder mantener constante la corriente a la cual se va a cargar la batería.

Los controles de corriente media tienen 2 lazos de realimentación, uno de tensión que viene de la salida, y otro de corriente que viene desde la bobina.

En este proyecto se va a usar una variante de este tipo de control, la cual, va a eliminar el lazo de corriente de tensión puesto que tenemos la tensión de salida impuesta por la batería del dron.

En la imagen 26 se puede ver como sería este control mediante bloques de estado.

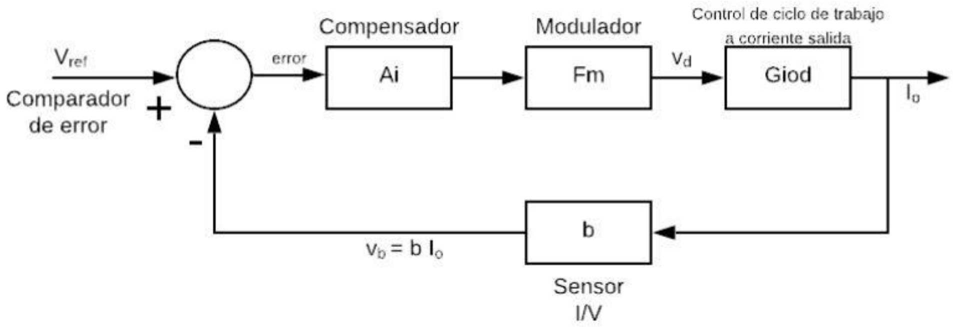


Imagen 28 Imagen 27 Diagrama bloques del control

4.3.1. Función de transferencia G_{id}(s)

Para obtener esta función debemos cortocircuitar la fuente de tensión, de modo que el circuito quede como se muestra en la imagen 29.

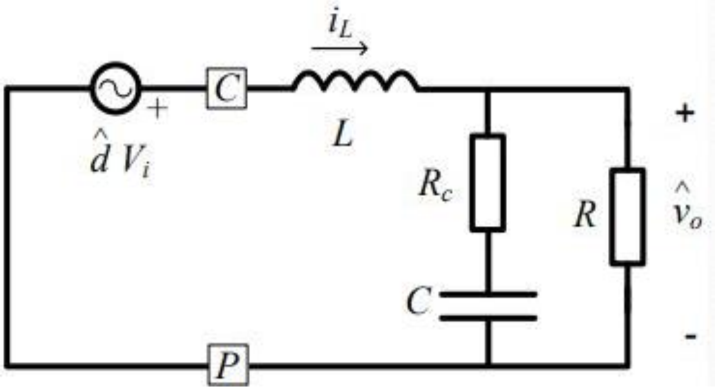


Imagen 29 circuito equivalente para Gid(s)

Teniendo la función de transferencia $G_{id}(\omega)$ obtenida anteriormente, podemos calcular los polos ω_n y los ceros ω_z y la resonancia Q.

$$\omega_z = 8 \cdot 10^5 \frac{rad}{s} \qquad \omega_n = 3{,}76 \cdot 10^4 \frac{rad}{s} \quad Q = 0{,}2324$$

Sustituyendo estos valores en la función de $G_{id}(\omega)$ anterior, podemos sacar el diagrama de bode de la función:

$$G_{Id}(\omega) = Go \frac{1 + \frac{j \cdot \omega}{\omega_z}}{(\frac{j \cdot \omega}{\omega_n})^2 + (\frac{j \cdot \omega}{Q \cdot \omega_n}) + 1}$$

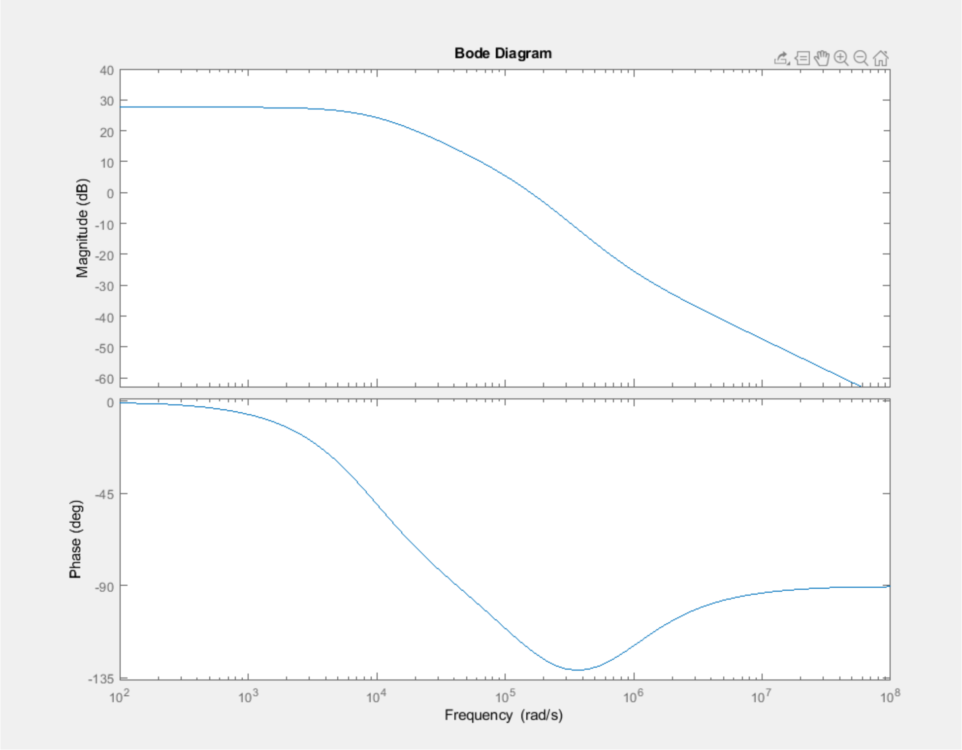


Imagen 30 Diagrama de bode Gid(ω)

4.3.2. Compensador de corriente

Para el diseño del compensador se va a utilizar el método del factor k, el cual consiste en obtener un margen de fase (MF) que concuerde con la frecuencia de cruce (f_c) seleccionada.

Este método añade un polo en el origen para que el error del estado estacionario sea cero.

Existen 3 tipos de compensadores dependiendo del argumento de $G_{vd}(\omega_c)$:

- Tipo 1: $0º < -arg(G_{vd}(j\omega_c)) < 30º$
- Tipo 2: $30º < -arg(G_{vd}(j\omega_c)) < 90º$
- Tipo 3: $90º < -arg(G_{vd}(j\omega_c))$

Para elegir la f_c hay que tener en cuenta que $3 \cdot f_n < f_c < f_z$ por lo que la f_c elegida será 20Khz.

Calculamos el argumento de $G_{vd}(\omega_c)$: $-arg(G_{Id}(\omega_c)) = -116{,}343°$ por lo que será del tipo 3.

Para ello elegiremos un margen de fase entre 60º y 70º ya que se considera que es el rango ideal. El margen de fase elegido será MF=60.

Determinaremos el aumento de fase a la frecuencia de cruce para conseguir el margen de fase deseado.

$$AUFA = MF - (-arg(G_{Id}(\omega_c))) - 90 = 86{,}34$$

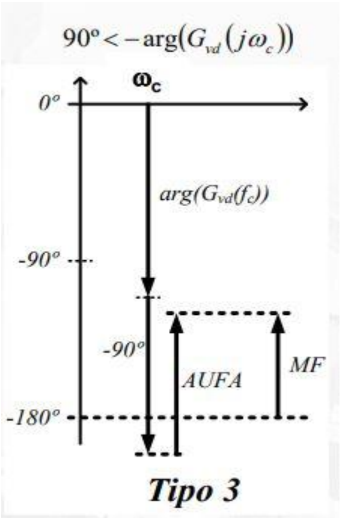


Imagen 31 Diagrama explicativo del cálculo del aumento de fase

Del AUFA calculado obtenemos el valor del factor K y los polos y ceros de la función de transferencia del compensador $A_i(s)$

$K = 5{,}3329$ $\omega_{cz} = 5{,}4416 \cdot 10^4 \frac{1}{s}$ $\omega_{pc} = 2{,}9019 \cdot 10^5 \frac{1}{s}$

$\omega_{p0c} = 5{,}104 \cdot 10^4 \frac{1}{s}$

$$A_i(\omega) = (\frac{\omega_{p0c}}{j \cdot \omega}) \cdot \frac{(1 + \frac{j \cdot \omega}{w_{cz}})^2}{(1 + \frac{j \cdot \omega}{\omega_{pc}})^2}$$

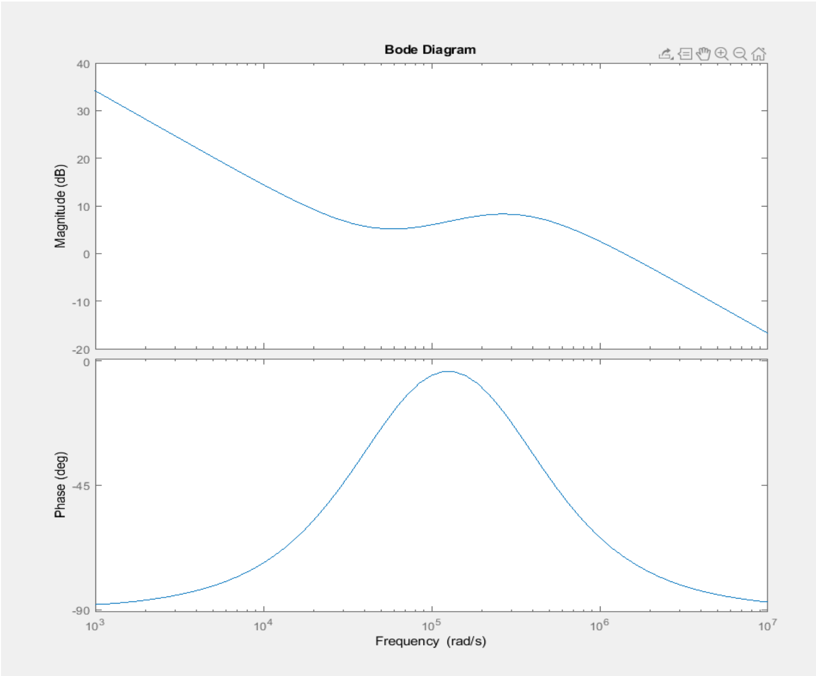


Imagen 32 Diagrama de bode Ai(ω)

4.3.3. Materialización del compensador

A continuación, pasaremos a materializar el compensador mediante un circuito electrónico compuesto por un amplificador operacional:

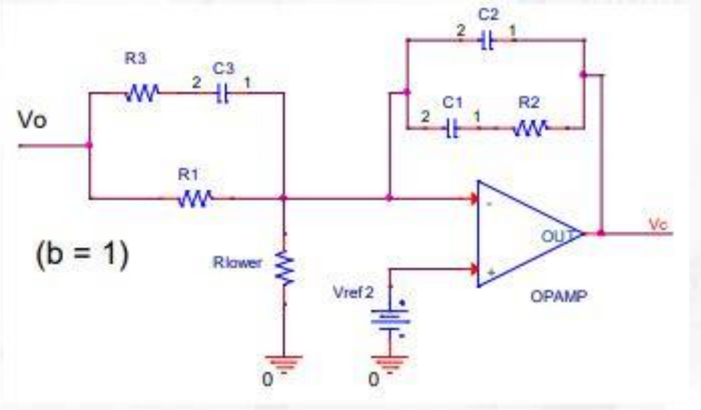


Imagen 33 Materialización del compensador de corriente

Para calcular el valor de los componentes supondremos que $C_2 \ll C_1 y$ $R_3 \ll R_1$y daremos valor a $R_1 = 100\text{k}\Omega$

$C1 = \frac{1}{\omega_{poc} \cdot R_1} = 1{,}9592 \cdot 10^{-10}\text{F}$ $\quad$ $R_2 = \frac{1}{\omega_{cz} \cdot C_1} = 9{,}3795 \cdot 10^4\Omega$

$C_3 = \frac{1}{\omega_{cz} \cdot R_1} = 1{,}8377 \cdot 10^{-10}\text{F}$ $\quad$ $C_2 = \frac{1}{\mathrm{w_{pc}} \cdot R_2} = 3{,}673 \cdot 10^{-11}\text{F}$

$$R_3 = \frac{1}{\mathrm{w_{pc}} \cdot C_3} = 1{,}875 \cdot 10^4\Omega$$

$$G_{sensor} = 0{,}1$$

$$V_{ref} = Io \cdot G_{sensor} = 10{,}7 \cdot 0{,}1 = 1{,}07\text{V}$$

$$R_{lower} = \frac{R_1 \cdot V_{ref}}{Vo - V_{ref}} = 1{,}066 \cdot 10^4\Omega$$

Una vez obtenido los valores pasamos a elegir unos valores normalizados y comprobar el AUFA.

$$C_{1norm} = 220pF \qquad R_{1norm} = 100k\Omega \qquad R_{2norm} = 100k\Omega$$

$$C_{3norm} = 220pF \qquad C_{2norm} = 33pF \qquad R_{3norm} = 18K\Omega \qquad R_{lower\ norm} = 10K\Omega$$

$AUFA_{norm}$=90 - $(-arg(Ai_{norm}(\omega_c)) = 84{,}818$

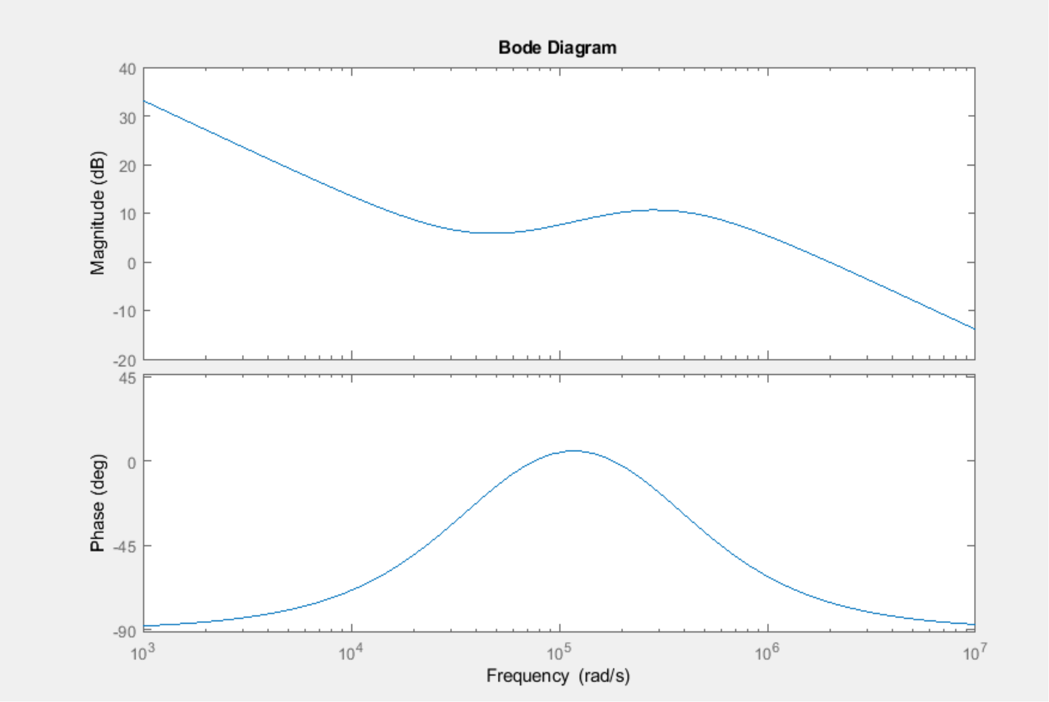


Imagen 34 respuesta del compensador normalizado

4.3.4. Ganancia del lazo

Una vez obtenido el valor de todos los componentes podemos calcular la función de transferencia del lazo y sacar su diagrama de bode gracias a la siguiente fórmula: $T_i(\omega) = Fm \cdot G_{Id}(\omega) \cdot A_i(\omega) \cdot b$

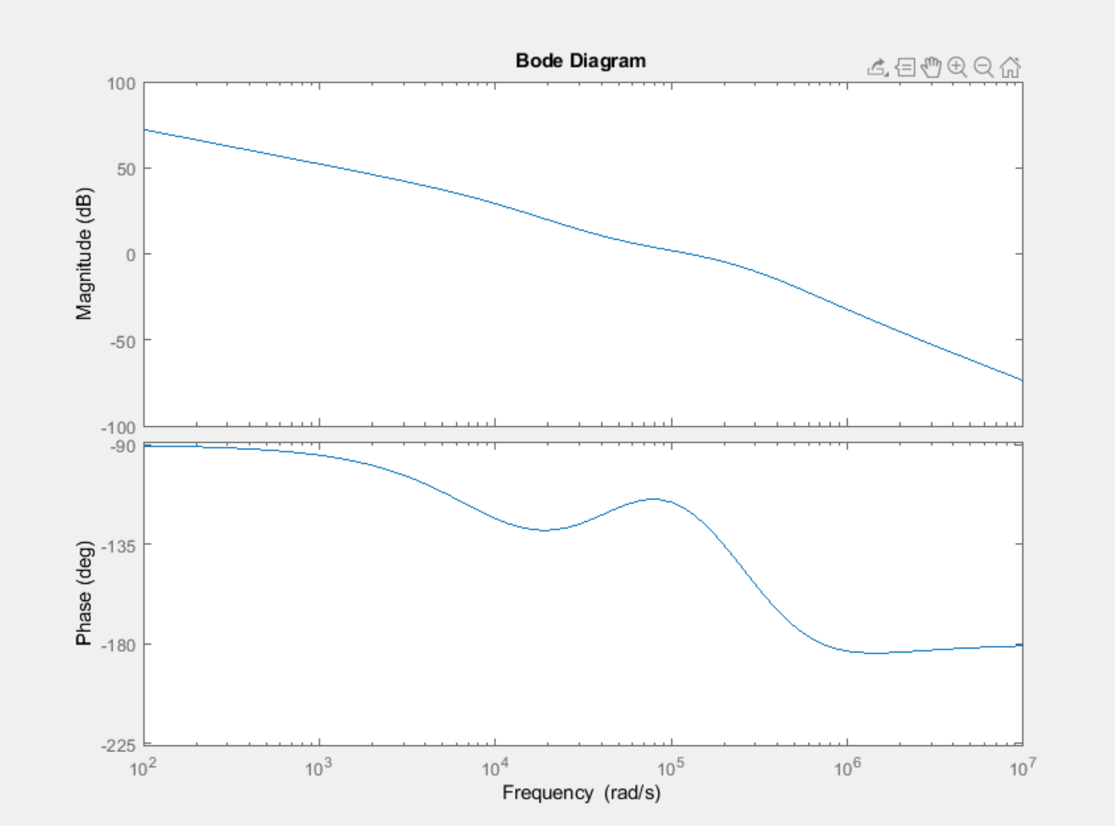


Imagen 35 Diagrama de bode Ti(ω)

Como podemos comprobar el sistema es estable al cumplir las siguientes condiciones:

- Desfase menor a -180º para $\omega < \omega_c$
- $|T_i(\omega_c)| = 1$
- Se obtiene el MF fijado en la frecuencia de corte

5.Simulaciones

En este apartado se comprobará que los resultados obtenidos en los cálculos teóricos responden como esperamos. Para este apartado vamos a usar el programa LTspice.

5.1. Simulación de lazo abierto

En este apartado simularemos en lazo abierto todo el circuito diseñado, tanto la etapa de potencia como la etapa de control.

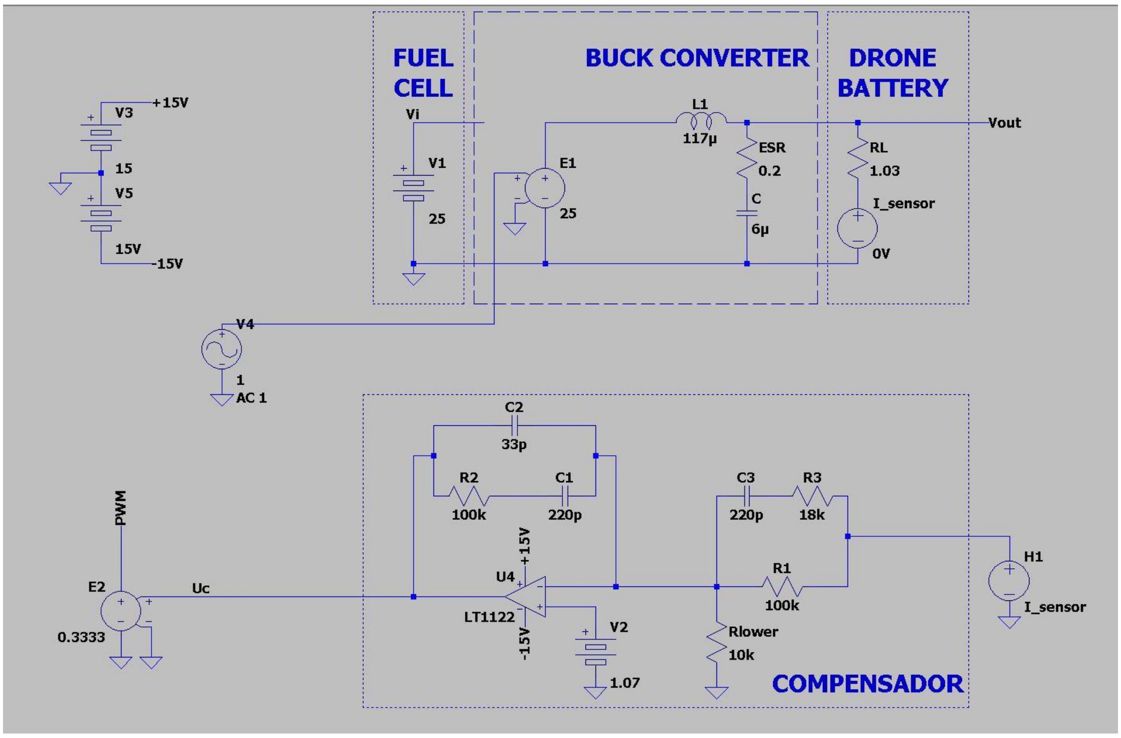


Imagen 36 Esquema en LA del circuito en LTspice

En la imagen 37 se mostrará el bode del circuito simulado en LA.

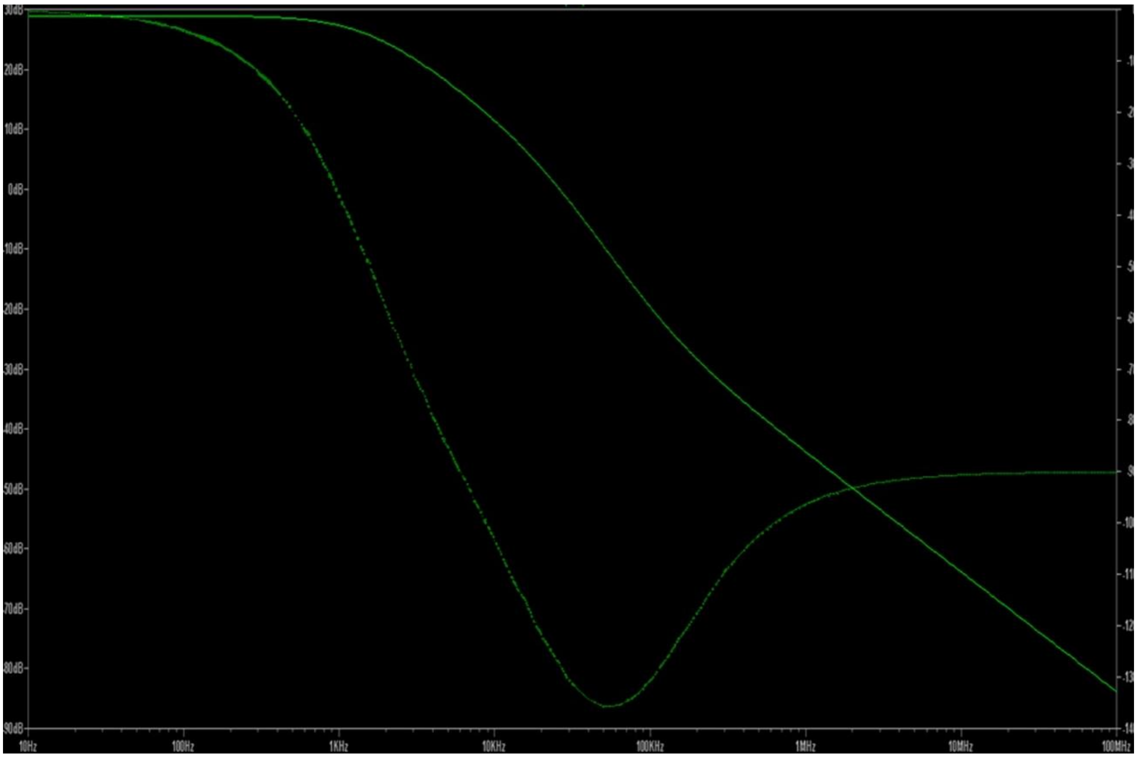


Imagen 37 Simulación en LTspice de Gid(ω)

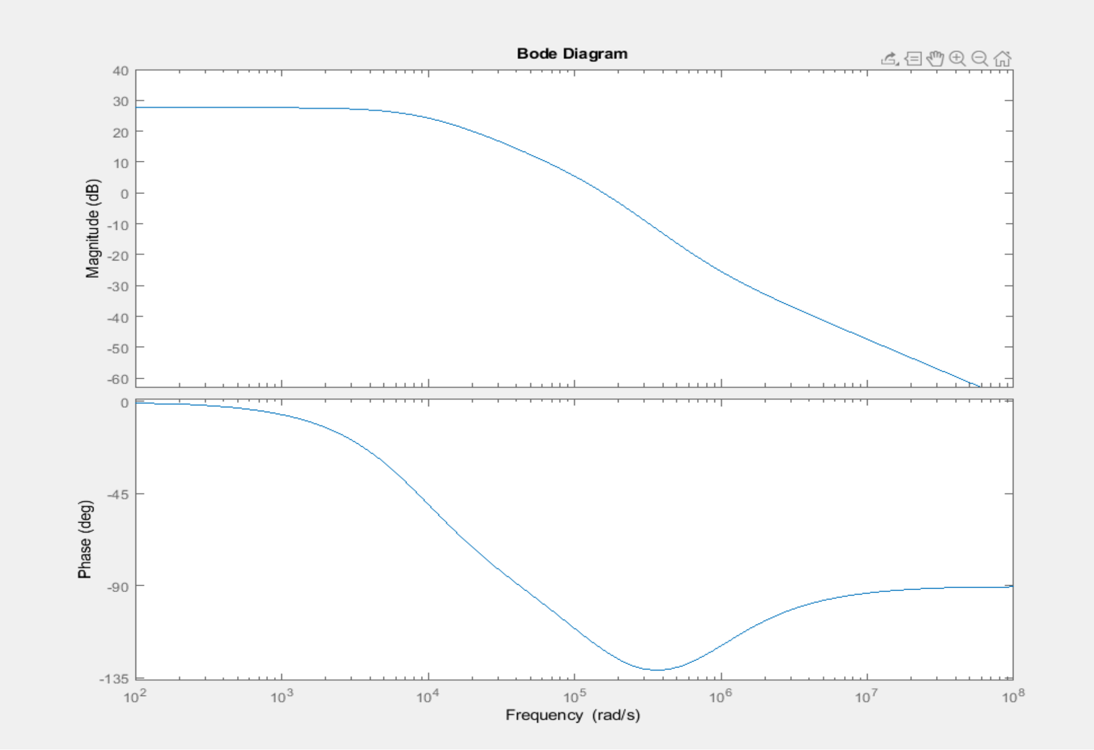


Imagen 38 Simulación en Matlab de Gid(ω)

Como podemos comprobar, las gráficas son muy similares, en la forma que tienen y en cuanto a los valores que nos dan.

	Teorico	Simulado
Ganancia frecuencia baja	27,6 dB	28,68 dB
Ganancia a frecuencia alta (10MHZ)	-63,4 dB	-6,68 dB
Fase a frecuencia baja	-0.04db	-0,42º
Fase a frecuencia alta	-90,6º	-90,1º

Tabla 2 comparación bodes teórico y simulado LA

Por lo que consideraremos que el circuito está funcionando como se espera.

5.2. Simulaciones de lazo cerrado

En este apartado conectaremos la realimentación y simularemos el circuito con todos los componentes que se han diseñado. En la imagen 38 tenemos el circuito en lazo cerrado.

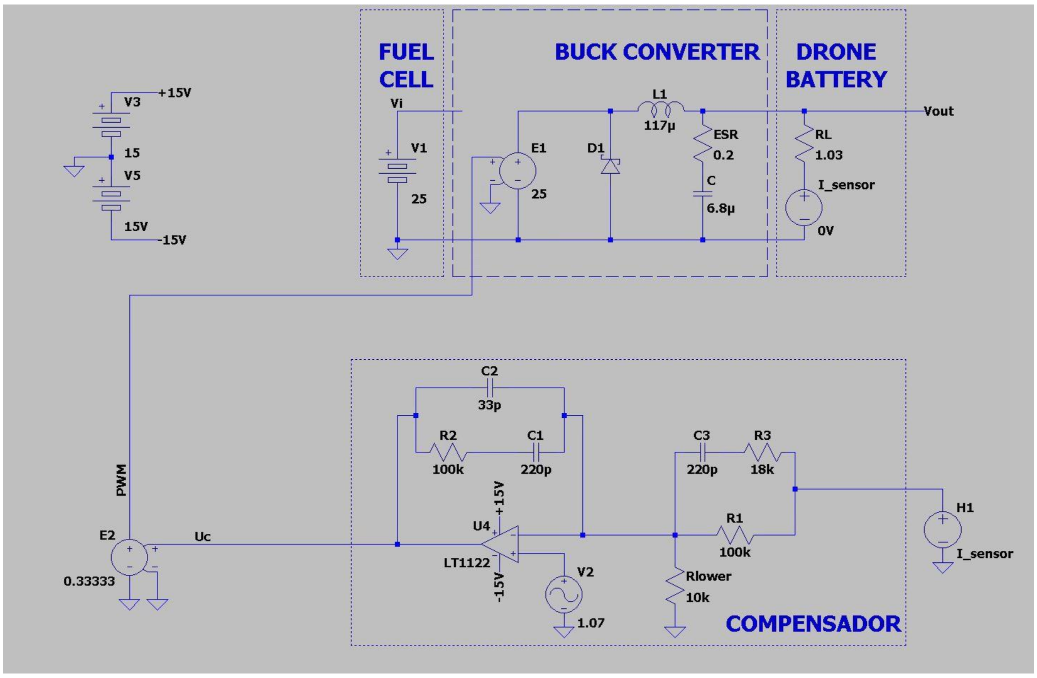


Imagen 39 Esquema en LC del circuito en LTspice

En la imagen 40 y 41, estará representado las gráficas obtenidas de este circuito, tanto las teóricas (imagen 41) como la simulada en LTspice (imagen 40).

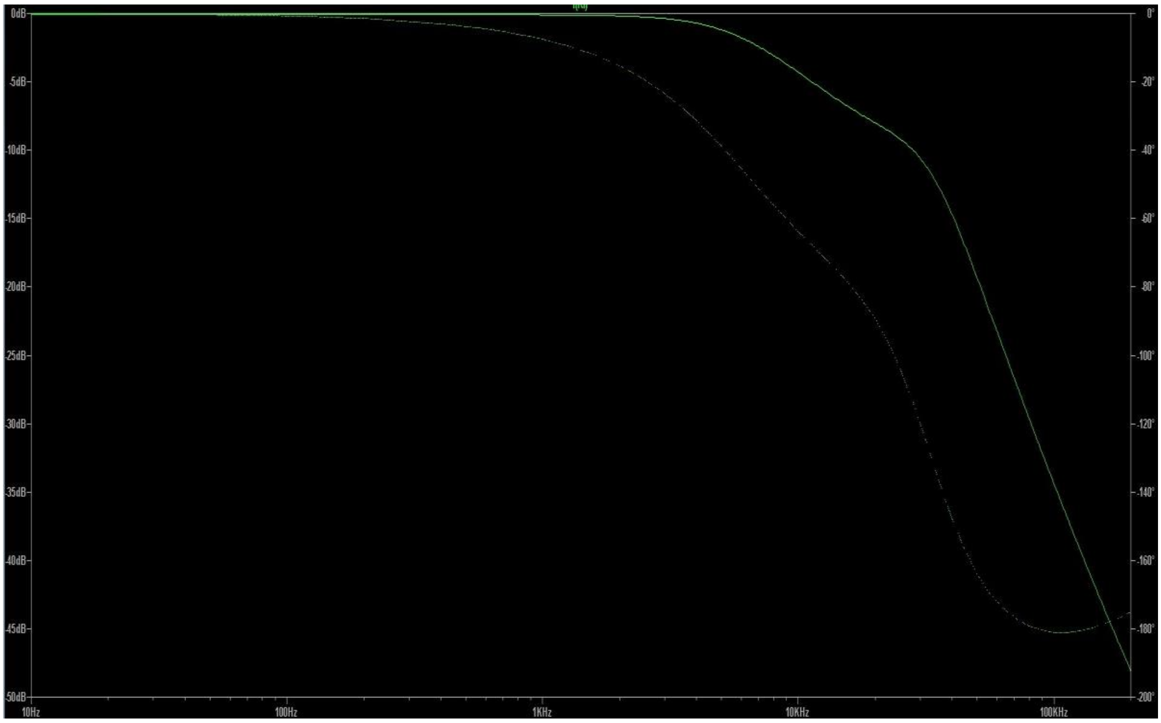


Imagen 40 Simulación en LTspice de Ti_LC(ω)

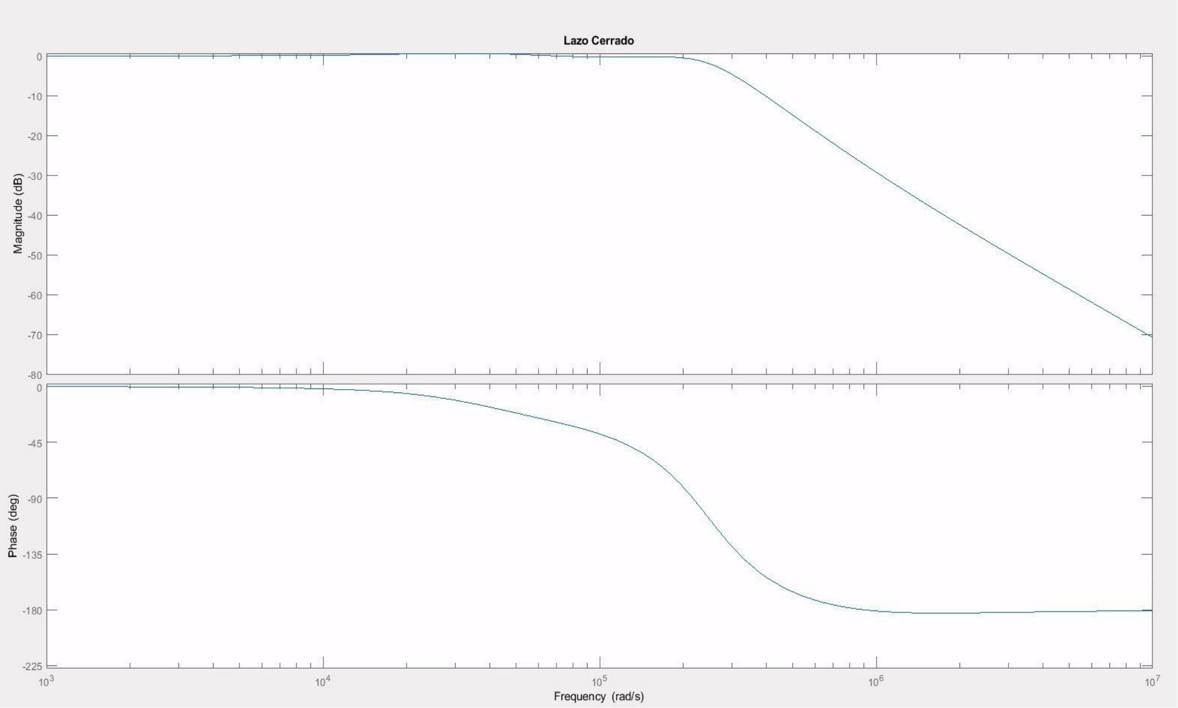


Imagen 41 simulación teórica de Ti_LC(ω)

Los resultados de ambas gráficas son muy parecidos.

	Teórico	Simulado
Ganancia frecuencia baja	0 dB	0dB
Ganancia frecuencia alta	-20dB	-33dB
Fase frecuencia baja	0º	0º
Fase frecuencia alta	-181º	-179º

Tabla 3 comparación bodes teórico y simulado en LC

5.3. Simulación temporal

En este caso vamos a comprobar que tanto la salida de corriente como la de tensión son las deseadas.

En la imagen 42 se muestra el circuito completo de este proyecto.

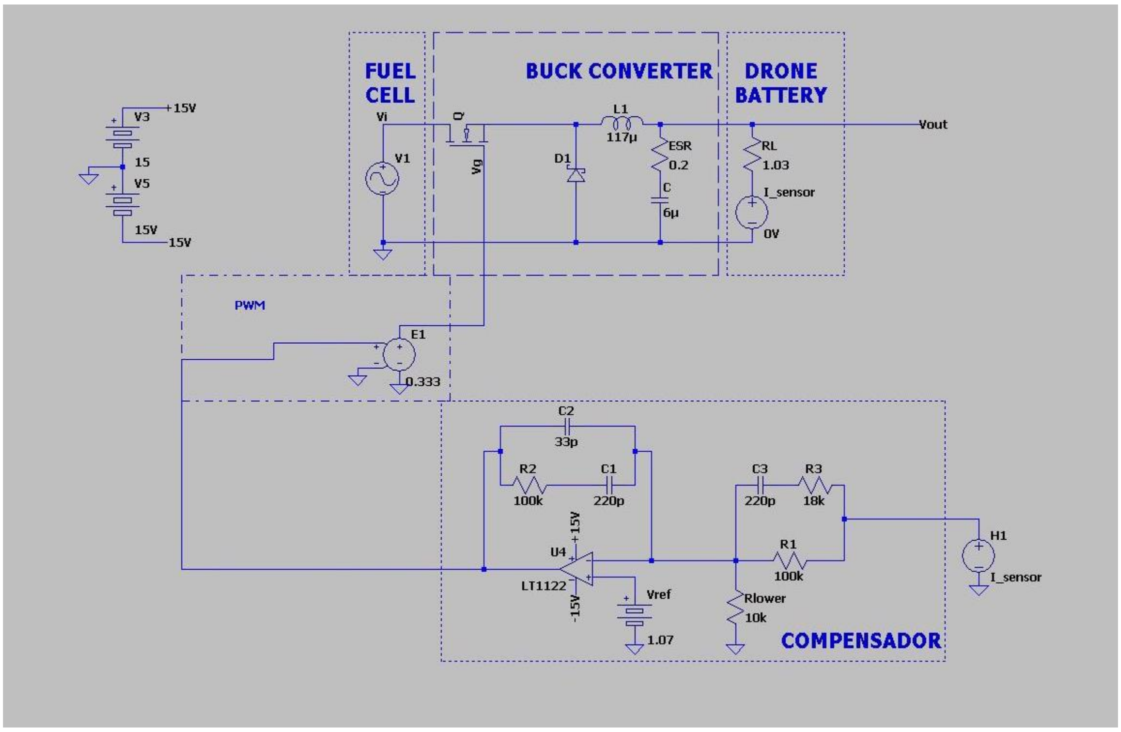


Imagen 42 Circuito simulado en LTspice

Comprobaremos cómo se comporta el circuito frente a cambios bruscos de entrada entre los valores de 25V y 28V.

Vamos a analizar tanto la salida de corriente como la de voltaje.
En la imagen 42 vamos a comparar la entrada, con los cambios de tensión frente a la salida, para ver su comportamiento.

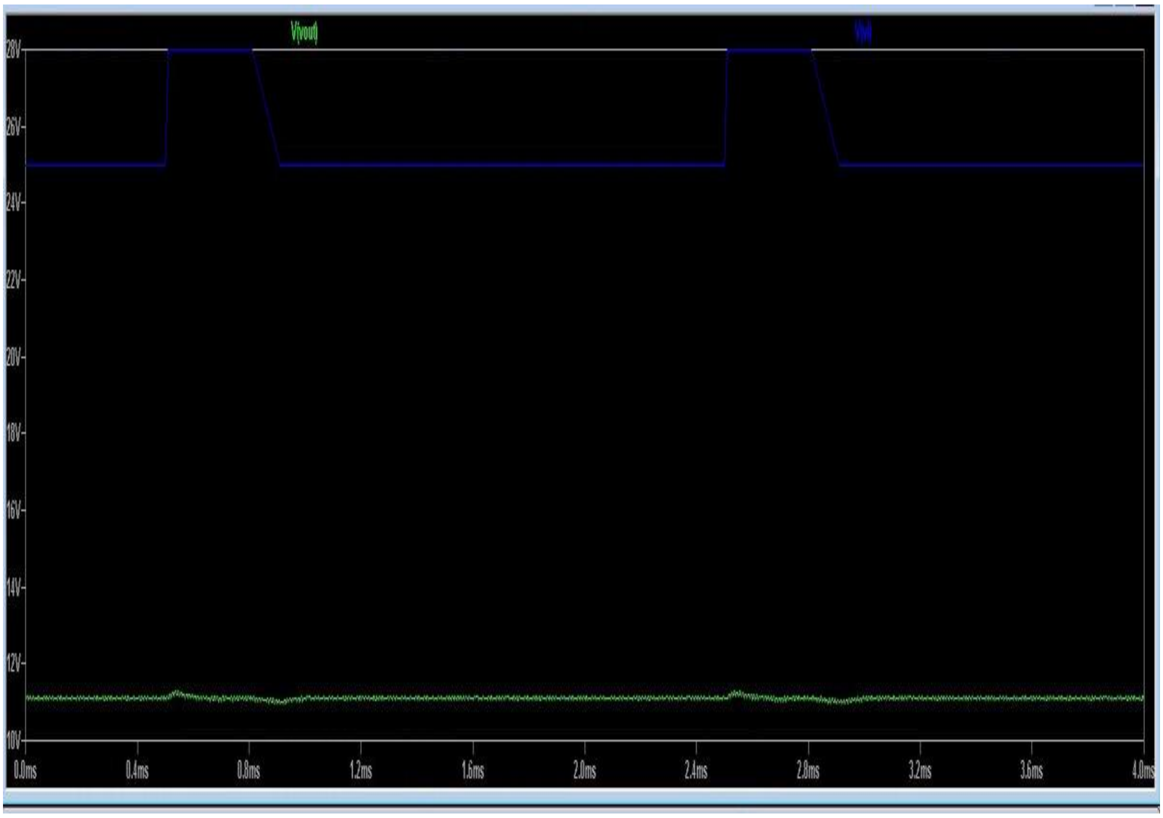


Imagen 43 Simulación en LTspice de Vi frente vo

Como no se aprecia bien la imagen, se le aplica en la imagen 43 un zoom a la salida para ver mejor cómo se comporta.

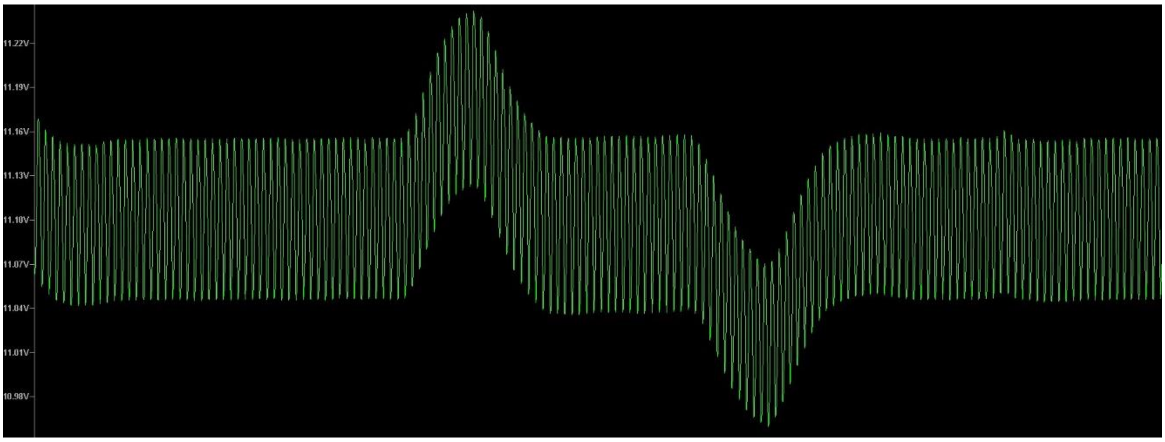


Imagen 44 Simulación en LTspice de Vo ampliada

En la imagen podemos ver como tenemos una buena respuesta frente a los cambios de entrada haciendo que mantenga el voltaje de salida en los 11,1 que necesitamos. Y el rizado es inferior a los 0,111V que hemos estipulado.

Ahora en la imagen 44 vamos a analizar la respuesta en corriente de la salida.

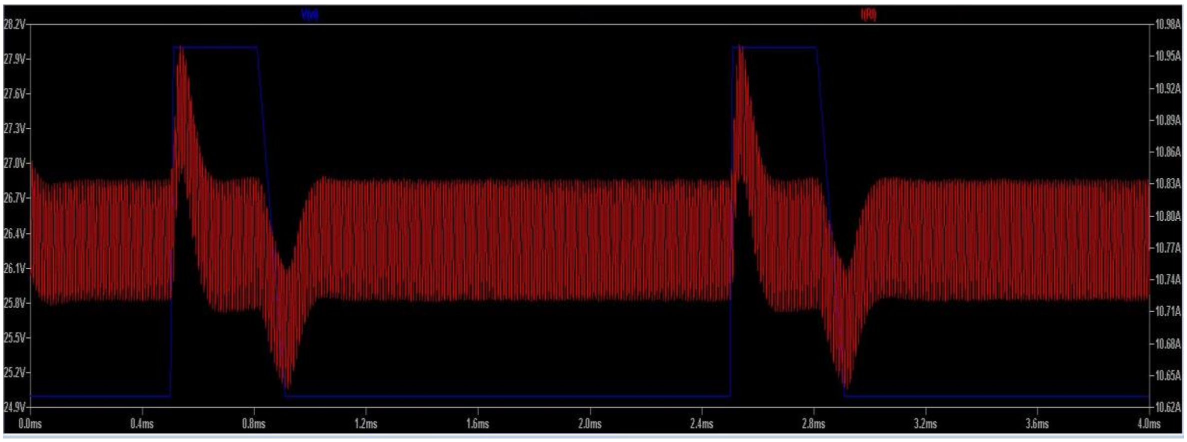


Imagen 45 Simulación en LTspice de Io

En la imagen 45, vamos a hacer un zoom para comprobar que se cumplen los valores que se piden.

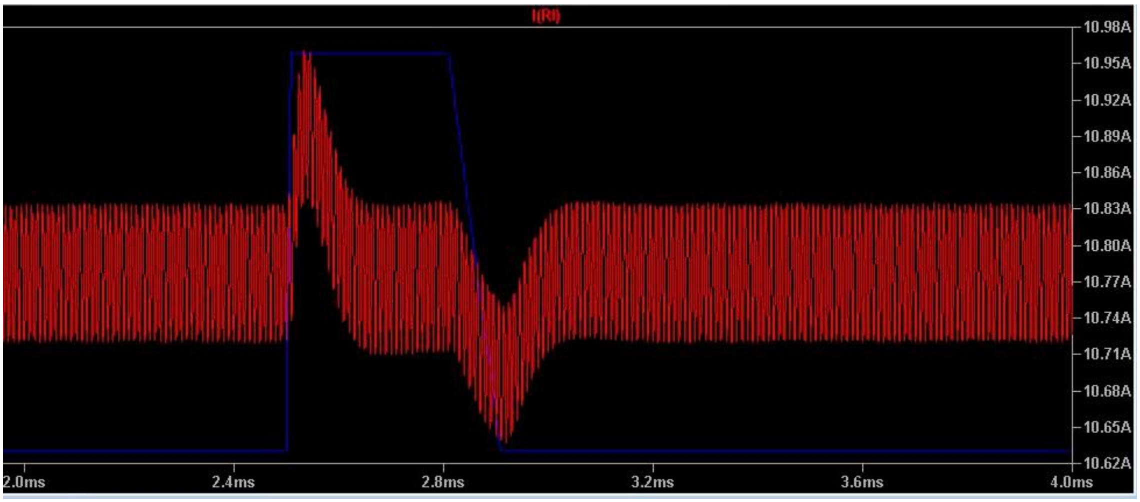


Imagen 46 Simulación en LTspice de Io ampliada

Como podemos observar, la salida se mantiene en los 10,7A que se han calculado. Y el rizado de la corriente es menor a los 0,535A que se ha pedido.

Como se observa en las gráficas el comportamiento frente a los cambios en la entrada son los esperados y los resultados son los que buscábamos.

6. Conclusiones

En este proyecto se ha analizado diferentes soluciones para resolver el problema de alimentar la batería de un dron mediante una pila de hidrógeno.
Tras estudiar varias alternativas se ha llegado a la conclusión que un convertidor sin aislamiento tipo Buck es la mejor solución.

Se ha estudiado el comportamiento del Buck y se ha calculado sus componentes para las especificaciones de este proyecto, seleccionando los componentes que de ajustan mejor a vista de un futuro montaje.

También se ha analizado y calculado la etapa de control, donde se ha implementado las funciones de transferencia oportunas y se ha calculado los componentes del compensador, y se han normalizado para el futuro montaje del proyecto.

Se han realizado las simulaciones con el programa LTspice para comprobar que el convertidor cumple con las especificaciones que se piden.

7. Bibliografía

- https://electronicsdesk.com/schottky-diode.html
- Apuntes asignatura Electrónica de Potencia.
- Apuntes asignatura Sistemas Electrónicos Industriales

Anexos

Cálculos

Datos:

$Vi_{min} = 25V \;\; Vi_{max} = 28V \;\; Ii_{min} = 3A \quad\; Ii_{max} = 5A$

$Vo = 11{,}1V \quad f = 100KHz$

Cálculo de potencias

Con los datos iniciales vamos a calcular la potencia de entrada y de salida para los 25V y los 28V respectivamente.

$$Pi_{min} = Vi_{max} \cdot Ii_{min} = 28 \cdot 3 = 84W$$

$$Pi_{max} = Vi_{min} \cdot Ii_{max} = 25 \cdot 5 = 125W$$

$$Po_{min} = 0.95 \cdot Pi_{min} = 0.95 \cdot 84 = 79{,}8W$$

$$Po_{max} = 0.95 \cdot Pi_{max} = 0.95 \cdot 125 = 118{,}75W$$

Cálculo de la intensidad de salida y su rizado

$$Io_{min} = \frac{Pi_{min}}{Vo} = \frac{84}{11{,}1} = 7{,}189A \qquad Io_{max} = \frac{Pi_{max}}{Vo} = \frac{125}{11{,}1} = 10{,}7A$$

$$Ro_{max} = \frac{Vo}{Io_{min}} = \frac{11{,}1}{7{,}189} = 1{,}544\Omega \qquad Ro_{min} = \frac{Vo}{Io_{max}} = \frac{11{,}1}{10{,}7} = 1{,}037\Omega$$

Queremos un rizado menor al 5% por lo que calculamos el rizado que necesitamos

$$\Delta Io_{min} = 0{,}05 \cdot Io_{min} = 0{,}05 \cdot 7{,}189 = 0{,}359A$$

$$\Delta Io_{max} = 0{,}05 \cdot Io_{max} = 0{,}05 \cdot 10{,}7 = 0{,}535A$$

$$I_{max} = Io_{max} + \frac{\Delta Io_{max}}{2} = 10{,}7 + \frac{0.535}{2} = 10{,}965A$$

$$I_{2max} = Io_{min} + \frac{\Delta Io_{min}}{2} = 7{,}189 + \frac{0{,}359}{2} = 7{,}368A$$

$$Vo_{riz} = 0{,}01 \cdot Vo = 0{,}01 \cdot 11{,}1 = 0{,}111V$$

$Rds_{on} = 0{,}007\Omega$

$V_f = 0{,}41V$

$$Vds_{on} = Rds_{on} \cdot I_{max} = 0{,}007 \cdot 10{,}965 = 0{,}0768V$$

$$Vds_{2on} = Rds_{on} \cdot I_{2max} = 0{,}007 \cdot 7{,}368 = 0{,}0516V$$

Cálculo del ciclo de trabajo

Ahora vamos a calcular el ciclo de trabajo. Para ello consideraremos las caídas de tensión en los componentes para sacar las ecuaciones pertinentes y así calcular el ciclo de trabajo.

Primero calcularemos el estado de Q_{on} donde el interruptor estará cerrado.

Q_{On}

$$Vi = Vds + V_L + Vo \rightarrow Vi = L\frac{di}{dt} + Vds + Vo \rightarrow \int \frac{Vi - Vds - Vo}{L} dt =$$

$$= \int di \rightarrow \frac{Vi - Vds - Vo}{L} t = i_1$$

$$i_{1(o)} = I_{min} = K$$

$$i_{2(t)} = \frac{Vi - Vds - Vo}{L} t + I_{min}$$

$$i_{(ton)} = I_{max} = \frac{Vi - Vds - Vo}{L} t_{on} + I_{min}$$

Ahora calcularemos en el estado Q_{off}, donde el interruptor estará abierto, por lo cual la corriente solo circulará a través del diodo, bobina y R_L sin pasar por el transistor.

Q_{Off}

$$0 = V_f + V_L + Vo \rightarrow 0 = V_f + L\frac{di}{dt} + Vo \rightarrow \int \frac{-V_f - Vo}{L} dt =$$

$$= \int di \rightarrow \frac{-V_f - Vo}{L} t + K' = i_2$$

$$i_{2(ton)} = I_{max} = -\frac{V_f + Vo}{L} t_{on} + K' \rightarrow K' = I_{max} + \frac{V_f + Vo}{L} t_{on}$$

$$i_{2(t)} = -\frac{V_f + Vo}{L} t + I_{max} \frac{V_f + Vo}{L} t_{on} \rightarrow i_{2(t)} = I_{max} - \frac{V_f + Vo}{L} (t - t_{on})$$

$$i_{2(T)} = I_{min} = I_{max} - \frac{V_f + Vo}{L} (T - t_{on})$$

Calculamos el rizado de la corriente sustituyendo I_{max} y I_{min} por las ecuaciones anteriores

$$I_{Lriz} = I_{max} - I_{min} = \frac{Vi - Vds - Vo}{L} t_{on} + I_{max} - I_{min} = I_{max} - \frac{V_f + Vo}{L} (T - t_{on})$$

$$\frac{Vi - Vds - Vo}{L} (\delta T) + I_{max} - I_{min} = I_{max} - \frac{V_f + Vo}{L} (1 - \delta) T$$

$$Vi \cdot \delta - Vds \cdot \delta - Vo \cdot \delta = Vo - Vo \cdot \delta + V_f - V_f \cdot \delta$$

$$Vo = -V_f (1 - \delta) + Vi \cdot \delta - Vds \cdot \delta \rightarrow Vo = (Vi - Vds_{on}) \delta - V_f (1 - \delta)$$

$$11{,}1 = (25 - 0{,}0768) \delta - 0{,}41(1 - \delta) \rightarrow \delta = 0{,}454$$

$$11{,}1 = (28 - 0{,}0516) \delta - 0{,}41(1 - \delta) \rightarrow \delta = 0{,}4059$$

Nos quedaremos con el ciclo de trabajo mayor ya que es el más crítico y pasaremos a calcular la bobina y el condensador que necesitamos para el sistema.

Cálculo de la bobina y el condensador

$$I_{Lriz} = I_{max} - I_{min} = \frac{Vi - Vds - Vo}{L} t_{on} + I_{max} - I_{min} = I_{max} - \frac{V_f + Vo}{L} (T - t_{on})$$

$$I_{Lriz} = I_{max} - I_{min} = \frac{Vi - Vds - Vo}{L} t_{on} = \frac{V_f + Vo}{L} (1 - \delta) \frac{1}{f}$$

$$I_{Lriz} = \Delta Io_{max}$$

$$L = \frac{V_f + Vo}{\Delta I_{Lriz}} (1 - \delta) \frac{1}{f} = \frac{11{,}1 + 0{,}41}{0{,}535} (1 - 0{,}454) \frac{1}{100000} = 1{,}174 \cdot 10^{-4} H$$

$$L = 117{,}4 \mu\mathrm{H}$$

$$C = \frac{\Delta I_{Lriz}}{8 \cdot Vo_{riz} \cdot f} = \frac{0{,}535}{8 \cdot 0{,}111 \cdot 100000} = 6{,}0238 \cdot 10^{-6} F$$

$$C = 6{,}0238 \mu F$$

$$ESR = \frac{Vo_{riz}}{\Delta I_{Lriz}} = \frac{0{,}111}{0{,}535} = 0{,}207 \Omega$$

Función de transferencia Gvd

$$G_{Vo} = Vi$$

$$\omega_z = \frac{1}{ESR \cdot C} = \frac{1}{0{,}207 \cdot 6{,}0238 \cdot 10^{-6} \cdot} = 8 \cdot 10^5 \frac{rad}{s}$$

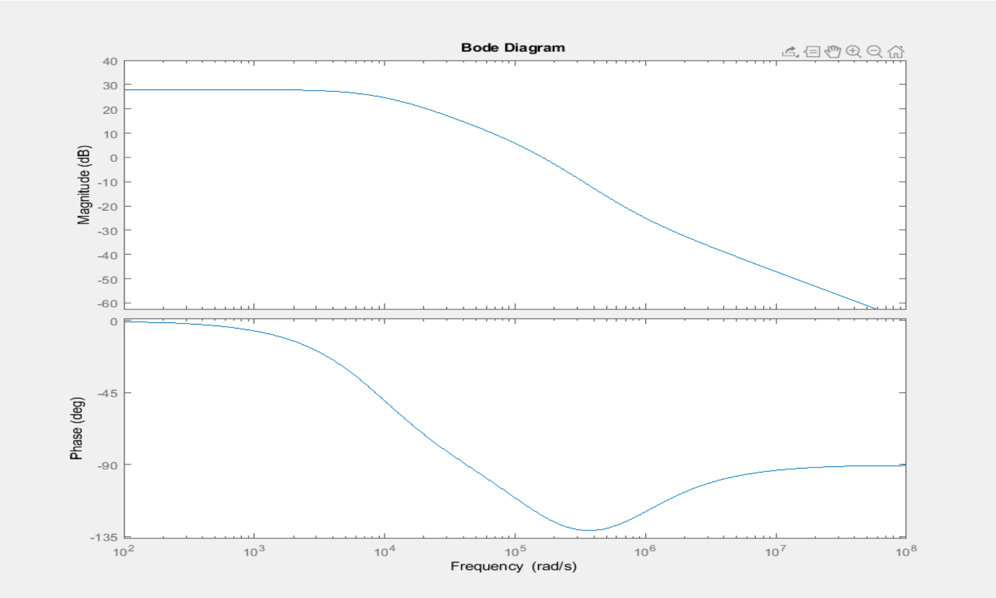
$$\omega_n = \frac{1}{\sqrt{L \cdot C}} = \frac{1}{\sqrt{1{,}174 \cdot 10^{-4} \cdot 6{,}0238 \cdot 10^{-6}}} = 3{,}76 \cdot 10^4 \frac{rad}{s}$$

$$Q = \frac{\sqrt{L \cdot C}}{\frac{L}{Ro} + C \cdot ESR} = \frac{\sqrt{1{,}174 \cdot 10^{-4} \cdot 6{,}0238 \cdot 10^{-6}}}{\frac{1{,}174 \cdot 10^{-4}}{1{,}037} + 6{,}0238 \cdot 10^{-6} \cdot 0{,}207} = 0{,}2324$$

$$f_z = \frac{\omega_z}{2 \cdot \pi} = \frac{8 \cdot 10^5}{2\pi} = 1.2732 \cdot 10^5 Hz$$

$$f_n = \frac{\omega_n}{2 \cdot \pi} = \frac{3{,}76 \cdot 10^4}{2\pi} = 5{,}984 \cdot 10^3 Hz$$

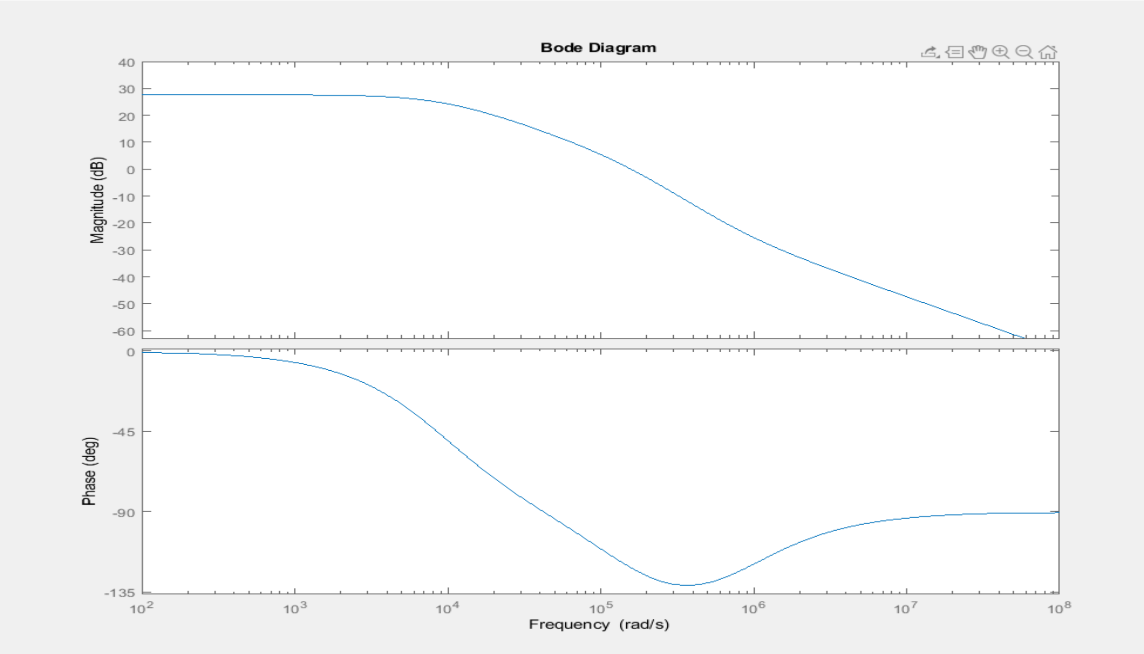
$$G_{Vd}(\omega) = G_{vo} \frac{1 + \frac{j \cdot \omega}{\omega_z}}{(\frac{j \cdot \omega}{\omega_n})^2 + (\frac{j \cdot \omega}{Q \cdot \omega_n}) + 1}$$



Función de transferencia G_{id}

$Go = \frac{Vi}{Ro} = 23{,}36\text{A}$

$$G_{id}(\omega) = Go\,\frac{1 + \dfrac{j \cdot \omega}{\omega_z}}{(\dfrac{j \cdot \omega}{\omega_n})^2 + (\dfrac{j \cdot \omega}{Q \cdot \omega_n}) + 1}$$

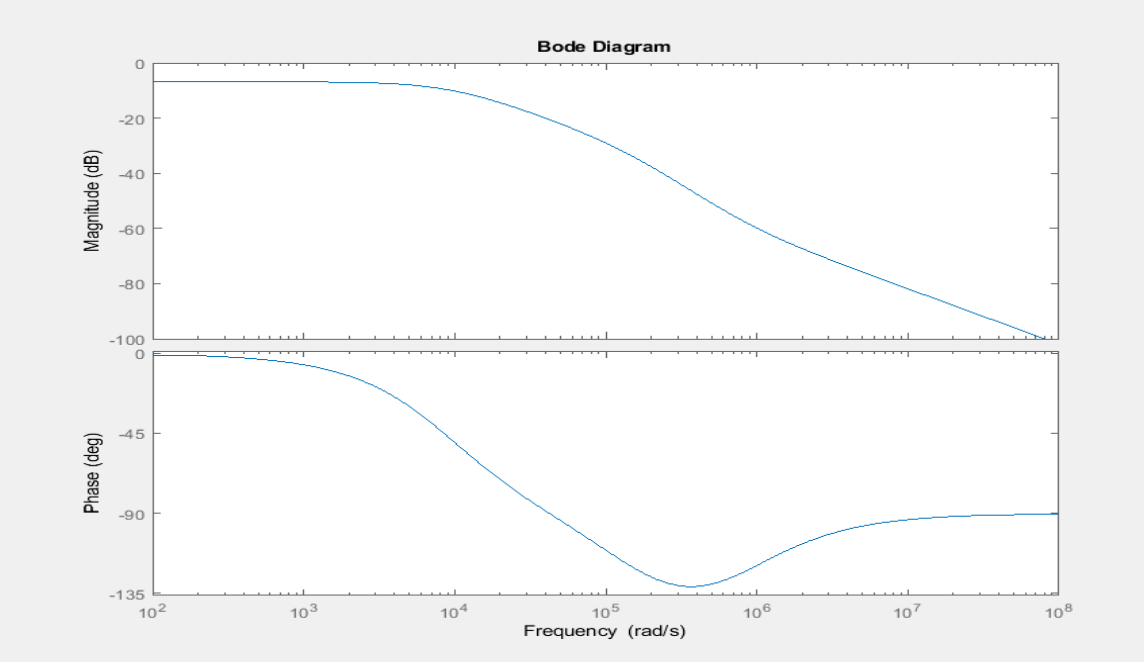


Audiosusceptibilidad

$$V_{cp} = \delta \cdot Vi = 0{,}454 \cdot 25 = 11{,}358$$

$$Ao = \delta = 0{,}454$$

$$A(\omega) = Ao \frac{1 + \frac{j \cdot \omega}{\omega_z}}{(\frac{j \cdot \omega}{\omega_n})^2 + (\frac{j \cdot \omega}{Q \cdot \omega_n}) + 1}$$



Impedancia de salida

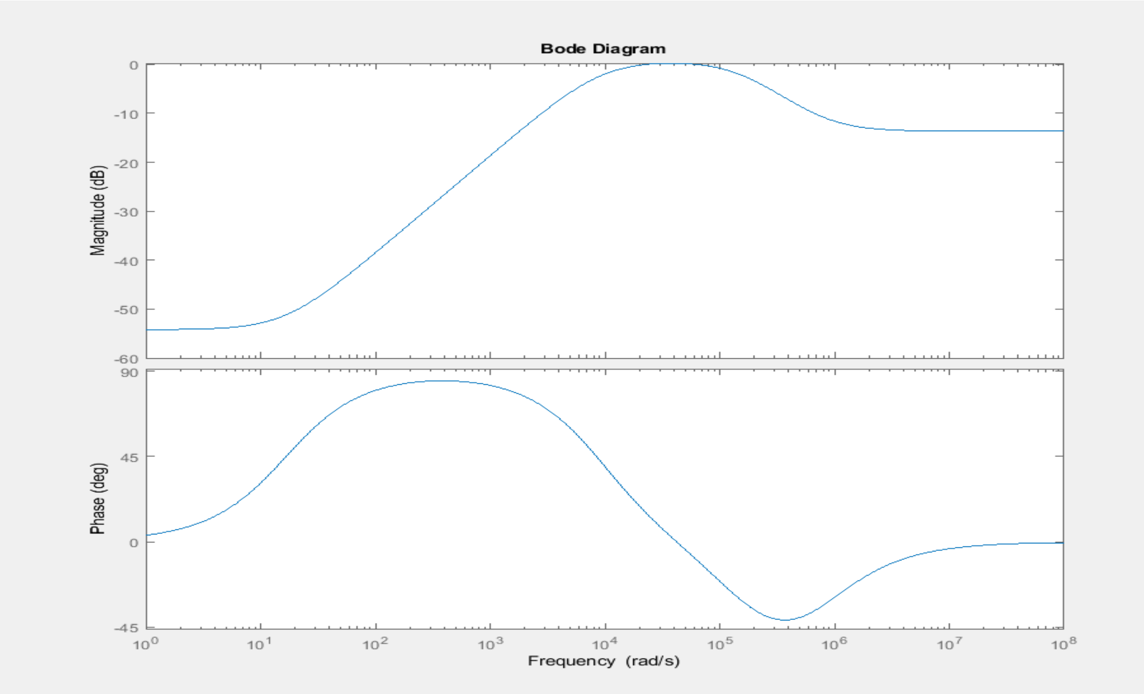
$$R_1 = 1{,}95 \cdot 10^{-3}\Omega$$

$$\omega_{z2} = \frac{R_1}{L} = \frac{1{,}95 \cdot 10^{-3}}{1{,}174 \cdot 10^{-4}} = 16{,}6081\frac{rad}{s}$$

$$Q_2 = \frac{\sqrt{L \cdot C}}{\frac{L}{Ro} + C \cdot (ESR + R_1)} = \frac{\sqrt{1{,}174 \cdot 10^{-4} \cdot 6{,}0238 \cdot 10^{-6}}}{\frac{1{,}174 \cdot 10^{-4}}{1{,}037} + 6{,}0238 \cdot 10^{-6} \cdot (0{,}207 + 1{,}95 \cdot 10^{-3})}$$

$$= 0{,}2324$$

$$Zo(w) = R_1 \frac{1 + \frac{j \cdot \omega}{\omega_z} + \frac{j \cdot w}{\omega_{z2}}}{(\frac{j \cdot \omega}{\omega_n})^2 + (\frac{j \cdot \omega}{Q \cdot \omega_n}) + 1}$$



Cálculo del compensador

$Vm = 3V \qquad Fm = \frac{1}{Vm} = 0,333$

Vamos a calcular que tipo de compensador necesitaremos.

Para ello necesitamos elegir una fc que sea mayor a 3 veces f_n pero menor a f_z.

$$f_{n3} = 3 \cdot f_n = 3 \cdot 5,984 \cdot 10^3 = 1,7954 \cdot 10^4 Hz$$

$f_c = 20000$Hz

$$\omega_c = 2\pi \cdot f_c = 2\pi \cdot 20000 = 1,2566 \cdot 10^5 \frac{1}{s}$$

Para saber el tipo de compensador a calcular, debemos calcular el $-arg(G_{Id}(\omega_c))$ y dependiendo del resultado, será tipo 1, tipo 2 o tipo 3.

$|G_{Id}(\omega_c)| = 1,385A \qquad\qquad -arg(G_{Id}(\omega_c)) = -116,343°$

Como es mayor a 90º el compensador será de tipo 3, así que elegimos un valor de MF que esté entre 60 y 70 ya que es el valor ideal.

$MF = 60$

$AUFA = MF - (-arg(G_{Id}(\omega_c))) - 90 = 60 - (-116,343) - 90 = 86,34$

$$K = tg(\frac{AUFA}{4} + 45)^2 = 5,3329$$

$$\omega_{cz} = \frac{\omega_c}{\sqrt{K}} = \frac{1,2566 \cdot 10^5}{\sqrt{5,3329}} = 5,4416 \cdot 10^4 \frac{1}{s}$$

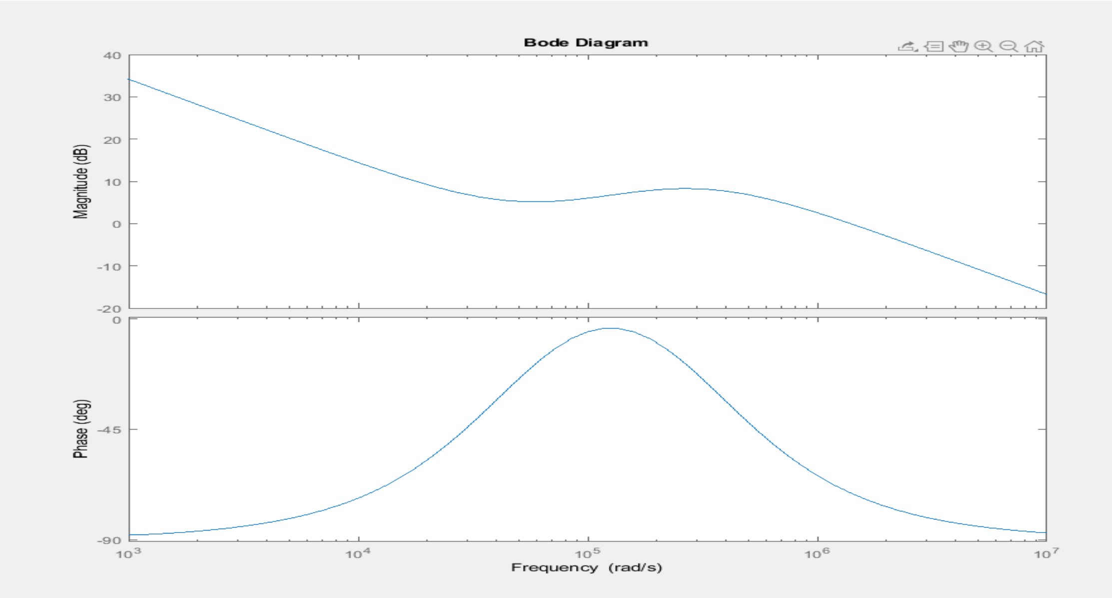
$$\omega_{pc} = w_c \cdot \sqrt{K} = 1,2566 \cdot 10^5 \cdot \sqrt{5,3329} = 2,9019 \cdot 10^5 \frac{1}{s}$$

$$\omega_{p0c} = \frac{\omega_c}{b \cdot Fm \cdot |G_{Id}(\omega_c)| \cdot \left| \frac{(1 + \frac{\omega_c}{\omega_{cz}})^2}{(1 + \frac{s}{\omega_{pc}})^2} \right|} =$$

$$= \frac{1,2566 \cdot 10^5}{1 \cdot 0,333 \cdot 1,385 \cdot \left| \frac{(1 + \frac{1,2566 \cdot 10^5}{5,4416 \cdot 10^4})^2}{(1 + \frac{s}{2,9019 \cdot 10^5})^2} \right|} = 5,104 \cdot 10^4 \frac{1}{s}$$

Materialización con Ao

$$A_i(\omega) = \left(\frac{\omega_{p0c}}{j\cdot\omega}\right)\cdot\frac{(1+\frac{j\cdot\omega}{w_{cz}})^2}{(1+\frac{j\cdot\omega}{\omega_{pc}})^2} \qquad\qquad -arg(A_i(\omega_c)) = 3{,}65°$$

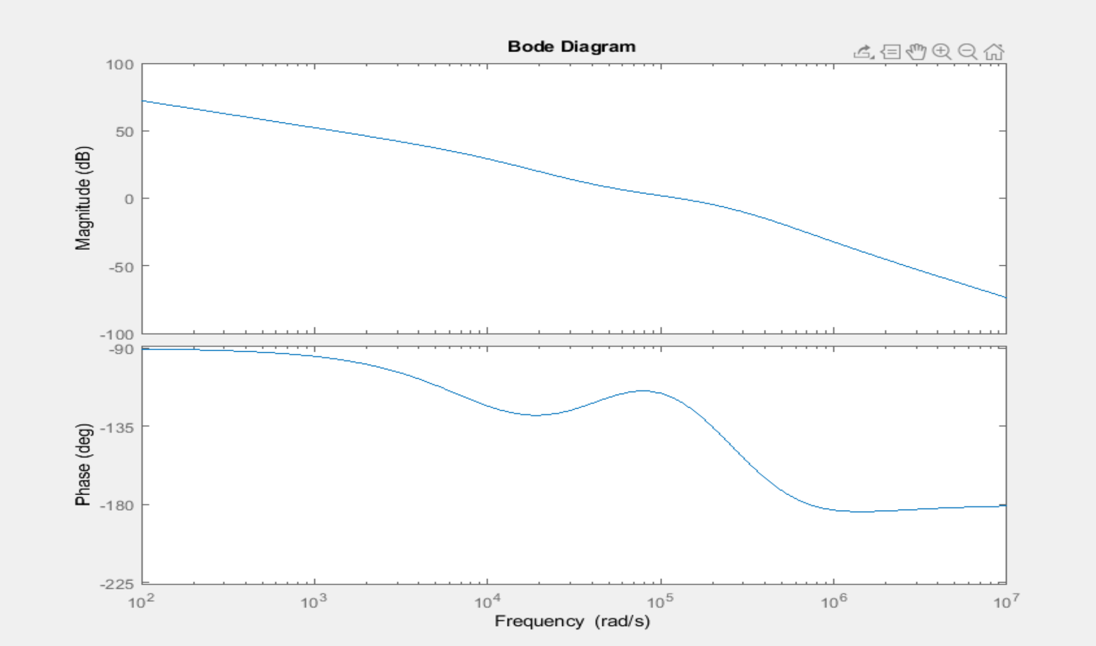


Comprobación AUFA:

$$AUFA = -arg(Ai(\omega_c)) - (-90) = 3{,}65 - (-90) = 86{,}3433$$

$$T_i(\omega) = Fm\cdot G_{Id}(\omega)\cdot A_i(\omega)\cdot b \qquad\qquad |T_i(\omega_c)| = 1$$

$$MF = arg(T_i(\omega_c) + 180 = 60$$



Valores de los componentes del compensador

$R_1 = 100\text{k}\Omega$

$$C1 = \frac{1}{\omega_{p0c} \cdot R_1} = \frac{1}{5{,}104 \cdot 10^4 \cdot 100 \cdot 10^3} = 1{,}9592 \cdot 10^{-10} F$$

$$R_2 = \frac{1}{\omega_{cz} \cdot C_1} = \frac{1}{5{,}4416 \cdot 10^4 \cdot 1{,}9592 \cdot 10^{-10}} = 9{,}3795 \cdot 10^4 \Omega$$

$$C_3 = \frac{1}{\omega_{cz} \cdot R_1} = \frac{1}{5{,}4416 \cdot 10^4 \cdot 100 \cdot 10^3} = 1{,}8377 \cdot 10^{-10} F$$

$$C_2 = \frac{1}{\omega_{pc} \cdot R_2} = \frac{1}{2{,}9019 \cdot 10^5 \cdot 9{,}3795 \cdot 10^4} = 3{,}673 \cdot 10^{-11} F$$

$$R_3 = \frac{1}{\omega_{pc} \cdot C_3} = \frac{1}{2{,}9019 \cdot 10^5 \cdot 1{,}8377 \cdot 10^{-10}} = 1{,}875 \cdot 10^4 \Omega$$

$$G_{sensor} = 0{,}1 \qquad V_{ref} = Io \cdot G_{sensor} = 10{,}7 \cdot 0{,}1 = 1{,}07V$$

$$R_{lower} = \frac{R_1 \cdot V_{ref}}{Vo - V_{ref}} = \frac{100 \cdot 10^3 \cdot 1{,}07}{11{,}1 - 1{,}07} = 1{,}066 \cdot 10^4 \Omega$$

Valores normalizados:

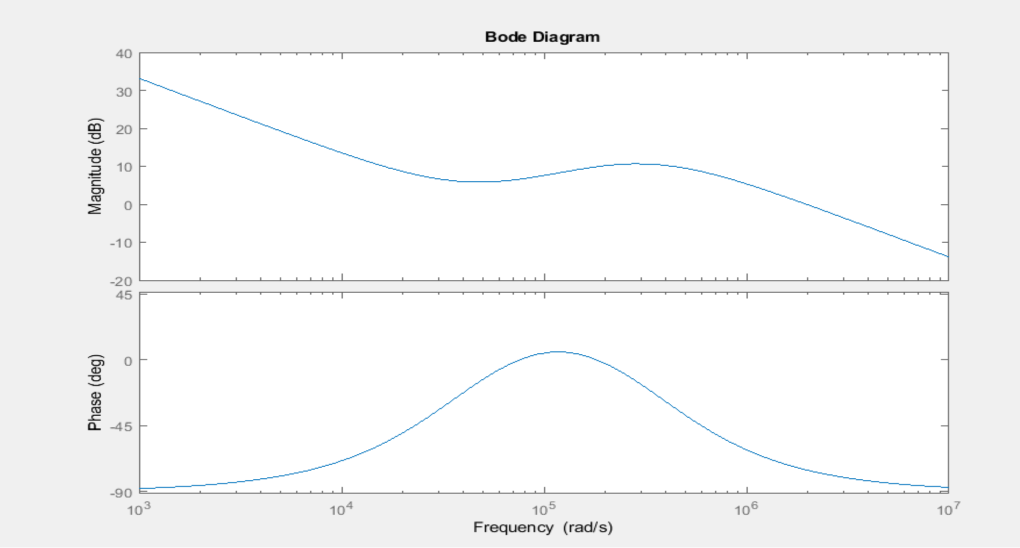
$$C_{1norm} = 220pF \qquad R_{1norm} = 100k\Omega \qquad R_{2norm} = 100k\Omega$$

$$C_{3norm} = 220pF \qquad C_{2norm} = 33pF \qquad R_{3norm} = 18K\Omega \qquad R_{lower\ norm} = 10K\Omega$$

Teórico	Normalizado
$\omega_{p0c} = \frac{1}{R_1 \cdot C_1} = 5{,}104 \cdot 10^4 \frac{1}{s}$	$\omega_{p0c\ norm} = \frac{1}{R_{1norm} \cdot C_{1norm}} = 4{,}545 \cdot 10^4 \frac{1}{s}$
$\omega_{cz} = \frac{1}{R_2 \cdot C_1} = 5{,}44 \cdot 10^4 \frac{1}{s}$	$\omega_{cz\ norm} = \frac{1}{R_{2norm} \cdot C_{1norm}} = 4{,}545 \cdot 10^4 \frac{1}{s}$
$\omega_{cz2} = \frac{1}{R_1 \cdot C_3} = 5{,}44 \cdot 10^4 \frac{1}{s}$	$\omega_{cz2\ norm} = \frac{1}{R_{1norm} \cdot C_{3norm}} = 4{,}545 \cdot 10^4 \frac{1}{s}$
$\omega_{pc} = \frac{1}{R_2 \cdot C_2} = 2{,}901 \cdot 10^5 \frac{1}{s}$	$\omega_{pc\ norm} = \frac{1}{R_{2norm} \cdot C_{2norm}} = 3{,}03 \cdot 10^5 \frac{1}{s}$
$\omega_{pc2} = \frac{1}{R_3 \cdot C_3} = 2{,}901 \cdot 10^5 \frac{1}{s}$	$\omega_{pc2\ norm} = \frac{1}{R_{3norm} \cdot C_{3norm}} = 2{,}525 \cdot 10^5 \frac{1}{s}$

Compensador con valores normalizados

$$Ai_{norm}(\omega) = \left(\frac{w_{p0c\,norm}}{j\cdot\omega}\right)\cdot\frac{(1+\frac{j\cdot w}{\omega_{cz\,norm}})^2}{(1+\frac{j\cdot\omega}{\omega_{pc\,norm}})^2} \qquad -arg(A_{i\,norm}(\omega_c)) = 5{,}18°$$



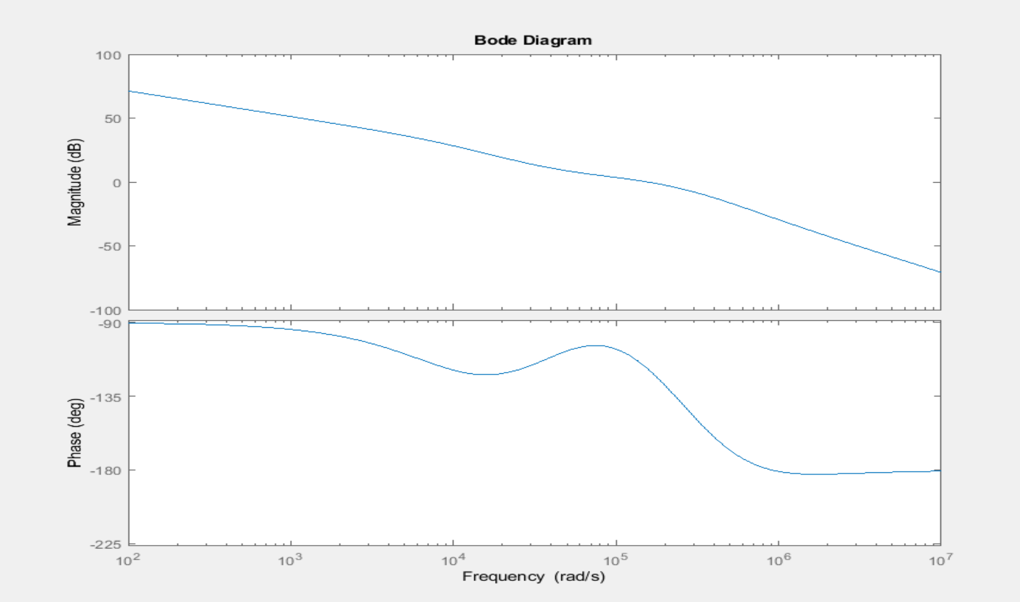
Comprobación AUFA normalizado

$$AUFA_{norm}=90 - (-arg(Ai_{norm}(\omega_c)) = 84{,}818$$

$$T_{i\,norm}(\omega) = Fm\cdot G_{Id}(\omega)\cdot A_{i\,norm}(\omega)\cdot b$$

$$|T_{i\,norm}(\omega_c)| = 1{,}2316$$

$$MF = arg(T_{i\,norm}(\omega_c) + 180 = 68{,}83$$



Hojas de características

SMT COMMON MODE CHOKES

Industrial Grade

- Enhanced SLIC platform
- Dielectric strength: 1500 VRMS
- Designed for DC/DC converter
- Moisture Sensitivity Level : 1

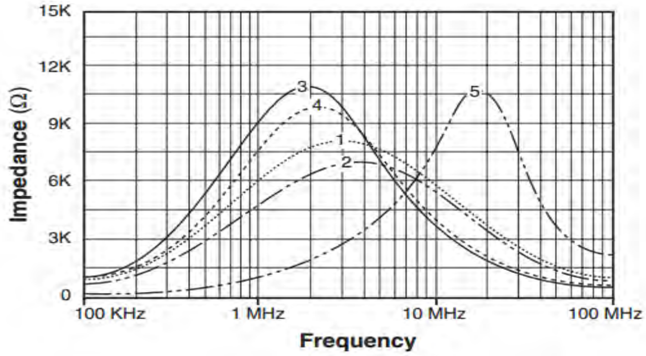
Electrical Specifications @ 25˚C – Operating Temperature – 40˚C to +125˚C

Part Number	Inductance per Winding (uH ±35%)	Irated (A)	DCR per winding (mΩ MAX)	Curve (see # below)	Package	Weight (grams)	Quantity in Tube	Quantity in Reel
R8100NL	470	14.0	8	9	HCCI-80	14.8	15	75
R8101NL	630	11.6	10	7	HCCI-80	15.38	20	75
R8102NL	810	9.70	14	6	HCCI-80	14.42	20	75
R8103NL	534	7.20	15	8	HCCI-68	7.27	15	100
R8104NL	590	5.60	21	7	LCCI-50	4.97	30	200
R8105NL	768	4.70	40	6	LCCI-50	4.69	30	200
R8106NL	225	3.30	60	5	LCCI-50	4.78	30	200
R8107NL	1320	3.30	60	4	LCCI-50	4.38	30	200
R8108NL	1470	2.80	80	3	LCCI-50	4.40	30	200
R8109NL	880	1.63	110	2	Polecat	1.4	40	500
R8110NL	1170	1.22	200	1	Polecat	1.4	40	500
R8111NL	10040	1.4	210	10	LCCI-50	5.47	20	200
R8112NL	1125	1.8	55	11	Polecat	1.55	40	500
R8113NL	800	3	27	12	Polecat	2.46	40	300
R8114NL	382.5	3.3	18	13	Polecat	1.71	40	200
R8115NL	536	3.8	17.1	14	LCCI-37	2.52	30	200
R8116NL	280	4	13.2	15	Polecat	1.6	40	500
R8117NL	486	4.2	16	16	LCCI-44LP	2.99	40	300
R8118NL	130	5	6.75	17	Polecat	1.6	40	500
R8119NL	96	6	4.3	18	Polecat	1.67	40	500
R8120NL	400	6	9.4	19	LCCI-44LP	3.53	40	200
R8121NL	61	7	2.9	20	Polecat	1.73	40	500
R8122NL	484	8	7.7	21	LCCI-50	5.31	30	200
R8123NL	1030	9	9.75	22	HCCI-80	14.63	20	75
R8124NL	215	10	3.75	23	Makeni	6.26	25	150
R8125NL	95	12.5	3	24	LCCI-50	5.3	30	200
R8126NL	117	14	1.95	25	Makeni	6.2	25	150
R8127NL	500	16	4.25	26	HCCI-80	18.13	20	75
R8128NL	380	20	4.1	27	HCCI-80	15.70	20	75

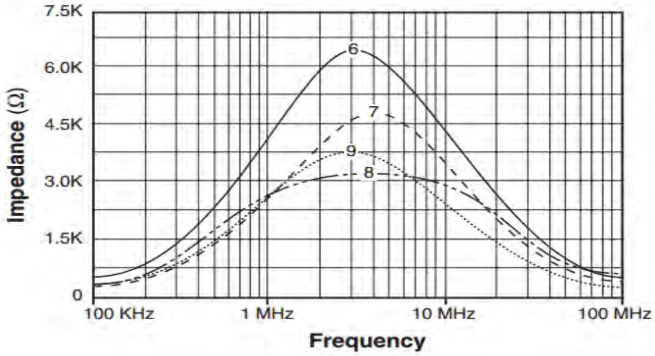
Notes: 1. The current rating (irated) is based upon the temperature rise of the component and represents the rms current, which will cause a typical temperature rise of 55°C with 50LFM forced cooling.

2. The temperature of the component (ambient plus temperature rise) must be within the stated operating temperature range.
3. Optional Tape & Reel packaging can be ordered by adding a "T" suffix to the part number (i.e. R8100NL becomes **R8100NLT.**)

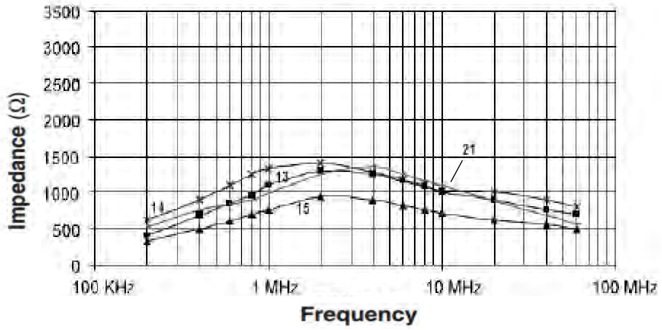
Impedance Curves



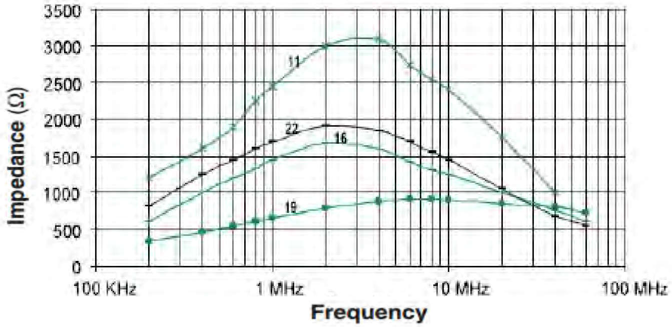
R8106NL (#5), R8107NL (#4), R8108NL (#3), R8109NL (#2), R8110NL (#1)



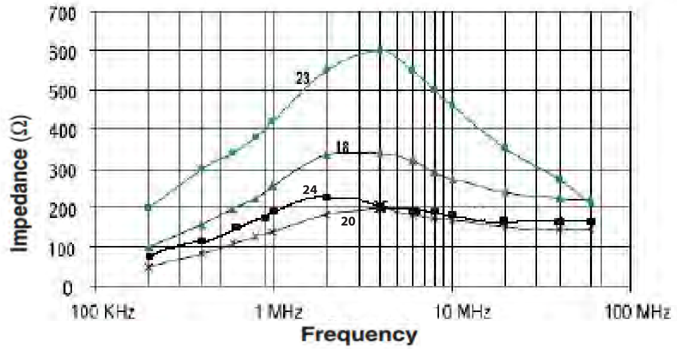
R8100NL (#9), PR8101NL (#7), R8102NL (#6), R8103NL (#8), R8104NL (#7), R8105NL (#6)



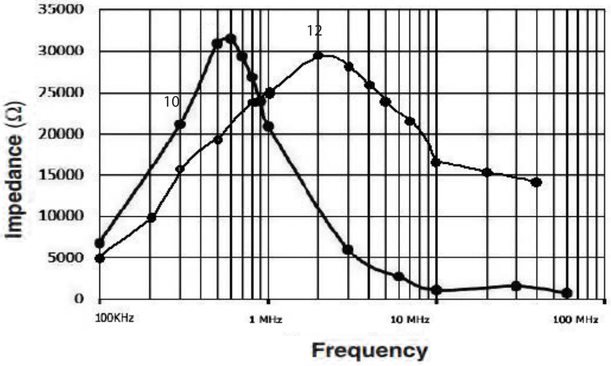
R8114NL (#13), R8115NL (#14), R8116NL (#15), R8122NL (#21)



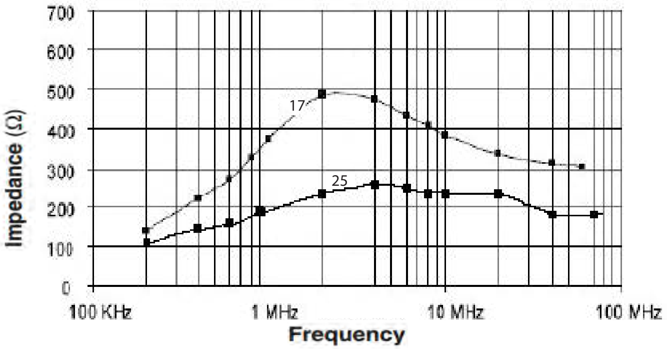
R8112NL (#11), R8117NL(#16), R8120 NL(#19), R8123NL (#22)



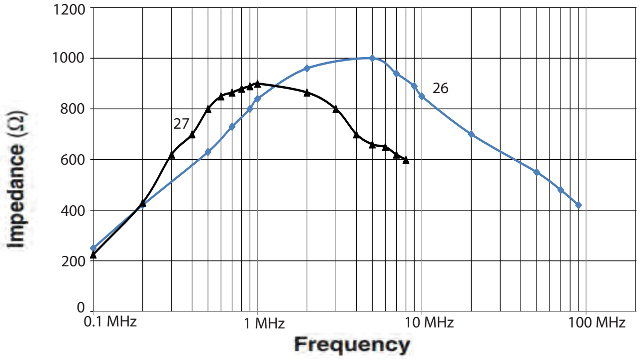
R8119NL (#18), R8121NL (#20), R8124NL (#23), R8125NL (#24)



R8111NL (#10), R8113NL (#12)



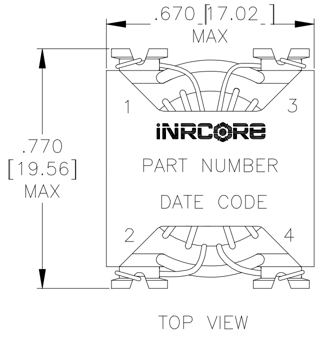
R8118NL (#17), R8126NL (#25)



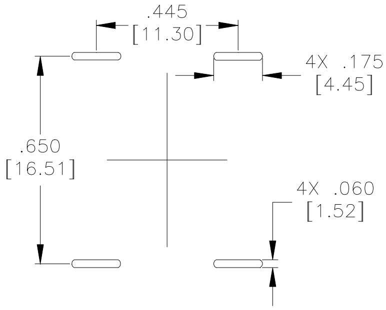
R8127NL (#26), R8128NL (#27)

Mechanicals

LCCI-50 - R8104/05/06/07/08NL, R8111NL,R8122/25NL

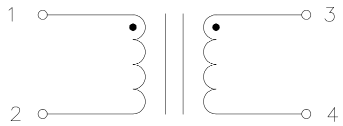


TOP VIEW

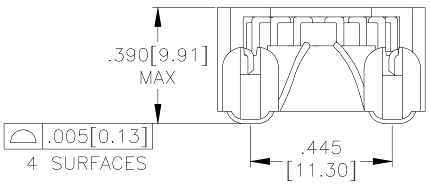


SUGGESTED PADS LAYOUT

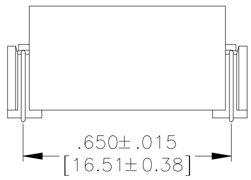
Electrical Schematics



SCHEMATIC



SIDE VIEW



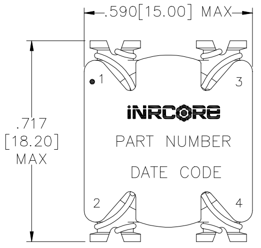
SIDE VIEW

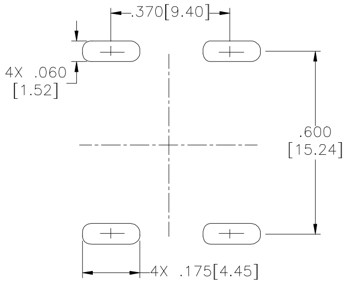
Dimensions: Inches / mm

Unless otherwise specified, all tolerances are: ± .010 / 0,25

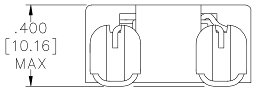
Mechanicals

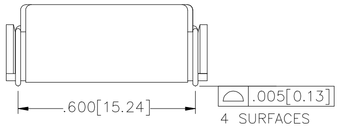
LCCI-44LP - R8117NL, R8120NL

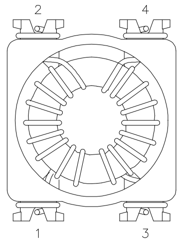


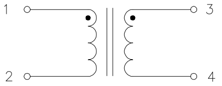


SUGGESTED PCB LAYOUT





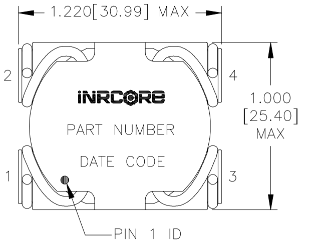


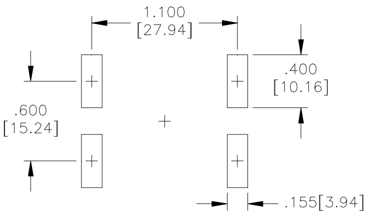


SCHEMATIC

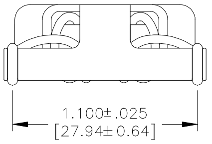
Electrical Schematics

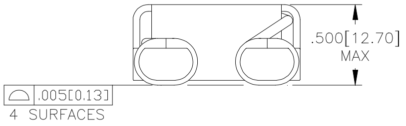
HCCI-80 - R8100/01/02NL,R8123/27/28NL



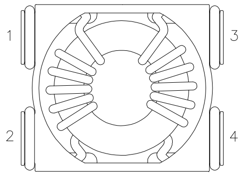


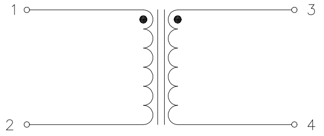
SUGGESTED PCB LAYOUT





Electrical Schematics

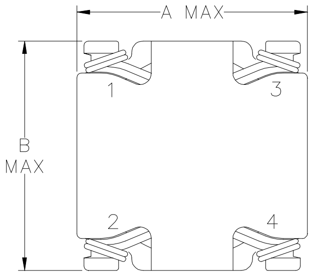




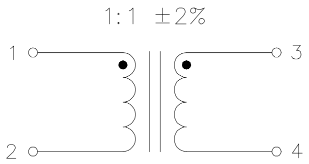
SCHEMATIC

Mechanicals

PoleCat - R8109NL, R8110/12/13NL/14NL/16/18/19NL, R8121NL



TOP VIEW

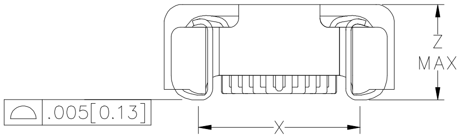


SCHEMATIC

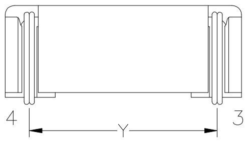
Electrical Schematic

PoleCat Dimensions

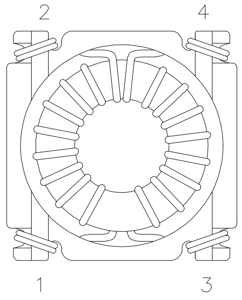
Part number	A	B	X	Y	Z
R8109NL	13.0	13.0	8.4	10.4	5.6
R8110NL	12.7	12.7	8.4	10.4	5.6
R8112NL	12.7	13.2	8.4	10.4	5.6
R8113NL	13.0	13.0	8.4	10.4	5.6
R8114NL	13.0	13.0	8.4	10.4	5.6
R8116NL	13.0	13.0	8.4	10.4	5.6
R8118NL	13.2	13.2	8.6	10.7	5.6
R8119NL	13.2	13.2	8.6	10.7	5.6
R8121NL	13.5	13.5	8.6	10.7	5.6



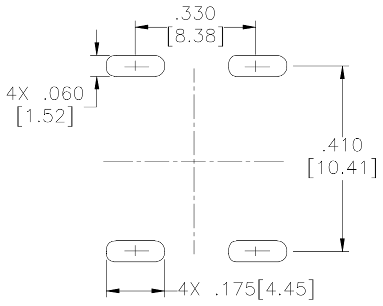
SIDE VIEW



SIDE VIEW



BOTTOM VIEW



SUGGESTED PCB LAYOUT

Dimensions: $\frac{\text{Inches}}{\text{mm}}$

Unless otherwise specified, all tolerances are: $\pm\frac{.010}{0{,}25}$

SMT COMMON MODE CHOKES

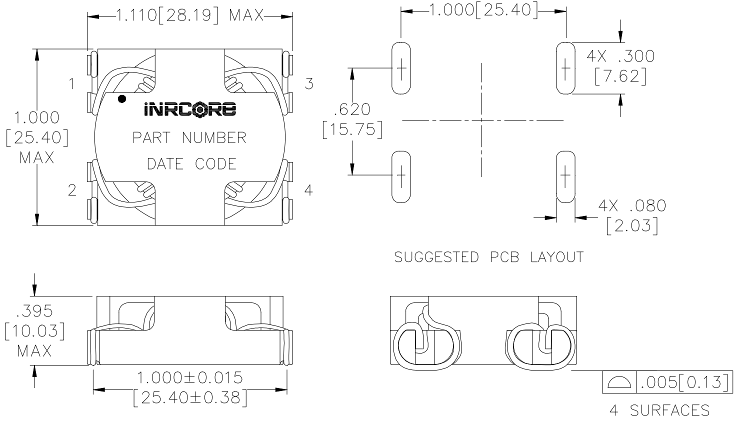
SLIC Series

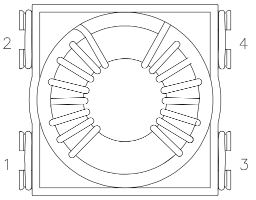
Industrial Grade

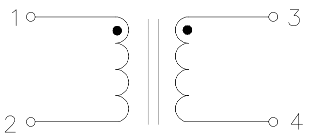
Mechanicals

Electrical Schematics

HCCI-68 - R8103NL







SCHEMATIC

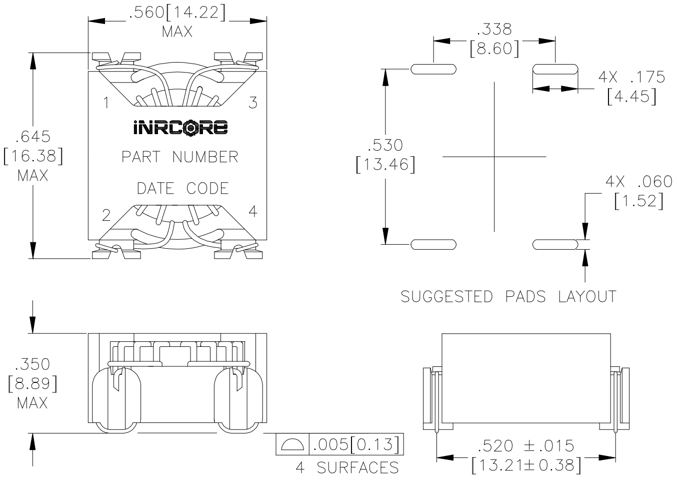
Dimensions: $\frac{\text{Inches}}{\text{mm}}$

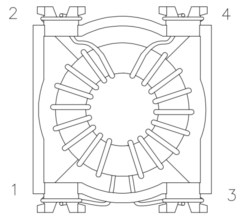
Unless otherwise specified, all tolerances are: ± $\frac{.010}{0,25}$

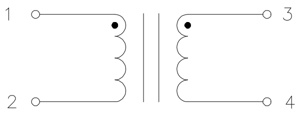
Mechanicals

LCCI-37 - R8115NL

Makeni - R8124/26NL

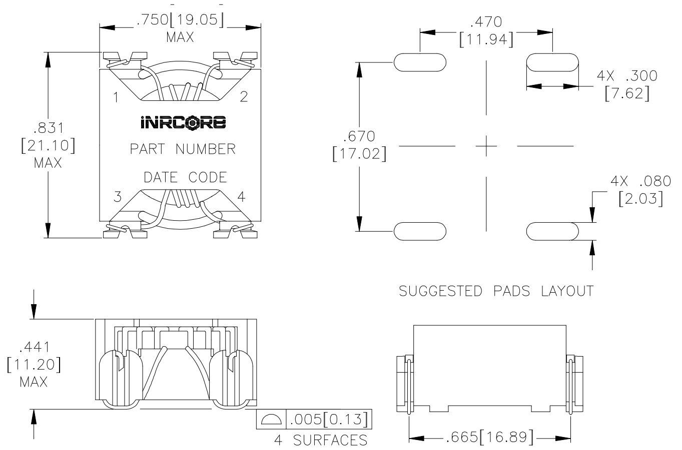


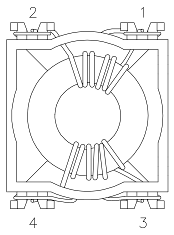


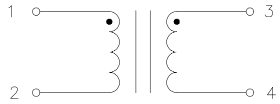


SCHEMATIC

Electrical Schematics



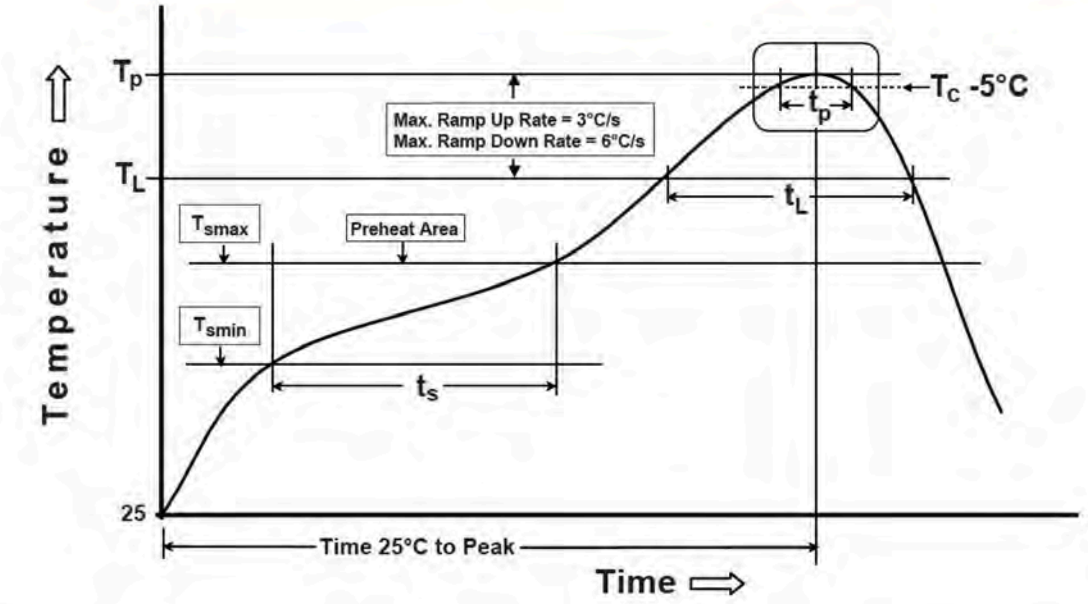




SCHEMATIC

Electrical Schematics

Non-Lead Recommended Reflow Profile (Based on J-STD-020D)



T_{SMIN} (°C)	T_{SMAX} (°C)	T_L (°C)	T_P (°C MAX)	t_S (s)	t_L (s)	t_P (s MAX)	Ramp-up rate (T_L to T_P)	Ramp-down rate (T_P to T_L)	Time 25°C to peak temperature (s MAX)
150	200	217	245	60-120	60-150	30	3°C/s MAX	6°C/s MAX	480

Notes:

1. All temperatures measured on the package leads.
2. Maximum times of reflow cycle: 2.

For More Information

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311 Sinclair Road Bristol,
PA 19007-6812 U.S.A
Tel: + 1.215.781.6400
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No.7,An Li Road,Changan Town,
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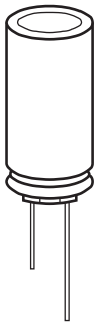
Aluminum electrolytic capacitors

Single-ended capacitors

Series/Type: **B43858**
Date: December 2019

Long-life grade capacitors



Applications

- Professional power supplies
- Not for automotive applications unless otherwise specified

Features

- High ripple current capability at high frequency
- Long useful life
- RoHS-compatible

Construction

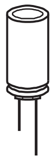
- Radial leads
- Charge-discharge proof, polar
- Aluminum case with insulating sleeve
- Minus pole marking on the insulating sleeve
- Case with safety vent

Delivery mode

Terminal configurations and packing:

- Bulk
- Taped, Ammo pack
- Cut
- Kinked
- PAPR (Protection Against Polarity Reversal): crimped leads, J leads, bent leads

Refer to chapter "Single-ended capacitors – Taping, packing and lead configurations" for further details.



Specifications and characteristics in brief

Rated voltage V_R Surge voltage V_S	160 ... 450 V DC $1.1 \cdot V_R$			
Rated capacitance C_R Capacitance tolerance	2.2 ... 330 µF ±20% ≙ M			
Dissipation factor tan δ (20 °C, 120 Hz)	$V_R \leq 250$ V DC: tan δ (max.) = 0.20 $V_R \geq 350$ V DC: tan δ (max.) = 0.24			
Leakage current I_{leak} (20 °C, 5 min)	$I_{leak} = 0.03\,\mu A \cdot \left(\frac{C_R}{\mu F} \cdot \frac{V_R}{V}\right) + 15\,\mu A$			
Self-inductance ESL	Diameter (mm)	≤ 12.5	16	18
	ESL (nH)	20	26	34
Useful life[1]			Requirements:	
105 °C; V_R; $I_{AC,R}$	> 5000 h		$\lvert \Delta C/C \rvert$	≤ 35% of initial value
			tan δ	≤ 3 times initial specified limit
			I_{leak}	≤ initial specified limit
Voltage endurance test			Post test requirements:	
105 °C; V_R	5000 h		$\lvert \Delta C/C \rvert$	≤ 25% of initial value
			tan δ	≤ 2 times initial specified limit
			I_{leak}	≤ initial specified limit
Vibration resistance test	To IEC 60068-2-6, test Fc: Frequency range 10 Hz ... 2 kHz, displacement amplitude 0.75 mm, acceleration max. 10 *g,* duration 3 × 2 h. Capacitor rigidly clamped by the aluminum case e.g. using our standard fixture			
IEC climatic category	To IEC 60068-1: $V_R \leq 250$ V: 40/105/56 (−40 °C/+105 °C/56 days damp heat test) $V_R \geq 350$ V: 25/105/56 (−25 °C/+105 °C/56 days damp heat test)			
Sectional specification	IEC 60384-4			

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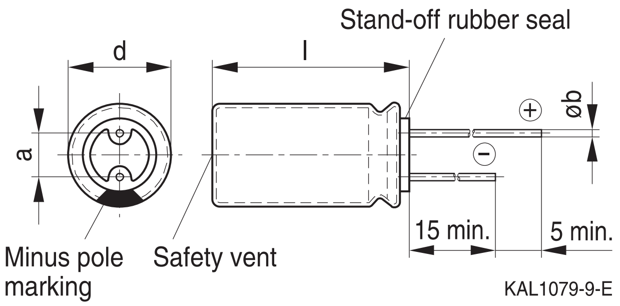
[1] Refer to chapter "General technical information, 5 Useful life" on how to interpret useful life.

Dimensional drawings

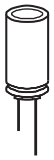
With stand-off rubber seal

Diameters (mm): 10, 12.5, 16, 18



Dimensions and weights

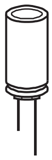
Dimensions (mm)				Approx. weight
d +0.5	l	a ±0.5	b	g
10	12.5 +1.0	5.0	0.60 ±0.05	1.6
10	16 +1.0	5.0	0.60 ±0.05	1.9
10	20 +2.0	5.0	0.60 ±0.05	2.6
12.5	20 +2.0	5.0	0.60 ±0.05	3.6
12.5	25 +2.0	5.0	0.60 ±0.05	4.5
16	20 +2.0	7.5	0.80 ±0.05	5.5
16	25 +2.0	7.5	0.80 ±0.05	7.5
16	31.5 +2.0	7.5	0.80 ±0.05	7.8
18	20 +2.0	7.5	0.80 ±0.1	8.0
18	25 +2.0	7.5	0.80 ±0.1	9.0
18	31.5 +2.0	7.5	0.80 ±0.1	11.0
18	35 +2.0	7.5	0.80 ±0.1	13.0
18	40 +2.0	7.5	0.80 ±0.1	16.0



Overview of available types

Other voltage and capacitance ratings are available upon request.

V_R (V DC)	160	200	250	350	400	450
	Case dimensions d × l (mm)					
C_R (µF)						
2.2				10 × 12.5	10 × 12.5	10 × 12.5
3.3				10 × 12.5	10 × 16	10 × 16
4.7				10 × 12.5	10 × 16	10 × 16
6.8				10 × 16	10 × 16	10 × 16
10			10 × 16	10 × 16	10 × 20	10 × 20
22	10 × 16	10 × 16	10 × 20	12.5 × 20	12.5 × 25 16 × 20	16 × 20
33	10 × 16	10 × 20	12.5 × 20	12.5 × 25 16 × 20	16 × 20	16 × 25
47	12.5 × 20	12.5 × 20	12.5 × 25	16 × 25 18 × 20	16 × 31.5 18 × 25	16 × 31.5
68	12.5 × 20	12.5 × 25 16 × 20	16 × 20	16 × 31.5 18 × 25	18 × 31.5	18 × 35
82						18 × 40
100	16 × 20	16 × 25	16 × 31.5 18 × 25	18 × 35	18 × 40	
220	18 × 31.5	18 × 35	18 × 40			
330	18 × 40					



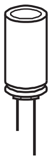
Technical data and ordering codes

C_R 120 Hz 20 °C µF	Case dimensions d × l mm	$I_{AC,R}$ 100 kHz 105 °C mA	Ordering code (composition see below)
V_R = 160 V DC			
22	10 × 16	300	B43858G1226M***
33	10 × 16	350	B43858G1336M***
47	12.5 × 20	650	B43858G1476M***
68	12.5 × 20	700	B43858G1686M***
100	16 × 20	950	B43858G1107M***
220	18 × 31.5	1800	B43858G1227M***
330	18 × 40	2300	B43858G1337M***
V_R = 200 V DC			
22	10 × 16	300	B43858G2226M***
33	10 × 20	470	B43858G2336M***
47	12.5 × 20	590	B43858G2476M***
68	12.5 × 25	780	B43858J2686M***
68	16 × 20	780	B43858G2686M***
100	16 × 25	1250	B43858G2107M***
220	18 × 35	2000	B43858G2227M***
V_R = 250 V DC			
10	10 × 16	280	B43858L2106M***
22	10 × 20	480	B43858L2226M***
33	12.5 × 20	630	B43858L2336M***
47	12.5 × 25	790	B43858L2476M***
68	16 × 20	850	B43858L2686M***
100	16 × 31.5	1450	B43858L2107M***
100	18 × 25	1200	B43858M2107M***
220	18 × 40	2200	B43858L2227M***

Composition of ordering code

*** = Version

- 000 = for standard leads, bulk
- 001 = for kinked leads, bulk (for d × l = 10 × 20 mm and ∅ 12.5 ... 18 mm)
- 002 = for cut leads, bulk
- 003 = for crimped leads, blister (for ∅ 16 ... 18 mm)
- 004 = for J leads, blister (for ∅ 10 ... 18 mm, excluding d × l = 18 × 40 mm)
- 008 = for taped leads, Ammo pack, lead spacing F = 5.0 mm (for ∅ 10 ... 12.5 mm)
- 009 = for taped leads, Ammo pack, lead spacing F = 7.5 mm (for ∅ 16 mm and d × l = 18 × 20 ... 18 × 31.5 mm)
- 012 = for bent 90° leads, blister (for ∅ 16 ... 18 mm)



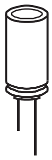
Technical data and ordering codes

C_R 120 Hz 20 °C µF	Case dimensions d × l mm	$I_{AC,R}$ 100 kHz 105 °C mA	Ordering code (composition see below)
V_R = 350 V DC			
2.2	10 × 12.5	100	B43858G4225M***
3.3	10 × 12.5	130	B43858G4335M***
4.7	10 × 12.5	140	B43858G4475M***
6.8	10 × 16	200	B43858G4685M***
10	10 × 16	220	B43858G4106M***
22	12.5 × 20	450	B43858G4226M***
33	12.5 × 25	580	B43858G4336M***
33	16 × 20	580	B43858J4336M***
47	16 × 25	850	B43858G4476M***
47	18 × 20	820	B43858J4476M***
68	16 × 31.5	1100	B43858G4686M***
68	18 × 25	900	B43858J4686M***
100	18 × 35	1450	B43858G4107M***
V_R = 400 V DC			
2.2	10 × 12.5	100	B43858G9225M***
3.3	10 × 16	130	B43858G9335M***
4.7	10 × 16	180	B43858G9475M***
6.8	10 × 16	190	B43858G9685M***
10	10 × 20	290	B43858G9106M***
22	12.5 × 25	520	B43858G9226M***
22	16 × 20	530	B43858J9226M***
33	16 × 20	650	B43858G9336M***
47	16 × 31.5	1050	B43858G9476M***
47	18 × 25	900	B43858J9476M***
68	18 × 31.5	1300	B43858G9686M***
100	18 × 40	1600	B43858G9107M***

Composition of ordering code

*** = Version

000 =	for standard leads, bulk
001 =	for kinked leads, bulk (for d × l = 10 × 20 mm and ∅ 12.5 ... 18 mm)
002 =	for cut leads, bulk
003 =	for crimped leads, blister (for ∅ 16 ... 18 mm)
004 =	for J leads, blister (for ∅ 10 ... 18 mm, excluding d × l = 18 × 40 mm)
008 =	for taped leads, Ammo pack, lead spacing F = 5.0 mm (for ∅ 10 ... 12.5 mm)
009 =	for taped leads, Ammo pack, lead spacing F = 7.5 mm (for ∅ 16 mm and d × l = 18 × 20 ... 18 × 31.5 mm)
012 =	for bent 90° leads, blister (for ∅ 16 ... 18 mm)



Technical data and ordering codes

C_R 120 Hz 20 °C µF	Case dimensions d × l mm	$I_{AC,R}$ 100 kHz 105 °C mA	Ordering code (composition see below)
V_R = 450 V DC			
2.2	10 × 12.5	100	B43858G5225M***
3.3	10 × 16	130	B43858G5335M***
4.7	10 × 16	150	B43858G5475M***
6.8	10 × 16	190	B43858G5685M***
10	10 × 20	310	B43858G5106M***
22	16 × 20	600	B43858G5226M***
33	16 × 25	800	B43858G5336M***
47	16 × 31.5	1050	B43858G5476M***
68	18 × 35	1350	B43858G5686M***
82	18 × 40	1600	B43858G5826M***

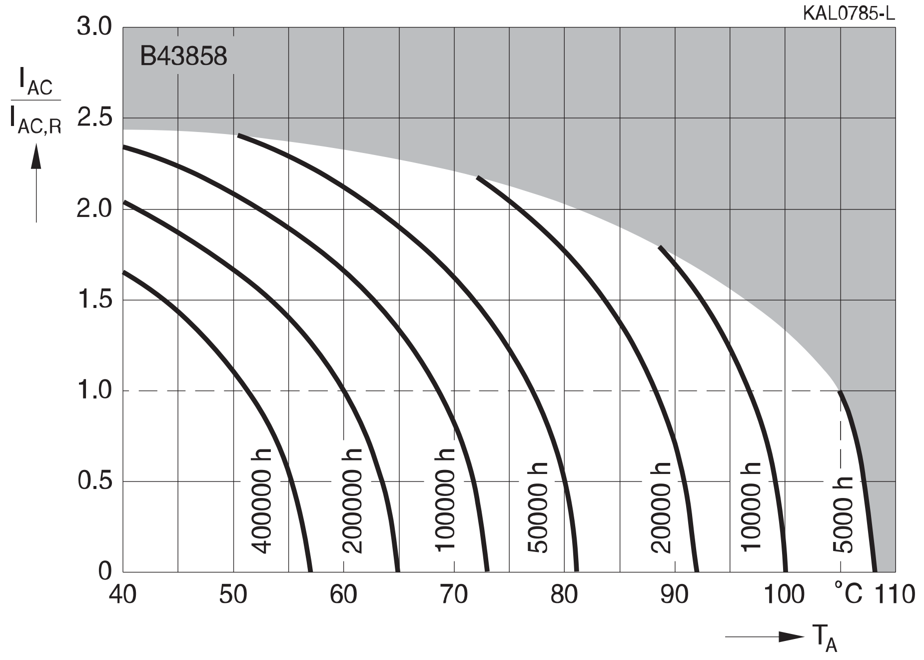
Composition of ordering code

*** = Version

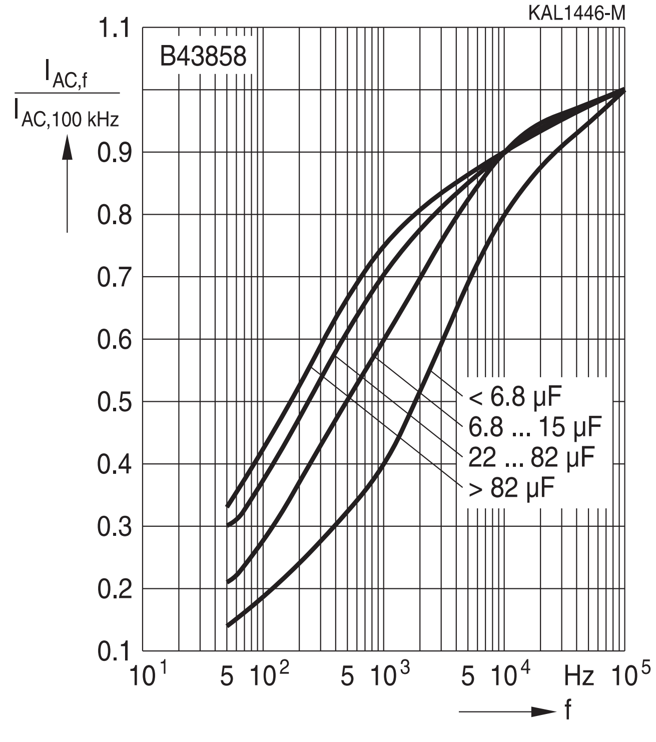
000 = for standard leads, bulk
001 = for kinked leads, bulk (for d × l = 10 × 20 mm and ∅ 12.5 ... 18 mm)
002 = for cut leads, bulk
003 = for crimped leads, blister (for ∅ 16 ... 18 mm)
004 = for J leads, blister (for ∅ 10 ... 18 mm, excluding d × l = 18 × 40 mm)
008 = for taped leads, Ammo pack, lead spacing F = 5.0 mm (for ∅ 10 ... 12.5 mm)
009 = for taped leads, Ammo pack, lead spacing F = 7.5 mm (for ∅ 16 mm and d × l = 18 × 20 ... 18 × 31.5 mm)
012 = for bent 90° leads, blister (for ∅ 16 ... 18 mm)

Useful life[1]

depending on ambient temperature T_A under ripple current operating conditions



Frequency factor of permissible ripple current I_{AC} versus frequency f



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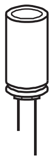
[1] Refer to chapter "General technical information, 5 Useful life" on how to interpret useful life.



Taping

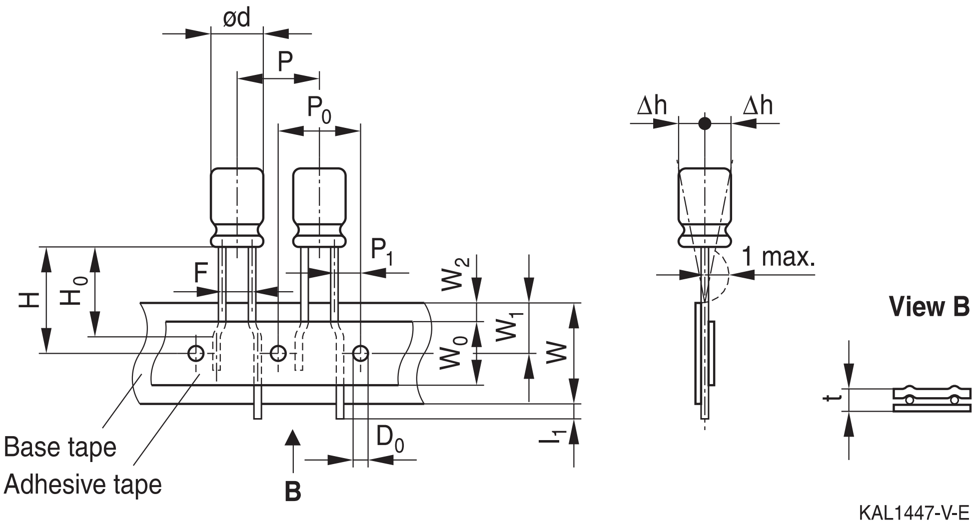
Single-ended capacitors are available taped in Ammo pack from diameter 8 to 18 mm as follows:

Lead spacing F = 3.5 mm (∅ d = 8 mm)
Lead spacing F = 5.0 mm (∅ d = 8 … 12.5 mm)
Lead spacing F = 7.5 mm (∅ d = 16 ... 18 mm).

The dimensions for F, P_1 and 1 max. are specified with reference to the center of the terminal wires.

Lead spacing 3.5 mm (∅ d = 8 mm)

Last 3 digits of ordering code: 006



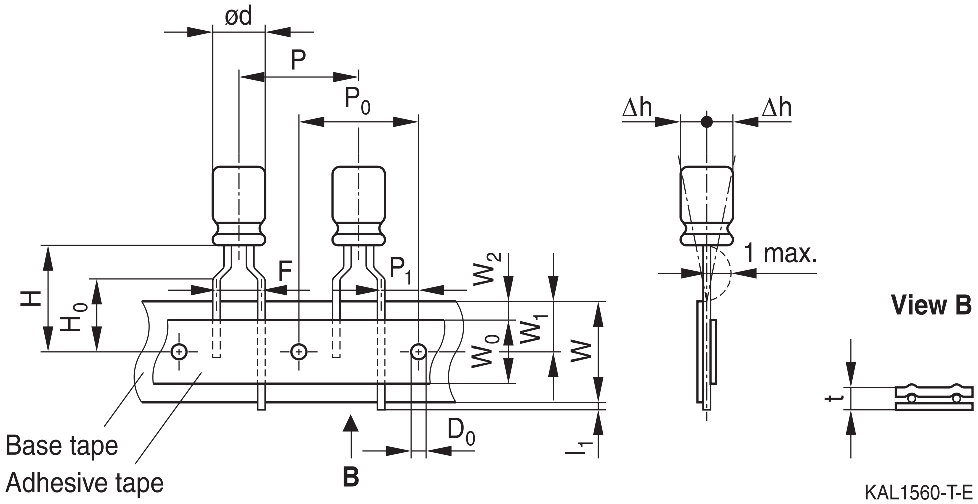
Dimensions in mm

∅ d	F	H	W	W_0	W_1	W_2	P	P_0	P_1	l_1	t	Δh	D_0
8	3.5	18.5	18.0	9.5	9.0	3.0	12.7	12.7	4.6	1.0	0.7	1.0	4.0
Toler-ance	+0.8 −0.2	±1.0	±0.5	min.	±0.5	max.	±1.0	±0.3	±0.6	max.	±0.2	max.	±0.2

Leads can also run straight through the taping area.

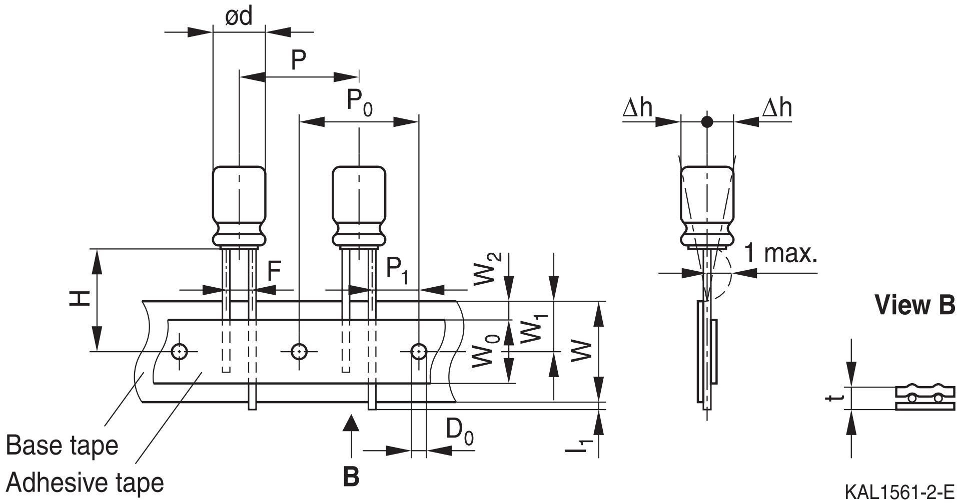
Lead spacing 5.0 mm (∅ d = 8 mm)

Last 3 digits of ordering code: 008



Lead spacing 5.0 mm (∅ d = 10 ... 12.5 mm)

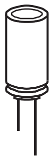
Last 3 digits of ordering code: 008



Dimensions in mm

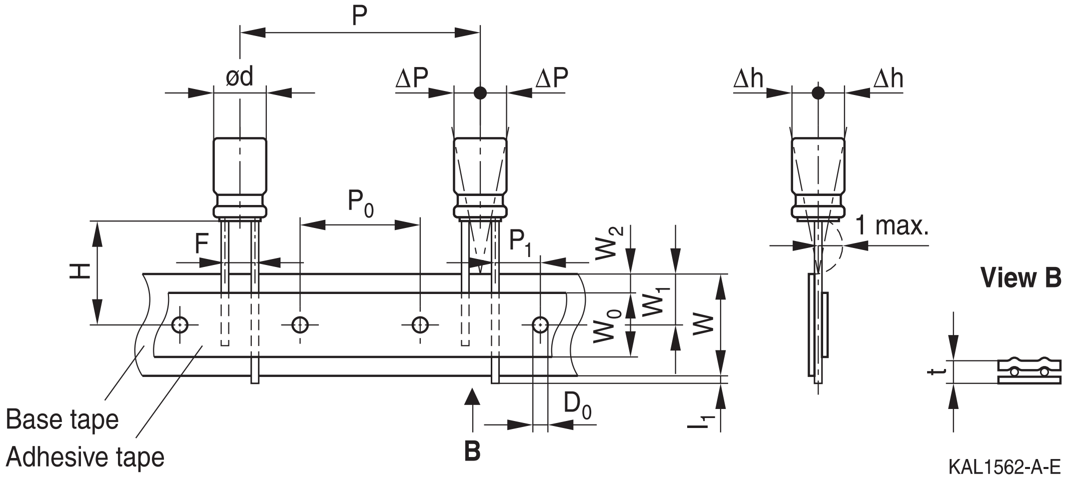
∅ d	F	H	W	W_0	W_1	W_2	H_0	P	P_0	P_1	l_1	t	Δh	D_0
8	5.0	20.0	18.0	9.5	9.0	1.5	16.0	12.7	12.7	3.85	1.0	0.6	1.0	4.0
10		19.0		9.5			−	12.7	12.7	3.85				
12.5		19.0		11.5			−	15.0	15.0	5.0				
Tolerance	+0.8 −0.2	±0.75	±0.5	min.	±0.5	max.	±0.5	±1.0	±0.2	±0.5	max.	+0.3 −0.2	max.	±0.2

Taping is available up to dimensions d × l = 12.5 × 25 mm.



Lead spacing 7.5 mm (∅ d = 16 ...18 mm)

Last 3 digits of ordering code: 009



KAL1562-A-E

Dimensions in mm

∅ d	F	H	W	W_0	W_1	W_2	P	P_0	P_1	l_1	t	ΔP	Δh	D_0
16	7.5	18.5	18.0	12.5	9.0	1.5	30.0	15.0	3.75	1.0	0.7	0	0	4.0
18														
Toler-ance	±0.8	−0.5 +0.75	±0.5	min.	±0.5	max.	±1.0	±0.2	±0.5	max.	±0.2	±1.0	±1.0	±0.2

Taping is available up to dimensions d × l = 16 × 31.5 mm and 18 × 31.5 mm.

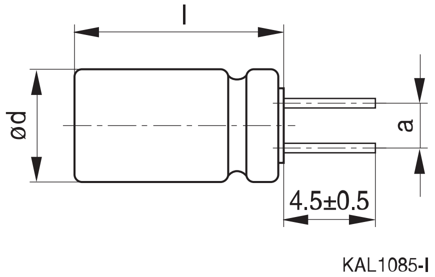
Cut or kinked leads

Single-ended capacitors are available with cut or kinked leads. Other lead configurations also available upon request.

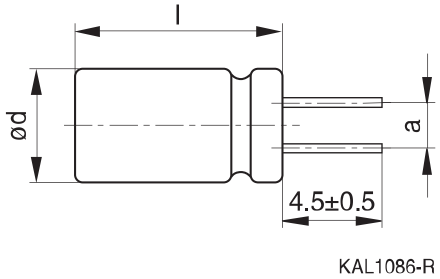
Cut leads

Last 3 digits of ordering code: 002

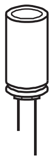
With stand-off rubber seal



With flat rubber seal



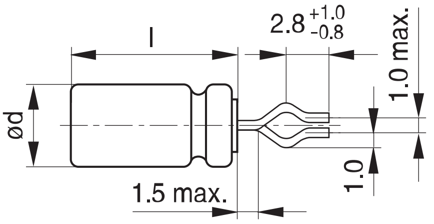
Case size d × l (mm)	Dimensions (mm) a ±0.5
10 × 12.5	5.0
10 × 16	5.0
10 × 20	5.0
12.5 × 20	5.0
12.5 × 25	5.0
16 × 20	7.5
16 × 25	7.5
16 × 31.5	7.5
16 × 35.5	7.5
16 × 40	7.5
18 × 20	7.5
18 × 25	7.5
18 × 31.5	7.5
18 × 35	7.5
18 × 40	7.5



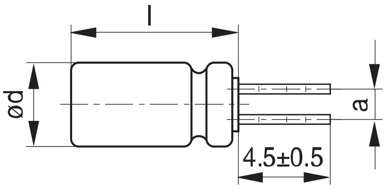
Kinked leads

Last 3 digits of ordering code: 001

With stand-off rubber seal

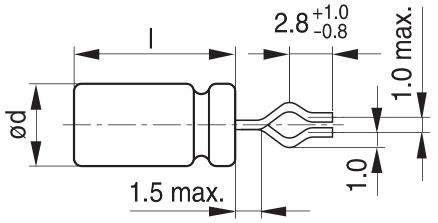


KAL1081-K

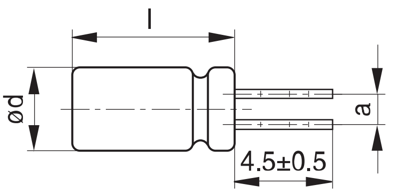


KAL1083-2

With flat rubber seal



KAL1082-T



KAL1084-A

Case size d × l (mm)	Dimensions (mm) a ±0.5
10 × 20	5.0
12.5 × 20	5.0
12.5 × 25	5.0
16 × 20	7.5
16 × 25	7.5
16 × 31.5	7.5
16 × 35.5	7.5
18 × 20	7.5
18 × 25	7.5
18 × 31.5	7.5
18 × 35	7.5
18 × 40	7.5

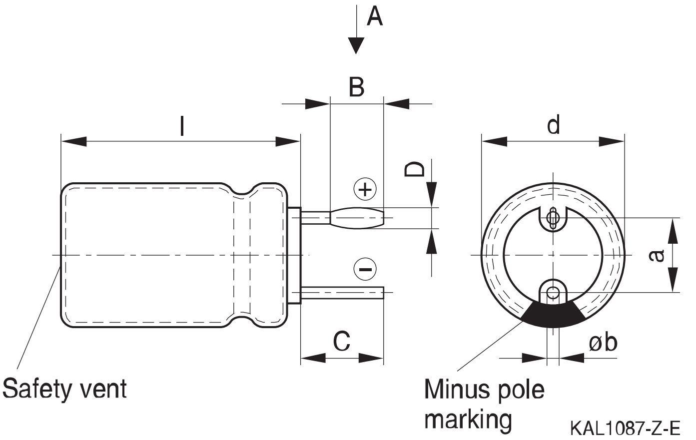
PAPR leads (Protection Against Polarity Reversal)

These lead configurations ensure correct placement of the capacitor on the PCB with regard to polarity. PAPR leads are available for diameters from 10 mm up to 18 mm.
There are three configurations available: Crimped leads, J leads, bent 90° leads.

Crimped leads

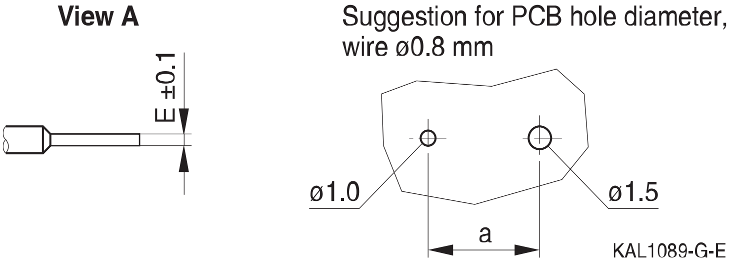
Last 3 digits of ordering code: 003

With stand-off rubber seal

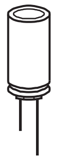


The series B41897 and B41898 have no sleeve nor minus pole marking, the positive pole is marked on the aluminum case side instead.

Suggestion for PCB hole diameter

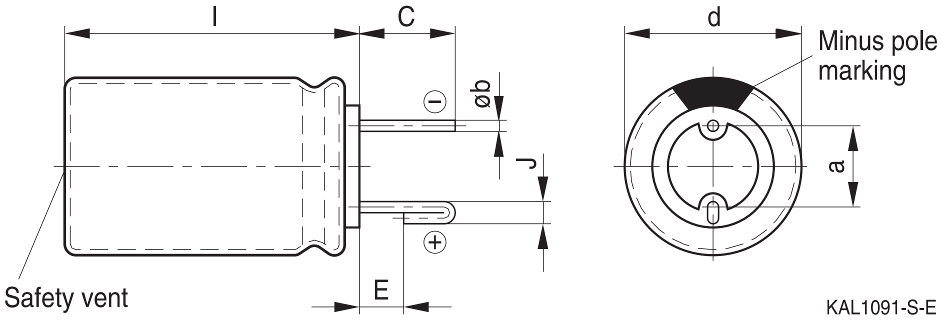


Case size	Dimensions (mm)					
d × l (mm)	B ±0.2	C ±0.5	D ±0.1	E ±0.1	a ±0.5	∅b
16 × 20	1.5	3.0	1.3	0.3	7.5	0.8 ±0.05
16 × 25	1.5	3.0	1.3	0.3	7.5	0.8 ±0.05
16 × 31.5	1.5	3.0	1.3	0.3	7.5	0.8 ±0.05
16 × 35.5	1.5	3.0	1.3	0.3	7.5	0.8 ±0.05
18 × 20	1.5	3.0	1.3	0.3	7.5	0.8 ±0.1
18 × 25	1.5	3.0	1.3	0.3	7.5	0.8 ±0.1
18 × 31.5	1.5	3.0	1.3	0.3	7.5	0.8 ±0.1
18 × 35	1.5	3.0	1.3	0.3	7.5	0.8 ±0.1
18 × 40	1.5	3.0	1.3	0.3	7.5	0.8 ±0.1



J leads

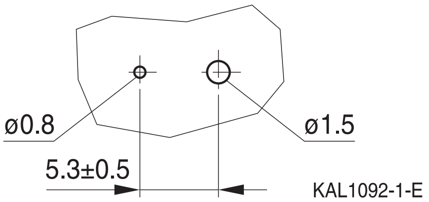
Last 3 digits of ordering code: 004



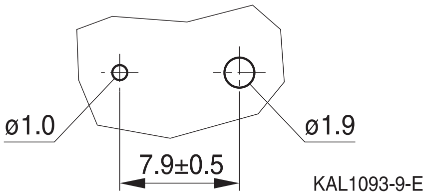
The series B41897 and B41898 have no sleeve nor minus pole marking, the positive pole is marked on the aluminum case side instead.

Suggestion for PCB hole diameter

Suggestion for PCB hole diameter, wire ø0.6 mm



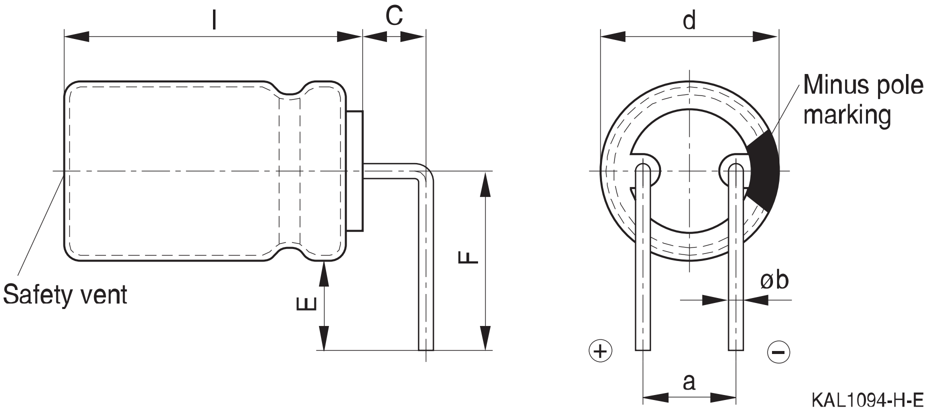
Suggestion for PCB hole diameter, wire ø0.8 mm



Case size	Dimensions (mm)				
d × l (mm)	C ±0.5	E ±0.5	J ±0.2	a ±0.5	∅b
10 × 12.5	3.2	0.7	1.2	5.0	0.6 ±0.05
10 × 16	3.2	0.7	1.2	5.0	0.6 ±0.05
10 × 20	3.2	0.7	1.2	5.0	0.6 ±0.05
12.5 × 20	3.2	0.7	1.2	5.0	0.6 ±0.05
12.5 × 25	3.2	0.7	1.2	5.0	0.6 ±0.05
16 × 20	3.5	0.7	1.6	7.5	0.8 ±0.05
16 × 25	3.5	0.7	1.6	7.5	0.8 ±0.05
16 × 31.5	3.5	0.7	1.6	7.5	0.8 ±0.05
16 × 35.5	3.5	0.7	1.6	7.5	0.8 ±0.05
16 × 40	3.5	0.7	1.6	7.5	0.8 ±0.05
18 × 20	3.5	0.7	1.6	7.5	0.8 ±0.1
18 × 25	3.5	0.7	1.6	7.5	0.8 ±0.1
18 × 31.5	3.5	0.7	1.6	7.5	0.8 ±0.1
18 × 35	3.5	0.7	1.6	7.5	0.8 ±0.1

Bent 90° leads for horizontal mounting pinning

Last 3 digits of ordering code: 012



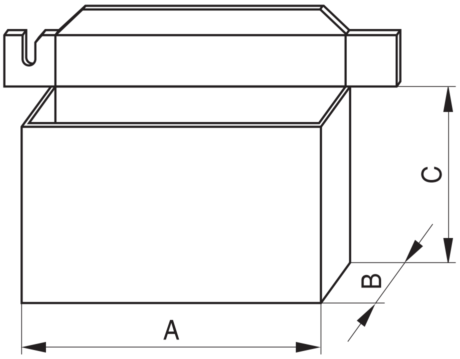
The series B41897 and B41898 have no sleeve nor minus pole marking, the positive pole is marked on the aluminum case side instead.

Case size	Dimensions (mm)				
d × l (mm)	C ±0.5	E ±0.5	F ±0.5	a ±0.5	∅b
16 × 20	4.0	4.0	12.0	7.5	0.8 ±0.05
16 × 25	4.0	4.0	12.0	7.5	0.8 ±0.05
16 × 31.5	4.0	4.0	12.0	7.5	0.8 ±0.05
16 × 35.5	4.0	4.0	12.0	7.5	0.8 ±0.05
16 × 40	4.0	4.0	13.0	7.5	0.8 ±0.05
18 × 20	4.0	4.0	13.0	7.5	0.8 ±0.1
18 × 25	4.0	4.0	13.0	7.5	0.8 ±0.1
18 × 31.5	4.0	4.0	13.0	7.5	0.8 ±0.1
18 × 35	4.0	4.0	13.0	7.5	0.8 ±0.1
18 × 40	4.0	4.0	13.0	7.5	0.8 ±0.1

Bent leads for diameter 12.5 mm available upon request.

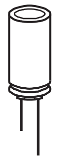
Packing units and box dimensions

Ammo pack



KAL0713-P

Case size d × l mm	Dimensions (mm) A_{max}	 B_{max}	 C_{max}	Packing units pcs.
8 × 11.5	345	60	240	1000
10 × 12.5	345	60	280	750
10 × 16	345	65	200	500
10 × 20	345	65	200	500
12.5 × 20	345	65	260	500
12.5 × 25	345	70	260	500
16 × 20	325	65	285	300
16 × 25	325	65	285	300
16 × 31.5	325	80	275	300
18 × 20	325	65	285	250
18 × 25	325	65	285	250
18 × 31.5	325	80	275	250



Overview of packing units and code numbers

<table>
<tr><th></th><th></th><th colspan="3"></th><th></th><th></th><th colspan="3">PAPR</th></tr>
<tr><th>Case size d × l
mm</th><th>Standard, bulk
pcs.</th><th colspan="3">Taped, Ammo pack
pcs.</th><th>Kinked leads, bulk
pcs.</th><th>Cut leads, bulk
pcs.</th><th>Crimped leads, blister
pcs.</th><th>J leads, blister
pcs.</th><th>Bent 90° leads, blister
pcs.</th></tr>
<tr><td>8 × 11.5</td><td>1000</td><td colspan="3">1000</td><td>–</td><td>–</td><td>–</td><td>–</td><td></td></tr>
<tr><td>10 × 12.5</td><td>1000</td><td colspan="3">750</td><td>–</td><td>1000</td><td>–</td><td>900</td><td></td></tr>
<tr><td>10 × 16</td><td>1000</td><td colspan="3">500</td><td>–</td><td>1000</td><td>–</td><td>675</td><td></td></tr>
<tr><td>10 × 20</td><td>500</td><td colspan="3">500</td><td>500</td><td>500</td><td>–</td><td>500</td><td></td></tr>
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<tr><td>12.5 × 25</td><td>250</td><td colspan="3">500</td><td>500</td><td>500</td><td>–</td><td>225</td><td>1)</td></tr>
<tr><td>16 × 20</td><td>250</td><td colspan="3">300</td><td>200</td><td>200</td><td>200</td><td>200</td><td>420</td></tr>
<tr><td>16 × 25</td><td>250</td><td colspan="3">300</td><td>200</td><td>200</td><td>216</td><td>216</td><td>216</td></tr>
<tr><td>16 × 31.5</td><td>200</td><td colspan="3">300</td><td>250</td><td>250</td><td>180</td><td>180</td><td>180</td></tr>
<tr><td>16 × 35.5</td><td>100</td><td colspan="3">–</td><td>100</td><td>100</td><td>150</td><td>150</td><td>150</td></tr>
<tr><td>16 × 40</td><td>125</td><td colspan="3">–</td><td>100</td><td>100</td><td>72</td><td>72</td><td>72</td></tr>
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<tr><td>18 × 35</td><td>100</td><td colspan="3">–</td><td>100</td><td>100</td><td>150</td><td>150</td><td>150</td></tr>
<tr><td>18 × 40</td><td>125</td><td colspan="3">–</td><td>100</td><td>100</td><td>72</td><td>–</td><td>72</td></tr>
<tr><td rowspan="2">The last three digits of the complete ordering code state the lead configuration</td><td rowspan="2">000</td><td>Code</td><td>F (mm)</td><td>d (mm)</td><td rowspan="2">001</td><td rowspan="2">002</td><td rowspan="2">003</td><td rowspan="2">004</td><td rowspan="2">012</td></tr>
<tr><td>006
008
009</td><td>3.5
5
7.5</td><td>8
8...12.5
16...18</td></tr>
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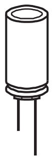
1) Available upon request



Cautions and warnings

Personal safety

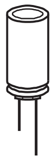
The electrolytes used have been optimized both with a view to the intended application and with regard to health and environmental compatibility. They do not contain any solvents that are detrimental to health, e.g. dimethyl formamide (DMF) or dimethyl acetamide (DMAC). Furthermore, some of the high-voltage electrolytes used are self-extinguishing.

As far as possible, we do not use any dangerous chemicals or compounds to produce operating electrolytes, although in exceptional cases, such materials must be used in order to achieve specific physical and electrical properties because no alternative materials are currently known. We do, however, restrict the amount of dangerous materials used in our products to an absolute minimum.

Materials and chemicals used in our aluminum electrolytic capacitors are continuously adapted in compliance with the TDK Electronics Corporate Environmental Policy and the latest EU regulations and guidelines such as RoHS, REACH/SVHC, GADSL, and ELV.

MDS (Material Data Sheets) are available on our website for all types listed in the data book.
MDS for customer specific capacitors are available upon request.
MSDS (Material Safety Data Sheets) are available for our electrolytes upon request.

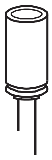
Nevertheless, the following rules should be observed when handling aluminum electrolytic capacitors: No electrolyte should come into contact with eyes or skin. If electrolyte does come into contact with the skin, wash the affected areas immediately with running water. If the eyes are affected, rinse them for 10 minutes with plenty of water. If symptoms persist, seek medical treatment. Avoid inhaling electrolyte vapor or mists. Workplaces and other affected areas should be well ventilated. Clothing that has been contaminated by electrolyte must be changed and rinsed in water.



Product safety

The table below summarizes the safety instructions that must be observed without fail. A detailed description can be found in the relevant sections of seperate file chapter "General technical information".

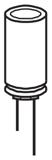
Topic	Safety information	Reference chapter "General technical information"
Polarity	Make sure that polar capacitors are connected with the right polarity.	1 "Basic construction of aluminum electrolytic capacitors"
Reverse voltage	Voltages of opposite polarity should be prevented by connecting a diode.	3.1.6 "Reverse voltage"
Mounting position of screw-terminal capacitors	Screw terminal capacitors must not be mounted with terminals facing down unless otherwise specified.	11.1. "Mounting positions of capacitors with screw terminals"
Robustness of terminals	The following maximum tightening torques must not be exceeded when connecting screw terminals: M5: 2.5 Nm M6: 4.0 Nm	11.3 "Mounting torques"
Mounting of single-ended capacitors	The internal structure of single-ended capacitors might be damaged if excessive force is applied to the lead wires. Avoid any compressive, tensile or flexural stress. Do not move the capacitor after soldering to PC board. Do not pick up the PC board by the soldered capacitor. Do not insert the capacitor on the PC board with a hole space different to the lead space specified.	11.4 "Mounting considerations for single-ended capacitors"
Soldering	Do not exceed the specified time or temperature limits during soldering.	11.5 "Soldering"
Soldering, cleaning agents	Do not allow halogenated hydrocarbons to come into contact with aluminum electrolytic capacitors.	11.6 "Cleaning agents"
Upper category temperature	Do not exceed the upper category temperature.	7.2 "Maximum permissible operating temperature"
Passive flammability	Avoid external energy, e.g. fire.	8.1 "Passive flammability"



Topic	Safety information	Reference chapter "General technical information"
Active flammability	Avoid overload of the capacitors.	8.2 "Active flammability"
Maintenance	Make periodic inspections of the capacitors. Before the inspection, make sure that the power supply is turned off and carefully discharge the capacitors. Do not apply excessive mechanical stress to the capacitor terminals when mounting.	10 "Maintenance"
Storage	Do not store capacitors at high temperatures or high humidity. Capacitors should be stored at +5 to +35 °C and a relative humidity of ≤ 75%.	7.3 "Shelf life and storage conditions"
		Reference chapter "Capacitors with screw terminals"
Breakdown strength of insulating sleeves	Do not damage the insulating sleeve, especially when ring clips are used for mounting.	"Screw terminals – accessories"

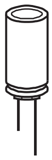
Display of ordering codes for TDK Electronics products

The ordering code for one and the same product can be represented differently in data sheets, data books, other publications, on the company website, or in order-related documents such as shipping notes, order confirmations and product labels. The varying representations of the ordering codes are due to different processes employed and do not affect the specifications of the respective products.
Detailed information can be found on the Internet under
www.tdk-electronics.tdk.com/orderingcodes.



Symbols and terms

Symbol	English	German
C	Capacitance	Kapazität
C_R	Rated capacitance	Nennkapazität
C_S	Series capacitance	Serienkapazität
$C_{S,T}$	Series capacitance at temperature T	Serienkapazität bei Temperatur T
C_f	Capacitance at frequency f	Kapazität bei Frequenz f
d	Case diameter, nominal dimension	Gehäusedurchmesser, Nennmaß
d_{max}	Maximum case diameter	Maximaler Gehäusedurchmesser
ESL	Self-inductance	Eigeninduktivität
ESR	Equivalent series resistance	Ersatzserienwiderstand
ESR_f	Equivalent series resistance at frequency f	Ersatzserienwiderstand bei Frequenz f
ESR_T	Equivalent series resistance at temperature T	Ersatzserienwiderstand bei Temperatur T
f	Frequency	Frequenz
I	Current	Strom
I_{AC}	Alternating current (ripple current)	Wechselstrom
$I_{AC,RMS}$	Root-mean-square value of alternating current	Wechselstrom, Effektivwert
$I_{AC,f}$	Ripple current at frequency f	Wechselstrom bei Frequenz f
$I_{AC,max}$	Maximum permissible ripple current	Maximal zulässiger Wechselstrom
$I_{AC,R}$	Rated ripple current	Nennwechselstrom
I_{leak}	Leakage current	Reststrom
$I_{leak,op}$	Operating leakage current	Betriebsreststrom
l	Case length, nominal dimension	Gehäuselänge, Nennmaß
l_{max}	Maximum case length (without terminals and mounting stud)	Maximale Gehäuselänge (ohne Anschlüsse und Gewindebolzen)
R	Resistance	Widerstand
R_{ins}	Insulation resistance	Isolationswiderstand
R_{symm}	Balancing resistance	Symmetrierwiderstand
T	Temperature	Temperatur
ΔT	Temperature difference	Temperaturdifferenz
T_A	Ambient temperature	Umgebungstemperatur
T_C	Case temperature	Gehäusetemperatur
T_B	Capacitor base temperature	Temperatur des Gehäusebodens
t	Time	Zeit
Δt	Period	Zeitraum
t_b	Service life (operating hours)	Brauchbarkeitsdauer (Betriebszeit)



Symbol	English	German
V	Voltage	Spannung
V_F	Forming voltage	Formierspannung
V_{op}	Operating voltage	Betriebsspannung
V_R	Rated voltage, DC voltage	Nennspannung, Gleichspannung
V_S	Surge voltage	Spitzenspannung
X_C	Capacitive reactance	Kapazitiver Blindwiderstand
X_L	Inductive reactance	Induktiver Blindwiderstand
Z	Impedance	Scheinwiderstand
Z_T	Impedance at temperature T	Scheinwiderstand bei Temperatur T
tan δ	Dissipation factor	Verlustfaktor
λ	Failure rate	Ausfallrate
ε_0	Absolute permittivity	Elektrische Feldkonstante
ε_r	Relative permittivity	Dielektrizitätszahl
ω	Angular velocity; $2 \cdot \pi \cdot f$	Kreisfrequenz; $2 \cdot \pi \cdot f$

Note

All dimensions are given in mm.

Important notes

The following applies to all products named in this publication:

1. Some parts of this publication contain **statements about the suitability of our products for certain areas of application**. These statements are based on our knowledge of typical requirements that are often placed on our products in the areas of application concerned. We nevertheless expressly point out **that such statements cannot be regarded as binding statements about the suitability of our products for a particular customer application**. As a rule, we are either unfamiliar with individual customer applications or less familiar with them than the customers themselves. For these reasons, it is always ultimately incumbent on the customer to check and decide whether a product with the properties described in the product specification is suitable for use in a particular customer application.
2. We also point out that **in individual cases, a malfunction of electronic components or failure before the end of their usual service life cannot be completely ruled out in the current state of the art, even if they are operated as specified**. In customer applications requiring a very high level of operational safety and especially in customer applications in which the malfunction or failure of an electronic component could endanger human life or health (e.g. in accident prevention or lifesaving systems), it must therefore be ensured by means of suitable design of the customer application or other action taken by the customer (e.g. installation of protective circuitry or redundancy) that no injury or damage is sustained by third parties in the event of malfunction or failure of an electronic component.
3. **The warnings, cautions and product-specific notes must be observed.**
4. In order to satisfy certain technical requirements, **some of the products described in this publication may contain substances subject to restrictions in certain jurisdictions (e.g. because they are classed as hazardous)**. Useful information on this will be found in our Material Data Sheets on the Internet (www.tdk-electronics.tdk.com/material). Should you have any more detailed questions, please contact our sales offices.
5. We constantly strive to improve our products. Consequently, **the products described in this publication may change from time to time**. The same is true of the corresponding product specifications. Please check therefore to what extent product descriptions and specifications contained in this publication are still applicable before or when you place an order. We also **reserve the right to discontinue production and delivery of products**. Consequently, we cannot guarantee that all products named in this publication will always be available. The aforementioned does not apply in the case of individual agreements deviating from the foregoing for customer-specific products.
6. Unless otherwise agreed in individual contracts, **all orders are subject to our General Terms and Conditions of Supply**.

Important notes

7. **Our manufacturing sites serving the automotive business apply the IATF 16949 standard.** The IATF certifications confirm our compliance with requirements regarding the quality management system in the automotive industry. Referring to customer requirements and customer specific requirements (“CSR”) TDK always has and will continue to have the policy of respecting individual agreements. Even if IATF 16949 may appear to support the acceptance of unilateral requirements, we hereby like to emphasize that **only requirements mutually agreed upon can and will be implemented in our Quality Management System.** For clarification purposes we like to point out that obligations from IATF 16949 shall only become legally binding if individually agreed upon.
8. The trade names EPCOS, CeraCharge, CeraDiode, CeraLink, CeraPad, CeraPlas, CSMP, CTVS, DeltaCap, DigiSiMic, ExoCore, FilterCap, FormFit, LeaXield, MiniBlue, MiniCell, MKD, MKK, MotorCap, PCC, PhaseCap, PhaseCube, PhaseMod, PhiCap, PowerHap, PQSine, PQvar, SIFERRIT, SIFI, SIKOREL, SilverCap, SIMDAD, SiMic, SIMID, SineFormer, SIOV, ThermoFuse, WindCap are **trademarks registered or pending** in Europe and in other countries. Further information will be found on the Internet at www.tdk-electronics.tdk.com/trademarks.

Release 2018-10

STTH3002

Ultrafast recovery diode

Main product characteristics

$I_{F(AV)}$	30 A
V_{RRM}	200 V
T_j (max)	175° C
V_F (typ)	0.77 V
t_{rr} (typ)	22 ns

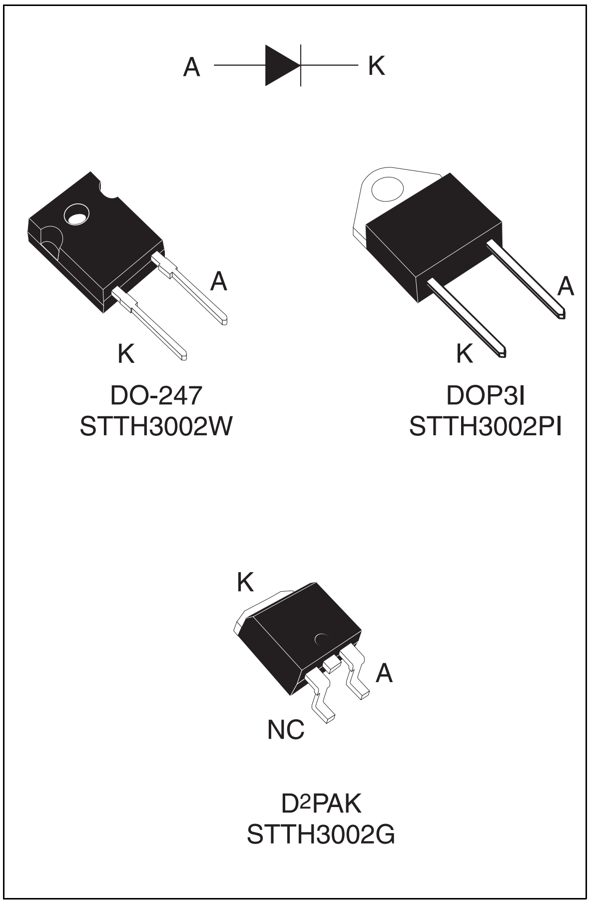
Features and benefits

- Very low conduction losses
- Negligible switching losses
- Low forward and reverse recovery time
- High junction temperature

Description

The STTH3002 uses ST's new 200 V planar Pt doping technology, and is specially suited for switching mode base drive and transistor circuits.

Packaged in DO-247, DOP3I, and D²PAK, this device is intended for use in low voltage, high frequency inverters, free wheeling and polarity protection.



Order codes

Part Number	Marking
STTH3002W	STTH3002
STTH3002PI	STTH3002
STTH3002G	STTH3002
STTH3002G-TR	STTH3002

1 Characteristics

Table 1. Absolute ratings (limiting values at T_j = 25° C, unless otherwise specified)

Symbol	Parameter		Value	Unit
V_{RRM}	Repetitive peak reverse voltage		200	V
$I_{F(RMS)}$	RMS forward current		50	A
$I_{F(AV)}$	Average forward current, $\delta = 0.5$	DO-247 T_c = 135° C	30	A
		DOP3I T_c = 115° C		
		D^2PAK T_c = 135° C		
I_{FSM}	Surge non repetitive forward current	t_p = 10 ms Sinusoidal	300	A
T_{stg}	Storage temperature range		-65 to + 175	° C
T_j	Maximum operating junction temperature		175	° C

Table 2. Thermal parameters

Symbol	Parameter		Value	Unit
$R_{th(j-c)}$	Junction to case	DO-247	1.2	° C/W
		DOP3I	1.8	
		D^2PAK	1.2	

Table 3. Static electrical characteristics

Symbol	Parameter	Test conditions		Min.	Typ	Max.	Unit
I_R(1)	Reverse leakage current	T_j = 25° C	$V_R = V_{RRM}$			20	µA
		T_j = 150° C			20	200	
V_F(2)	Forward voltage drop	T_j = 125° C	I_F = 25 A		0.77	0.85	V
		T_j = 25° C	I_F = 30 A			1.05	
		T_j = 150° C			0.8	0.88	

1. Pulse test: t_p = 5 ms, $\delta < 2$ %
2. Pulse test: t_p = 380 µs, $\delta < 2$ %

To evaluate the conduction losses use the following equation:
$P = 0.67 \times I_{F(AV)} + 0.007\, I_{F}^{2}{}_{(RMS)}$

Table 4. Dynamic characteristics

Symbol	Parameter	Test conditions	Min.	Typ	Max.	Unit
t_{rr}	Reverse recovery time	I_F = 1 A, dI_F/dt = -200 A/µs, V_R = 30 V, T_j = 25 °C		22	27	ns
		I_F = 1 A, dI_F/dt = -50 A/µs, V_R = 30 V, T_j = 25 °C		40	50	
I_{RM}	Reverse recovery current	I_F = 30 A, dI_F/dt = 200 A/µs, V_R = 160 V, T_j = 125 °C		7.6	9.5	A
t_{fr}	Forward recovery time	I_F = 30 A, dI_F/dt = 200 A/µs V_{FR} = 1.1 x V_{Fmax}, T_j = 25 °C		140		ns
V_{FP}	Forward recovery voltage	I_F = 30 A, dI_F/dt = 200 A/µs, V_{FR} = 1.1 x V_{Fmax}, T_j = 25 °C		2.5		V

Figure 1. Peak current versus duty cycle

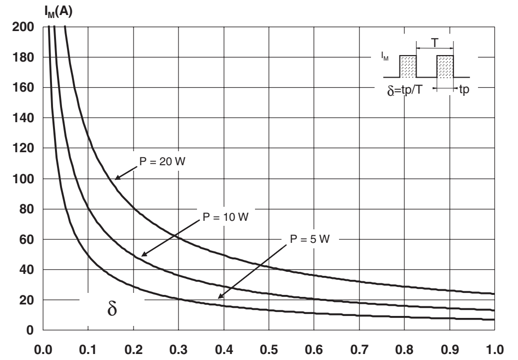


Figure 2. Forward voltage drop versus forward current (typical values)

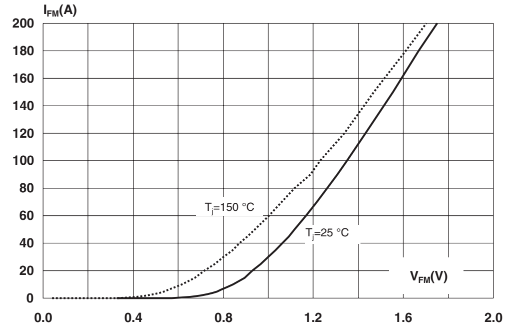


Figure 3. Forward voltage drop versus forward current (maximum values)

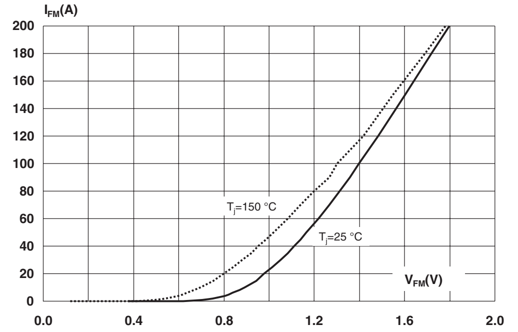


Figure 4. Relative variation of thermal impedance, junction to case, versus pulse duration

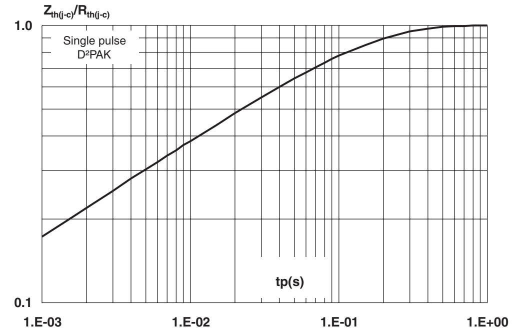


Figure 5. Junction capacitance versus reverse voltage applied (typical values)

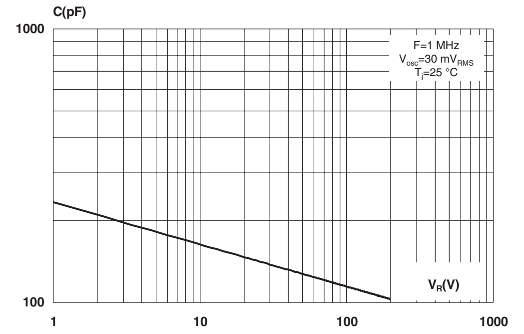


Figure 6. Reverse recovery charges versus dI_F/dt (typical values)

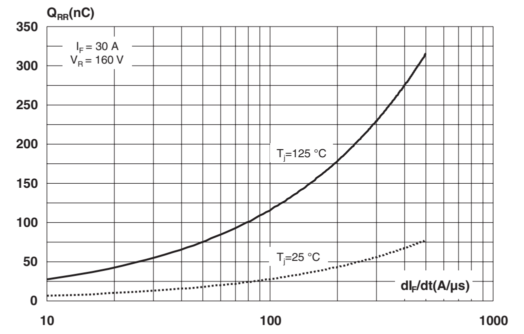


Figure 7. Reverse recovery time versus dI_F/dt (typical values)

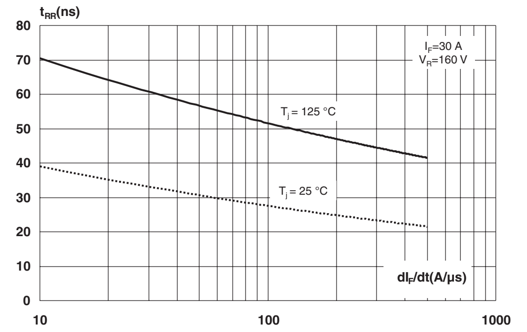


Figure 8. Peak reverse recovery current versus dI_F/dt (typical values)

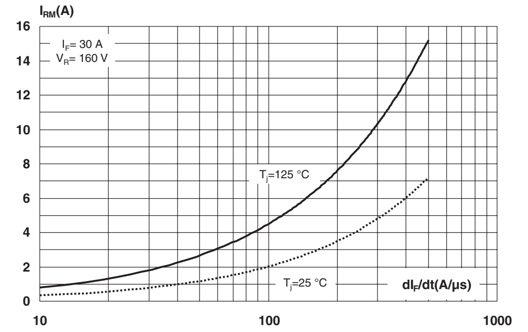


Figure 9. Dynamic parameters versus junction temperature

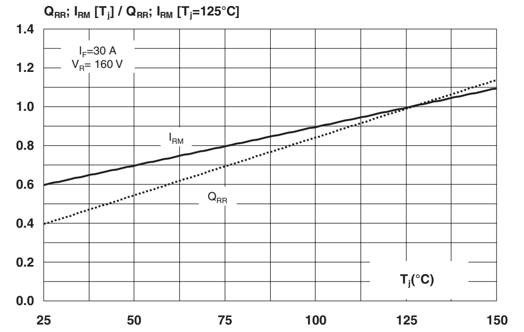
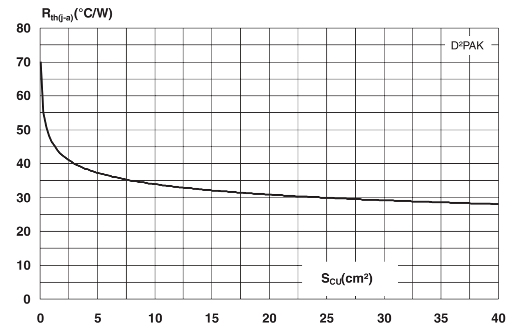
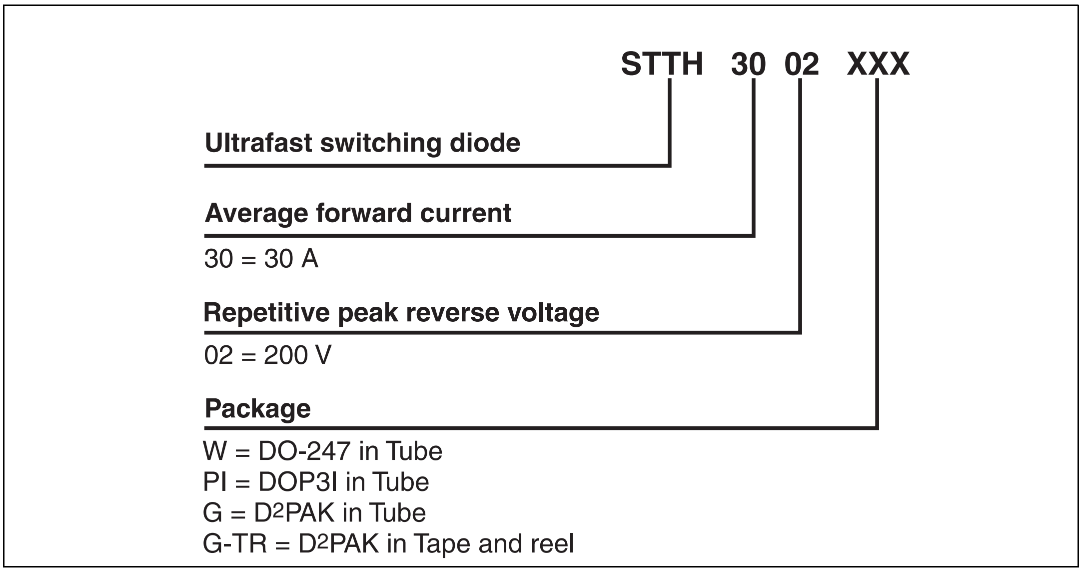


Figure 10. Thermal resistance, junction to ambient, versus copper surface under tab (Epoxy printed circuit board FR4, e_{cu} = 35 µm)



2 Ordering information scheme



STTH 30 02 XXX

Ultrafast switching diode

Average forward current

30 = 30 A

Repetitive peak reverse voltage

02 = 200 V

Package

W = DO-247 in Tube
PI = DOP3I in Tube
G = D^2PAK in Tube
G-TR = D^2PAK in Tape and reel

3 Package information

Epoxy meets UL94, V0

Cooling method: by conduction (C)

Recommended torque value: 0.8 Nm

Maximum torque value: 1.0 Nm

Table 5. DO-247 dimensions

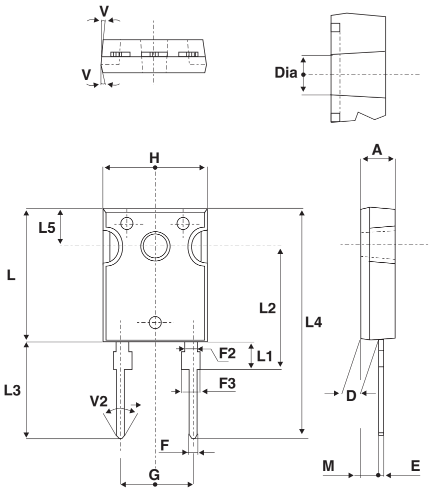
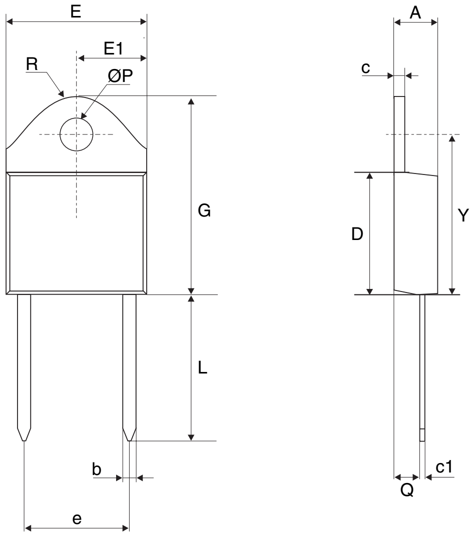
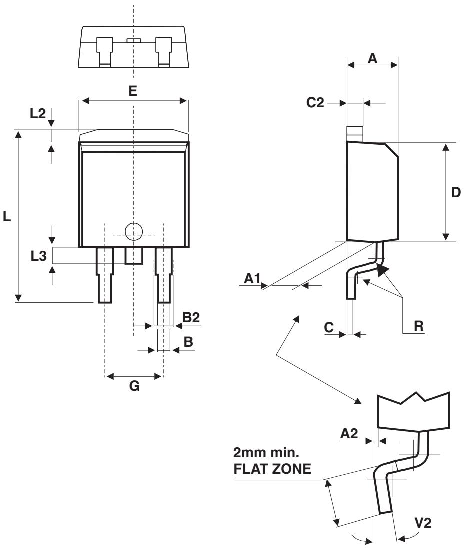
	REF.	DIMENSIONS					
		Millimeters			Inches		
		Min.	Typ.	Max.	Min.	Typ.	Max.
	A	4.85		5.15	0.191		0.203
	D	2.20		2.60	0.086		0.102
	E	0.40		0.80	0.015		0.031
	F	1.00		1.40	0.039		0.055
	F2		2.00			0.078	
	F3	2.00		2.40	0.078		0.094
	G		10.90			0.429	
	H	15.45		15.75	0.608		0.620
	L	19.85		20.15	0.781		0.793
	L1	3.70		4.30	0.145		0.169
	L2		18.50			0.728	
	L3	14.20		14.80	0.559		0.582
	L4		34.60			1.362	
	L5		5.50			0.216	
	M	2.00		3.00	0.078		0.118
	V		5°			5°	
	V2		60°			60°	
	Dia.	3.55		3.65	0.139		0.143

Table 6. DOP3I dimensions



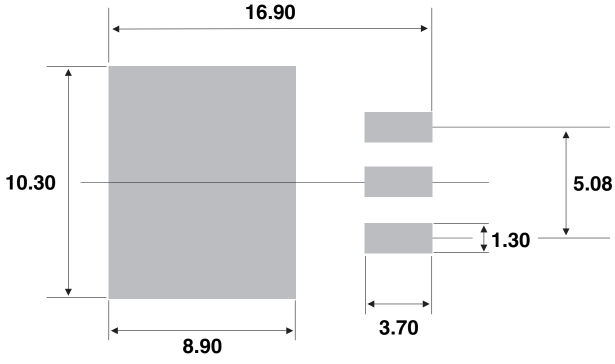
REF	DIMENSIONS			
	Millimeters		Inches	
	Min.	Max.	Min.	Max.
A	4.40	4.60	0.173	0.181
b	1.20	1.40	0.047	0.055
c	1.45	1.55	0.057	0.061
c1	0.50	0.70	0.020	0.028
D	12.15	13.10	0.474	0.516
E	15.10	15.50	0.594	0.610
E1	7.55	7.75	0.297	0.305
e	10.80	11.30	0.425	0.445
G	20.4	21.10	0.815	0.831
L	14.35	15.60	0.565	0.614
P	4.08	4.17	0.161	0.164
Q	2.70	2.90	0.106	0.114
R	4.60 typ.		0.181 typ.	
Y	15.80	16.50	0.622	0.650

Table 7. D²PAK dimensions



REF.	DIMENSIONS			
	Millimeters		Inches	
	Min.	Max	Min.	Max.
A	4.40	4.60	0.173	0.181
A1	2.49	2.69	0.098	0.106
A2	0.03	0.23	0.001	0.009
B	0.70	0.93	0.027	0.037
B2	1.14	1.70	0.045	0.067
C	0.45	0.60	0.017	0.024
C2	1.23	1.36	0.048	0.054
D	8.95	9.35	0.352	0.368
E	10.00	10.40	0.393	0.409
G	4.88	5.28	0.192	0.208
L	15.00	15.85	0.590	0.624
L2	1.27	1.40	0.050	0.055
L3	1.40	1.75	0.055	0.069
M	2.40	3.20	0.094	0.126
R	0.40 typ.		0.016 typ.	
V2	0°	8°	0°	8°

Figure 11. D²PAK footprint (dimensions in mm)



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

4 Ordering information

Part Number	Marking	Package	Weight	Base qty	Delivery mode
STTH3002W	STTH3002	DO-247	4.4 g	30	Tube
STTH3002PI	STTH3002	DOP3I	4.46 g	30	Tube
STTH3002G	STTH3002	D^2PAK	1.48 g	50	Tube
STTH3002G-TR	STTH3002	D^2PAK	1.48 g	1000	Tape and reel

5 Revision history

Date	Revision	Description of Changes
03-May-2006	1	First issue

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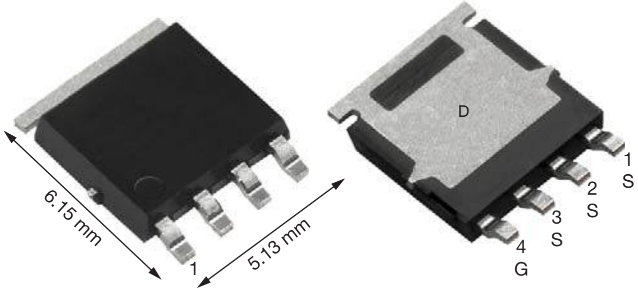
SQJA88EP

Vishay Siliconix

Automotive N-Channel 40 V (D-S) 175 °C MOSFET

PowerPAK® SO-8L Single



Top View Bottom View

FEATURES

- TrenchFET® power MOSFET
- AEC-Q101 qualified
- 100 % R_g and UIS tested
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

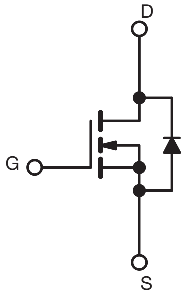
AUTOMOTIVE GRADE

Pb-free

RoHS COMPLIANT

HALOGEN FREE

PRODUCT SUMMARY	
V_{DS} (V)	40
$R_{DS(on)}$ (Ω) at V_{GS} = 10 V	0.0070
$R_{DS(on)}$ (Ω) at V_{GS} = 4.5 V	0.0095
I_D (A) per leg	30
Configuration	Single
Package	PowerPAK SO-8L



N-Channel MOSFET

ABSOLUTE MAXIMUM RATINGS (T_C = 25 °C, unless otherwise noted)

PARAMETER		SYMBOL	LIMIT	UNIT
Drain-source voltage		V_{DS}	40	V
Gate-source voltage		V_{GS}	± 20	
Continuous drain current [a]	T_C = 25 °C	I_D	30	A
	T_C = 125 °C		30	
Continuous source current (diode conduction) [a]		I_S	30	
Pulsed drain current [b]		I_{DM}	110	
Single pulse avalanche current	L = 0.1 mH	I_{AS}	26	
Single pulse avalanche energy		E_{AS}	33.8	mJ
Maximum power dissipation [b]	T_C = 25 °C	P_D	48	W
	T_C = 125 °C		16	
Operating junction and storage temperature range		T_J, T_{stg}	-55 to +175	°C
Soldering recommendations (peak temperature) [d, e]			260	

THERMAL RESISTANCE RATINGS

PARAMETER		SYMBOL	LIMIT	UNIT
Junction-to-ambient	PCB mount [c]	R_{thJA}	70	°C/W
Junction-to-case (drain)		R_{thJC}	3.1	

Notes

a. Package limited

b. Pulse test; pulse width ≤ 300 μs, duty cycle ≤ 2 %

c. When mounted on 1" square PCB (FR4 material)

d. See solder profile (www.vishay.com/doc?73257). The PowerPAK SO-8L is a leadless package. The end of the lead terminal is exposed copper (not plated) as a result of the singulation process in manufacturing. A solder fillet at the exposed copper tip cannot be guaranteed and is not required to ensure adequate bottom side solder interconnection

e. Rework conditions: manual soldering with a soldering iron is not recommended for leadless components

SPECIFICATIONS (T_C = 25 °C, unless otherwise noted)							
PARAMETER	**SYMBOL**	**TEST CONDITIONS**		**MIN.**	**TYP.**	**MAX.**	**UNIT**
Static							
Drain-source breakdown voltage	V_{DS}	V_{GS} = 0 V, I_D = 250 μA		40	-	-	V
Gate-source threshold voltage	$V_{GS(th)}$	V_{DS} = V_{GS}, I_D = 250 μA		1.5	2.0	2.5	
Gate-source leakage	I_{GSS}	V_{DS} = 0 V, V_{GS} = ± 20 V		-	-	± 100	nA
Zero gate voltage drain current	I_{DSS}	V_{GS} = 0 V	V_{DS} = 40 V	-	-	1	μA
		V_{GS} = 0 V	V_{DS} = 40 V, T_J = 125 °C	-	-	50	
		V_{GS} = 0 V	V_{DS} = 40 V, T_J = 175 °C	-	-	150	
On-state drain current [a]	$I_{D(on)}$	V_{GS} = 10 V	$V_{DS} \geq 5$ V	30	-	-	A
Drain-source on-state resistance [a]	$R_{DS(on)}$	V_{GS} = 10 V	I_D = 8 A	-	0.0058	0.0070	Ω
		V_{GS} = 4.5 V	I_D = 6 A	-	0.0079	0.0097	
		V_{GS} = 10 V	I_D = 8 A, T_J = 125 °C	-	-	0.0101	
		V_{GS} = 10 V	I_D = 8 A, T_J = 175 °C	-	-	0.0120	
Forward transconductance [b]	g_{fs}	V_{DS} = 15 V, I_D = 8 A		-	49	-	S
Dynamic [b]							
Input capacitance	C_{iss}	V_{GS} = 0 V	V_{DS} = 25 V, f = 1 MHz	-	1350	1800	pF
Output capacitance	C_{oss}			-	850	1150	
Reverse transfer capacitance	C_{rss}			-	40	55	
Total gate charge [c]	Q_g	V_{GS} = 10 V	V_{DS} = 20 V, I_D = 4 A	-	21	35	nC
Gate-source charge [c]	Q_{gs}			-	5	-	
Gate-drain charge [c]	Q_{gd}			-	3	-	
Gate resistance	R_g	f = 1 MHz		0.6	1.3	2.0	Ω
Turn-on delay time [c]	$t_{d(on)}$	V_{DD} = 20 V, R_L = 5 Ω $I_D \cong 4$ A, V_{GEN} = 10 V, R_g = 1 Ω		-	12	20	ns
Rise time [c]	t_r			-	4	10	
Turn-off delay time [c]	$t_{d(off)}$			-	25	40	
Fall time [c]	t_f			-	6	10	
Source-Drain Diode Ratings and Characteristics [b]							
Pulsed current [a]	I_{SM}			-	-	110	A
Forward voltage	V_{SD}	I_F = 8 A, V_{GS} = 0 V		-	0.81	1.2	V
Body diode reverse recovery time	t_{rr}	I_F = 5 A, di/dt = 100 A/μs		-	44	90	ns
Body diode reverse recovery charge	Q_{rr}			-	42	90	nC
Reverse recovery fall time	t_a			-	22	-	ns
Reverse recovery rise time	t_b			-	22	-	
Body diode peak reverse recovery current	$I_{RM(REC)}$			-	-1.8	-	A

Notes

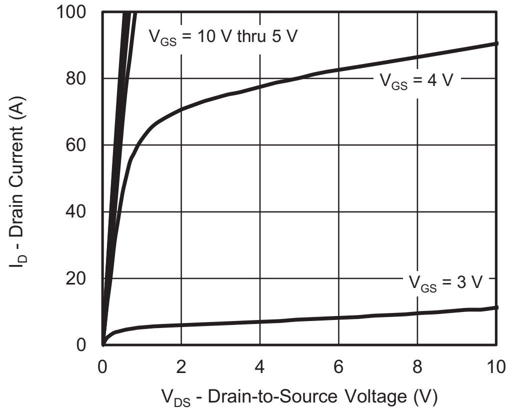
a. Pulse test; pulse width ≤ 300 μs, duty cycle ≤ 2 %

b. Guaranteed by design, not subject to production testing

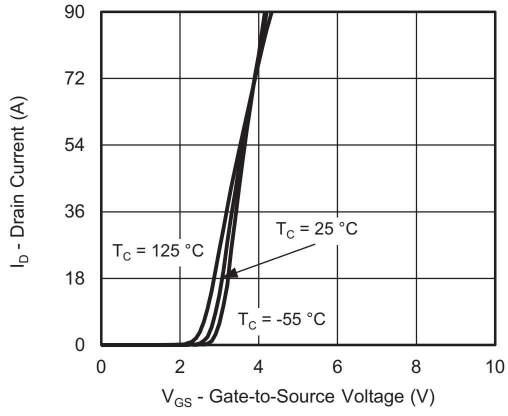
c. Independent of operating temperature

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

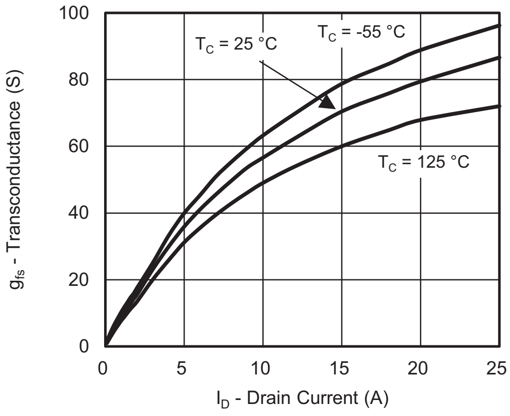
TYPICAL CHARACTERISTICS (T_A = 25 °C, unless otherwise noted)



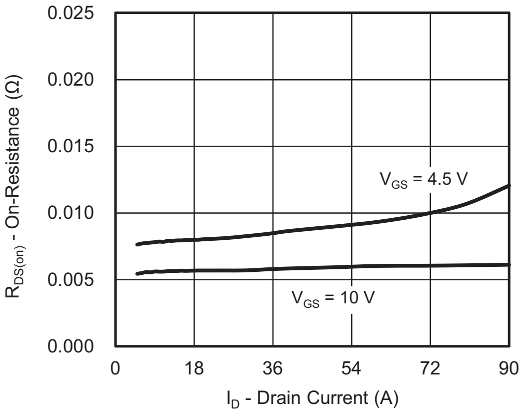
Output Characteristics



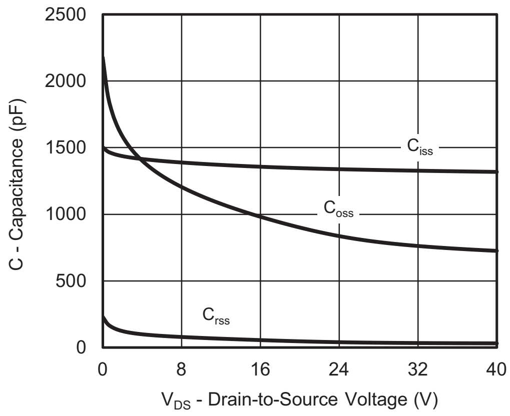
Transfer Characteristics



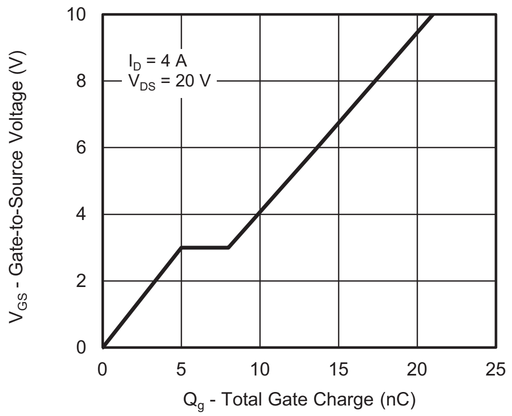
Transconductance



On-Resistance vs. Drain Current

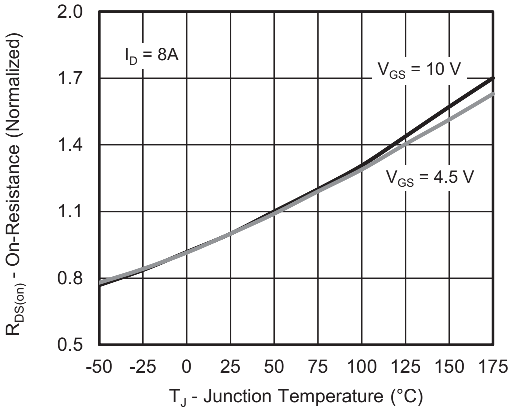


Capacitance

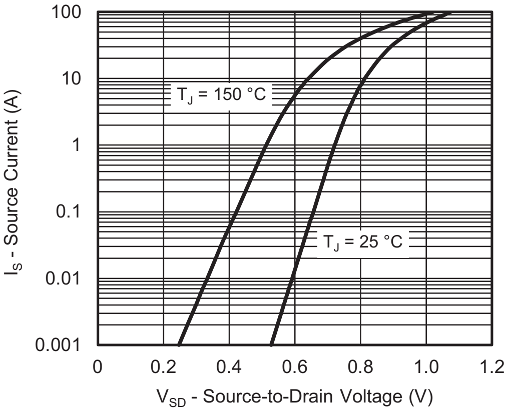


Gate Charge

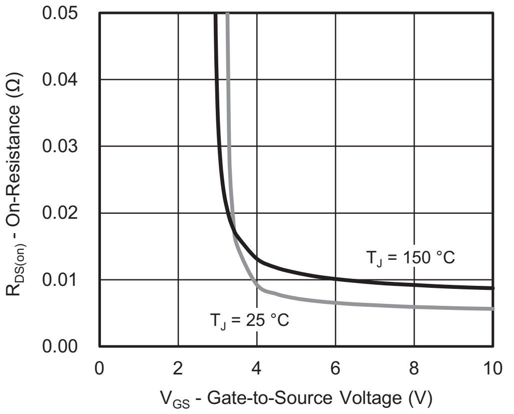
TYPICAL CHARACTERISTICS (T_A = 25 °C, unless otherwise noted)



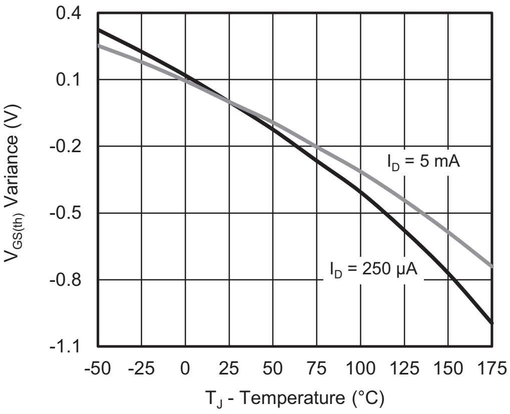
On-Resistance vs. Junction Temperature



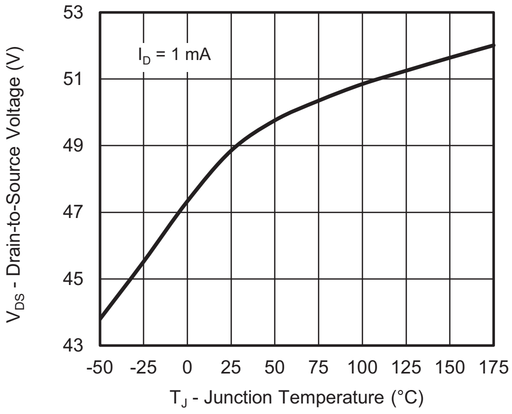
Source Drain Diode Forward Voltage



On-Resistance vs. Gate-to-Source Voltage

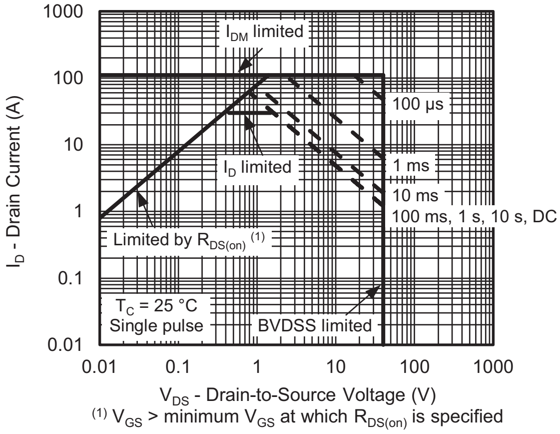


Threshold Voltage



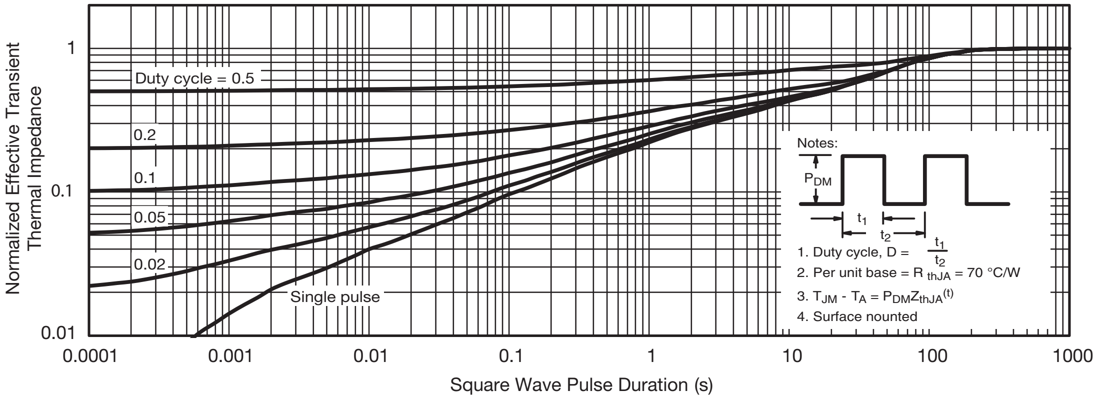
Drain Source Breakdown vs. Junction Temperature

THERMAL RATINGS (T_A = 25 °C, unless otherwise noted)



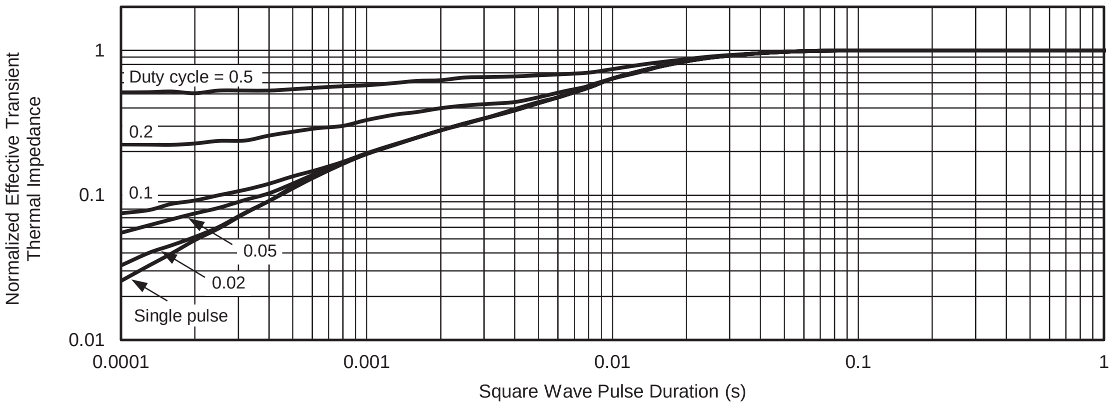
(1) V_{GS} > minimum V_{GS} at which $R_{DS(on)}$ is specified

Safe Operating Area



Normalized Thermal Transient Impedance, Junction-to-Ambient

THERMAL RATINGS (T_A = 25 °C, unless otherwise noted)



Normalized Thermal Transient Impedance, Junction-to-Case

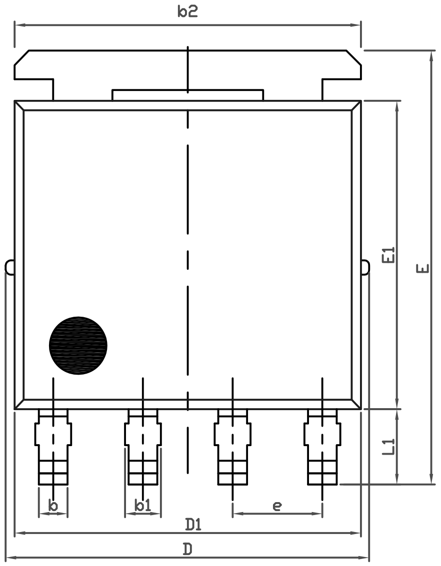
Note

- The characteristics shown in the two graphs
  - Normalized Transient Thermal Impedance Junction-to-Ambient (25 °C)
  - Normalized Transient Thermal Impedance Junction-to-Case (25 °C)

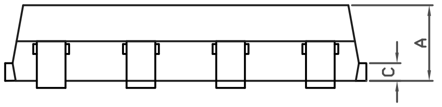
  are given for general guidelines only to enable the user to get a “ball park” indication of part capabilities. The data are extracted from single pulse transient thermal impedance characteristics which are developed from empirical measurements. The latter is valid for the part mounted on printed circuit board - FR4, size 1" x 1" x 0.062", double sided with 2 oz. copper, 100 % on both sides. The part capabilities can widely vary depending on actual application parameters and operating conditions

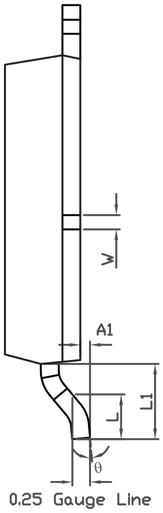
Vishay Siliconix maintains worldwide manufacturing capability. Products may be manufactured at one of several qualified locations. Reliability data for Silicon Technology and Package Reliability represent a composite of all qualified locations. For related documents such as package/tape drawings, part marking, and reliability data, see www.vishay.com/ppg?75564.

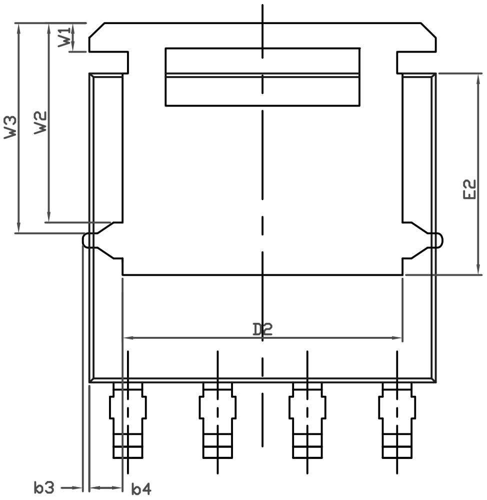
PowerPAK® SO-8L Case Outline 2



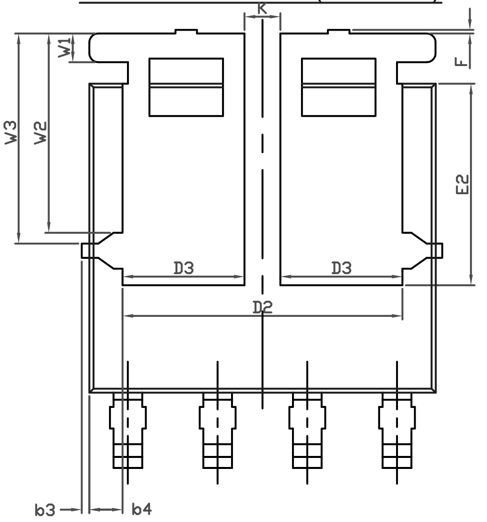
TOPSIDE VIEW







BACKSIDE VIEW(SINGLE)



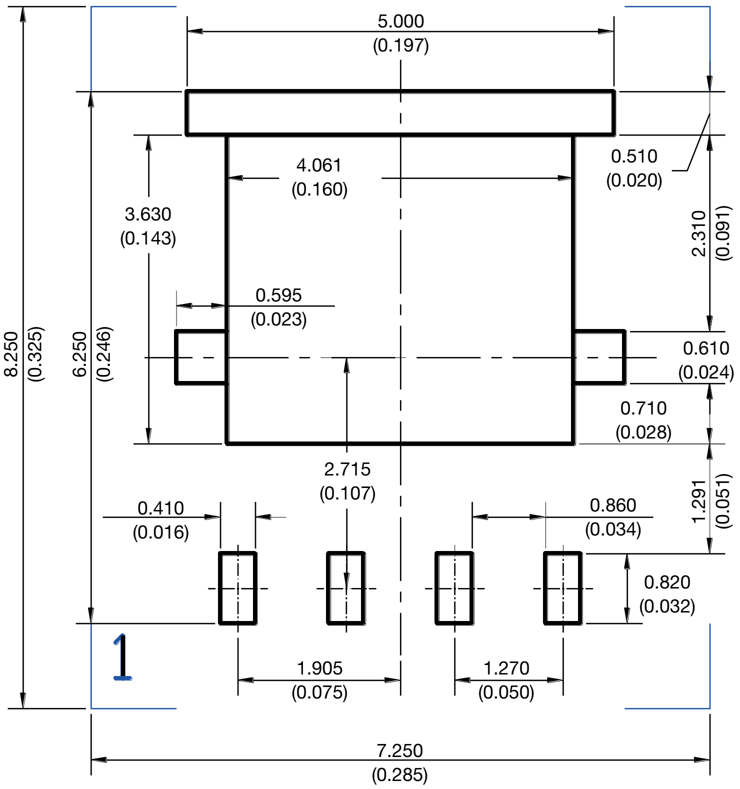
BACKSIDE VIEW(DUAL)

DIM.	MILLIMETERS			INCHES		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	1.00	1.07	1.14	0.039	0.042	0.045
A1	0.00	-	0.127	0.00	-	0.005
b	0.33	0.41	0.48	0.013	0.016	0.019
b1	0.44	0.51	0.58	0.017	0.020	0.023
b2	4.80	4.90	5.00	0.189	0.193	0.197
b3		0.094			0.004	
b4		0.47			0.019	
c	0.20	0.25	0.30	0.008	0.010	0.012
D	5.00	5.13	5.25	0.197	0.202	0.207
D1	4.80	4.90	5.00	0.189	0.193	0.197
D2	3.86	3.96	4.06	0.152	0.156	0.160
D3	1.63	1.73	1.83	0.064	0.068	0.072
e		1.27 BSC			0.050 BSC	
E	6.05	6.15	6.25	0.238	0.242	0.246
E1	4.27	4.37	4.47	0.168	0.172	0.176
E2	2.75	2.85	2.95	0.108	0.112	0.116
F	-	-	0.15	-	-	0.006
L	0.62	0.72	0.82	0.024	0.028	0.032
L1	0.92	1.07	1.22	0.036	0.042	0.048
K		0.51			0.020	
W		0.23			0.009	
W1		0.41			0.016	
W2		2.82			0.111	
W3		2.96			0.117	
q	0°	-	10°	0°	-	10°
ECN: S19-0643-Rev. B, 05-Aug-2019 DWG: 6044						

Note

- Millimeters will gover

RECOMMENDED MINIMUM PAD FOR PowerPAK® SO-8L SINGLE



Recommended Minimum Pads
Dimensions in mm (inches)

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Unitrode Products
from Texas Instruments

application
INFO
available

UC1825
UC2825
UC3825

High Speed PWM Controller

FEATURES

- Compatible with Voltage or Current Mode Topologies
- Practical Operation Switching Frequencies to 1MHz
- 50ns Propagation Delay to Output
- High Current Dual Totem Pole Outputs (1.5A Peak)
- Wide Bandwidth Error Amplifier
- Fully Latched Logic with Double Pulse Suppression
- Pulse-by-Pulse Current Limiting
- Soft Start / Max. Duty Cycle Control
- Under-Voltage Lockout with Hysteresis
- Low Start Up Current (1.1mA)

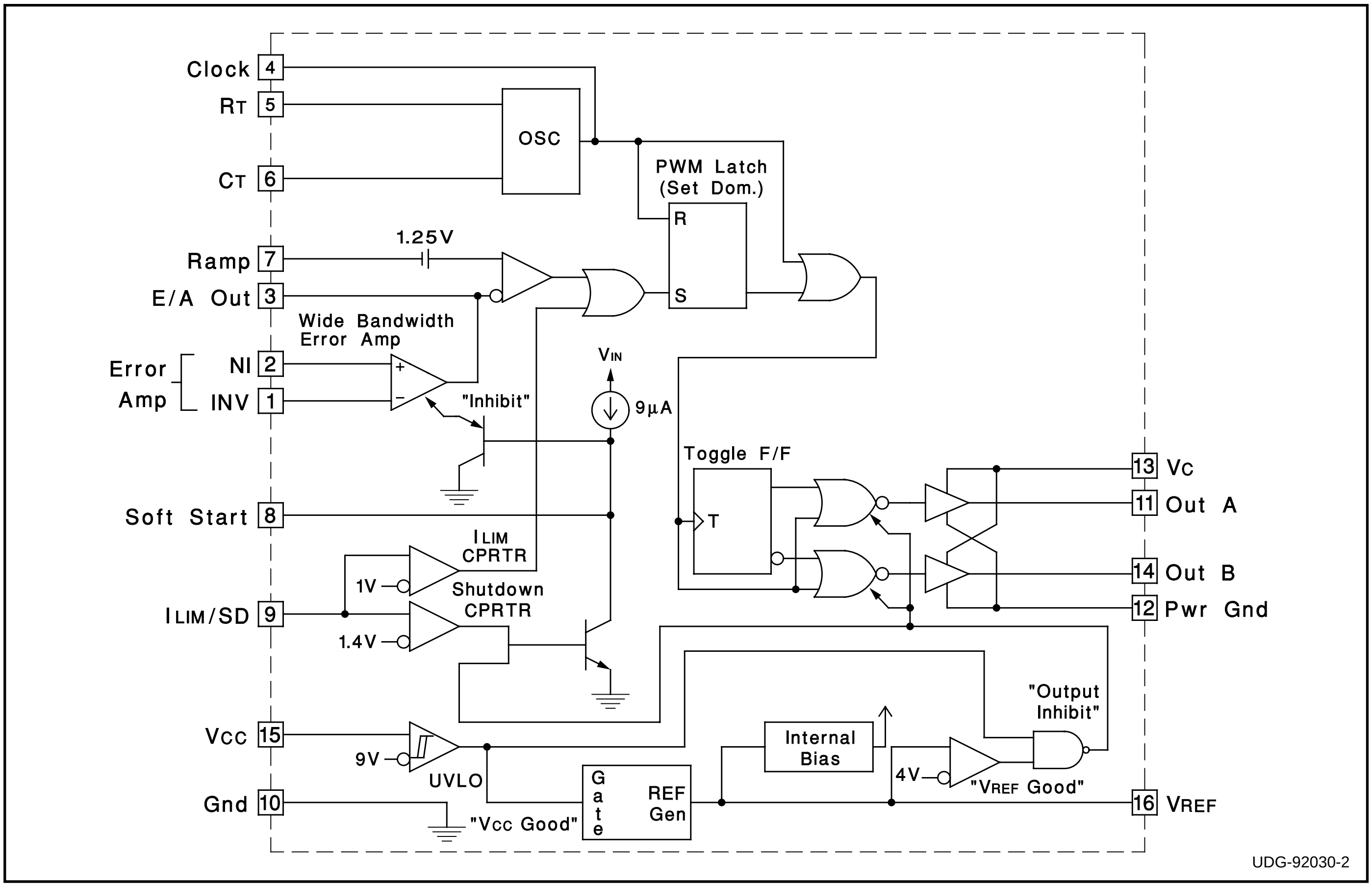
DESCRIPTION

The UC1825 family of PWM control ICs is optimized for high frequency switched mode power supply applications. Particular care was given to minimizing propagation delays through the comparators and logic circuitry while maximizing bandwidth and slew rate of the error amplifier. This controller is designed for use in either current-mode or voltage mode systems with the capability for input voltage feed-forward.

Protection circuitry includes a current limit comparator with a 1V threshold, a TTL compatible shutdown port, and a soft start pin which will double as a maximum duty cycle clamp. The logic is fully latched to provide jitter free operation and prohibit multiple pulses at an output. An under-voltage lockout section with 800mV of hysteresis assures low start up current. During under-voltage lockout, the outputs are high impedance.

These devices feature totem pole outputs designed to source and sink high peak currents from capacitive loads, such as the gate of a power MOSFET. The on state is designed as a high level.

BLOCK DIAGRAM



UDG-92030-2

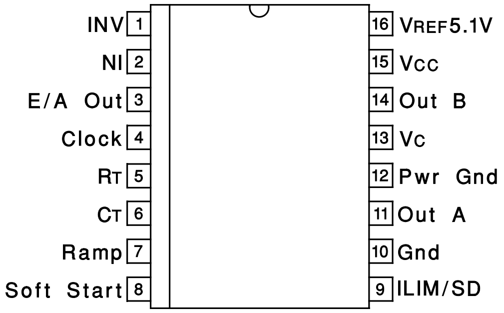
ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage (Pins 13, 15)	30V
Output Current, Source or Sink (Pins 11, 14)	
DC	0.5A
Pulse (0.5 s)	2.0A
Analog Inputs	
(Pins 1, 2, 7)	-0.3V to 7V
(Pin 8, 9)	-0.3V to 6V
Clock Output Current (Pin 4)	-5mA
Error Amplifier Output Current (Pin 3)	5mA
Soft Start Sink Current (Pin 8)	20mA
Oscillator Charging Current (Pin 5)	-5mA
Power Dissipation	1W
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

Note 1: All voltages are with respect to GND (Pin 10); all currents are positive into, negative out of part; pin numbers refer to DIL-16 package.

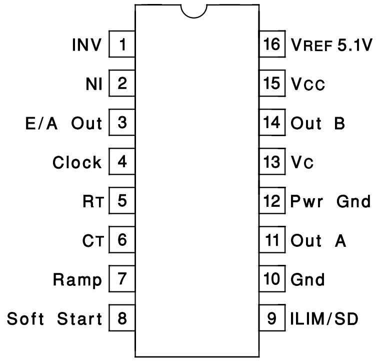
Note 3: Consult Unitrode Integrated Circuit Databook for thermal limitations and considerations of package.

SOIC-16 (Top View)
DW Package

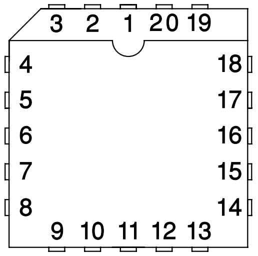


CONNECTION DIAGRAMS

DIL-16 (Top View)
J or N Package



PLCC-20 & LCC-20
(Top View)
Q & L Packages



PACKAGE PIN FUNCTION	
FUNCTION	**PIN**
N/C	1
INV	2
NI	3
E/A Out	4
Clock	5
N/C	6
RT	7
CT	8
Ramp	9
Soft Start	10
N/C	11
ILIM/SD	12
Gnd	13
Out A	14
Pwr Gnd	15
N/C	16
VC	17
Out B	18
VCC	19
VREF 5.1V	20

THERMAL RATINGS TABLE

Package	Θ_{JA}	Θ_{JC}
DIL-16J	80-120	28(2)
DIL-16N	90(1)	45
PLCC-20	43-75(1)	34
LCC-20	70-80	20(2)
SOIC-16	50-120(1)	35

(1) Specified Θ_{JA} (junction to ambient) is for devices mounted to 5in^2 FR4 PC board with one ounce copper where noted. When resistance range is given, lower values are for 5in^2 aluminum PC board. Test PWB was 0.062in thick and typically used 0.635mm trace widths for power packages and 1.3mm trace widths for non-power packages with 100 x 100 mil probe land area at the end of each trace.

(2) Θ_{JC} data values stated were derived from MIL-STD-1835B. MIL-STD-1835B states that the baseline values shown are worst case (mean +2s) for a 60 x 60mil microcircuit device silicon die and applicable for devices with die sizes up to 14400 square mils. For device die sizes greater than 14400 square mils use the following values; dual-in-line, 11°C/W; flat pack 10°C/W; pin grid array, 10°C/W.

ELECTRICAL CHARACTERISTICS: Unless otherwise stated, these specifications apply for , R_T = 3.65k, C_T = 1nF, V_{CC} = 15V, -55°C<T_A<125°C for the UC1825, –40°C<T_A<85°C for the UC2825, and 0°C<T_A<70°C for the UC3825, T_A=T_O.

PARAMETERS	TEST CONDITIONS	UC1825 UC2825			UC3825			
		MIN	TOP	MAX	MIN	TOP	MAX	UNITS
Reference Section								
Output Voltage	T_O = 25°C, I_O = 1mA	5.05	5.10	5.15	5.00	5.10	5.20	V
Line Regulation	10V < V_{CC} < 30V		2	20		2	20	mV
Load Regulation	1mA < I_O < 10mA		5	20		5	20	mV
Temperature Stability*	T_{MIN} < T_A < T_{MAX}		0.2	0.4		0.2	0.4	mV/°C
Total Output Variation*	Line, Load, Temperature	5.00		5.20	4.95		5.25	V
Output Noise Voltage*	10Hz < f < 10kHz		50			50		µV
Long Term Stability*	T_J = 125°C, 1000hrs.		5	25		5	25	mV
Short Circuit Current	V_{REF} = 0V	-15	-50	-100	-15	-50	-100	mA
Oscillator Section								
Initial Accuracy*	T_J = 2°C	360	400	440	360	400	440	kHz
Voltage Stability*	10V < V_{CC} < 30V		0.2	2		0.2	2	%
Temperature Stability*	T_{MIN} < T_A < T_{MAX}		5			5		%
Total Variation*	Line, Temperature	340		460	340		460	kHz
Oscillator Section (cont.)								
Clock Out High		3.9	4.5		3.9	4.5		V
Clock Out Low			2.3	2.9		2.3	2.9	V
Ramp Peak*****		2.6	2.8	3.0	2.6	2.8	3.0	V
Ramp Valley*****		0.7	1.0	1.25	0.7	1.0	1.25	V
Ramp Valley to Peak*****		1.6	1.8	2.0	1.6	1.8	2.0	V
Error Amplifier Section								
Input Offset Voltage				10			15	mV
Input Bias Current			0.6	3		0.6	3	µA
Input Offset Current			0.1	1		0.1	1	µA
Open Loop Gain	1V < V_O < 4V	60	95		60	95		dB
CMRR	1.5V < V_{CM} < 5.5V	75	95		75	95		dB
PSRR	10V < V_{CC} < 30V	85	110		85	110		dB
Output Sink Current	$V_{PIN\ 3}$ = 1V	1	2.5		1	2.5		mA
Output Source Current	$V_{PIN\ 3}$ = 4V	-0.5	-1.3		-0.5	-1.3		mA
Output High Voltage	$I_{PIN\ 3}$ = -0.5mA	4.0	4.7	5.0	4.0	4.7	5.0	V
Output Low Voltage	$I_{PIN\ 3}$ = 1mA	0	0 .5	1.0	0	0.5	1.0	V
Unity Gain Bandwidth*****		3	5.5		3	5.5		MHz
Slew Rate*****		6	12		6	12		V/µs

ELECTRICAL CHARACTERISTICS: Unless otherwise stated, these specifications apply for , $R_T = 3.65k$, $C_T = 1nF$, $V_{CC} = 15V$, -55°C<T_A<125°C for the UC1825, –40°C<T_A<85°C for the UC2825, and 0°C<T_A<70°C for the UC3825, $T_A=T_J$.

PARAMETERS	TEST CONDITIONS	UC1825 UC2825			UC3825			
		MIN	TOP	MAX	MIN	TOP	MAX	UNITS
PWM Comparator Section								
Pin 7 Bias Current	$V_{PIN\ 7} = 0V$		-1	-5		-1	-5	µA
Duty Cycle Range		0		80	0		85	%
Pin 3 Zero DC Threshold	$V_{PIN\ 7} = 0V$	1.1	1.25		1.1	1.25		V
Delay to Output*			50	80		50	80	ns
Soft-Start Section								
Charge Current	$V_{PIN\ 8} = 0.5V$	3	9	20	3	9	20	µA
Discharge Current	$V_{PIN\ 8} = 1V$	1			1			mA
Current Limit / Shutdown Section								
Pin 9 Bias Current	$0 < V_{PIN\ 9} < 4V$			15			10	µA
Current Limit Threshold		0.9	1.0	1.1	0.9	1.0	1.1	V
Shutdown Threshold		1.25	1.40	1.55	1.25	1.40	1.55	V
Delay to Output			50	80		50	80	ns
Output Section								
Output Low Level	$I_{OUT} = 20mA$		0.25	0.40		0.25	0.40	V
	$I_{OUT} = 200mA$		1.2	2.2		1.2	2.2	V
Output High Level	$I_{OUT} = -20mA$	13.0	13.5		13.0	13.5		V
	$I_{OUT} = -200mA$	12.0	13.0		12.0	13.0		V
Collector Leakage	$V_C = 30V$		100	500		10	500	µA
Rise/Fall Time*	CL = 1nF		30	60		30	60	ns
Under-Voltage Lockout Section								
Start Threshold		8.8	9.2	9.6	8.8	9.2	9.6	V
UVLO Hysteresis		0.4	0.8	1.2	0.4	0.8	1.2	V
Supply Current Section								
Start Up Current	$V_{CC} = 8V$		1.1	2.5		1.1	2.5	mA
ICC	$V_{PIN\ 1}$, $V_{PIN\ 7}$, $V_{PIN\ 9} = 0V$; $V_{PIN\ 2} = 1V$		22	33		22	33	mA

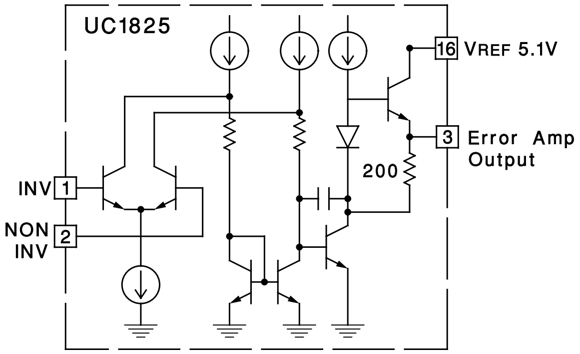
* This parameter not 100% tested in production but guaranteed by design.

Printed Circuit Board Layout Considerations

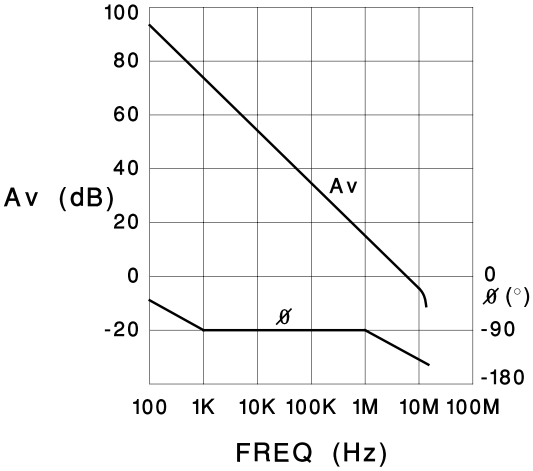
High speed circuits demand careful attention to layout and component placement. To assure proper performance of the UC1825 follow these rules: 1) Use a ground plane. 2) Damp or clamp parasitic inductive kick energy from the gate of driven MOSFETs. Do not allow the output pins to ring below ground. A series gate resistor or a shunt 1 Amp Schottky diode at the output pin will serve this purpose. 3) Bypass V_{CC}, V_C, and V_{REF}. Use 0.1µF monolithic ceramic capacitors with low equivalent series inductance. Allow less than 1 cm of total lead length for each capacitor between the bypassed pin and the ground plane. 4) Treat the timing capacitor, CT, like a bypass capacitor.

Error Amplifier Circuit

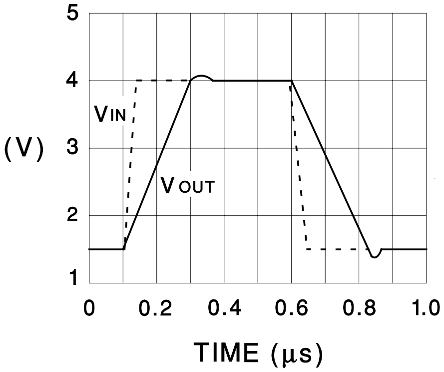
Simplified Schematic



Open Loop Frequency Response

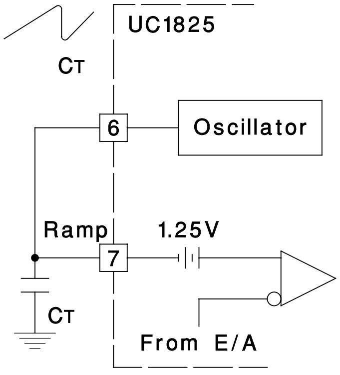


Unity Gain Slew Rate

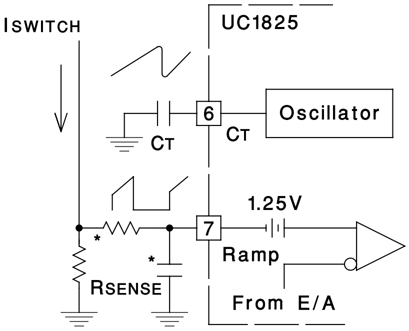


PWM Applications

Conventional (Voltage Mode)

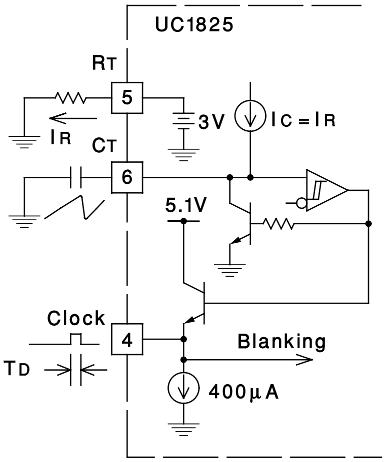


Current-Mode

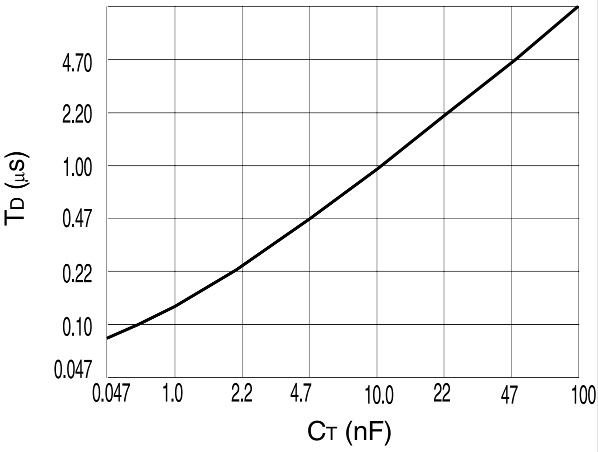


* A small filter may be required to suppress switch noise.

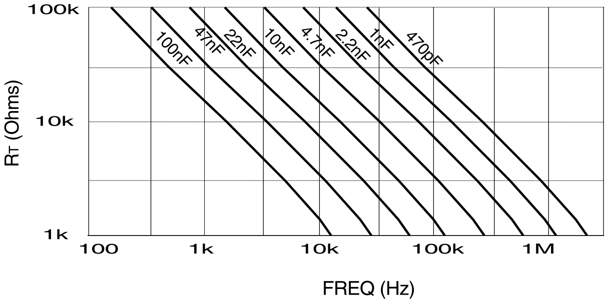
Oscillator Circuit



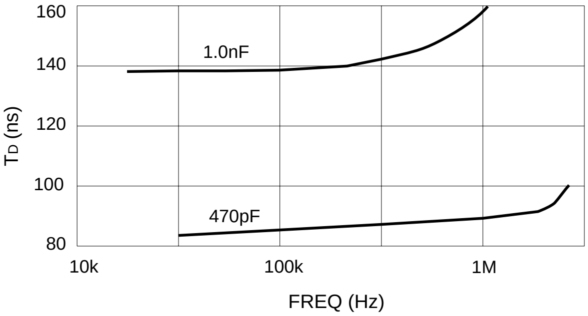
Deadtime vs C_T (3k R_T 100k)



Timing Resistance vs Frequency

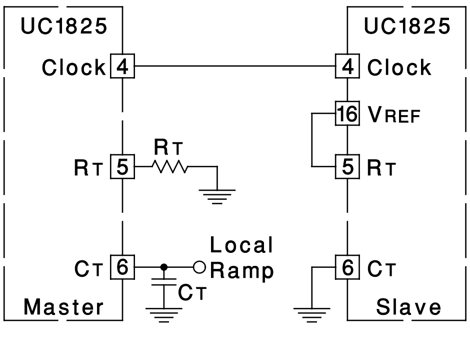


Deadtime vs Frequency

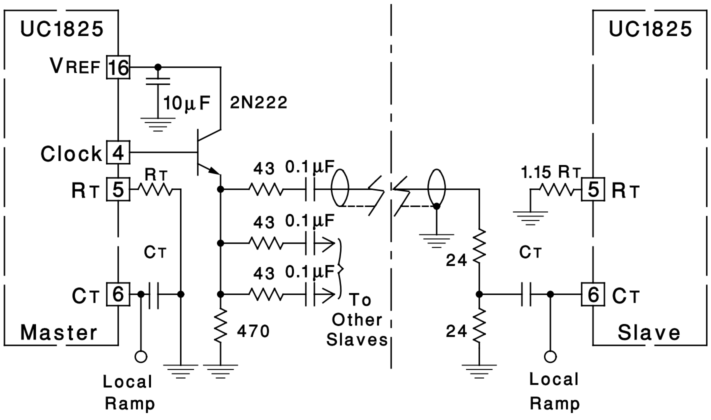


Synchronized Operation

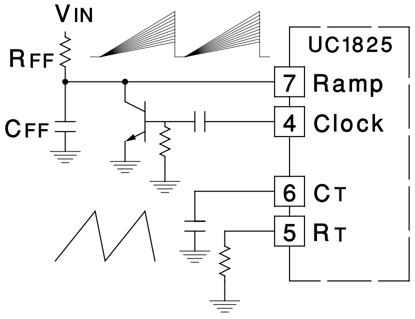
Two Units in Close Proximity



Generalized Synchronization

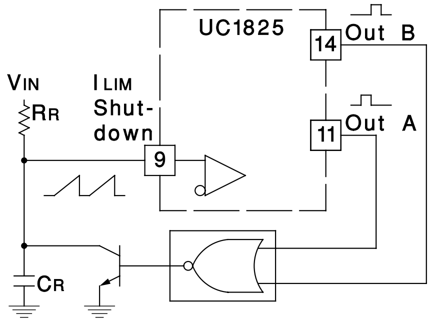


Forward Technique for Off-Line Voltage Mode Application



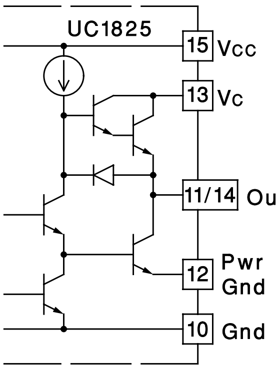
Constant Volt-Second Clamp Circuit

The circuit shown here will achieve a constant volt-second product clamp over varying input voltages. The ramp generator components, R_T and C_R are chosen so that the ramp at Pin 9 crosses the 1V threshold at the same time the desired maximum volt-second product is reached. The delay through the functional nor block must be such that the ramp capacitor can be completely discharged during the minimum deadtime.

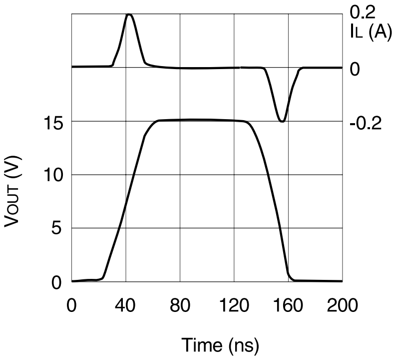


Output Section

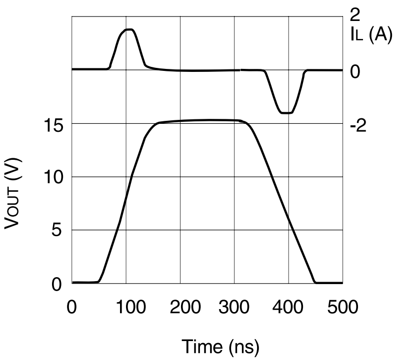
Simplified Schematic



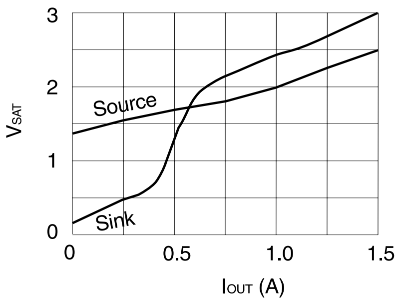
Rise/Fall Time (C_L=1nF)



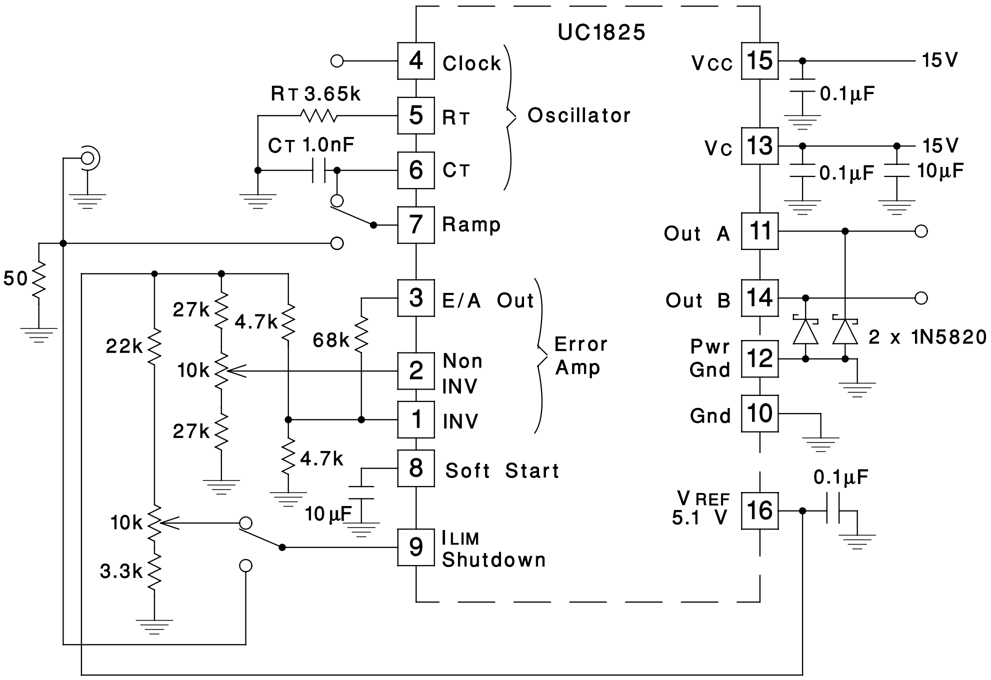
Rise/Fall Time (C_L=10nF)



Saturation Curves



Open Loop Laboratory Test Fixture

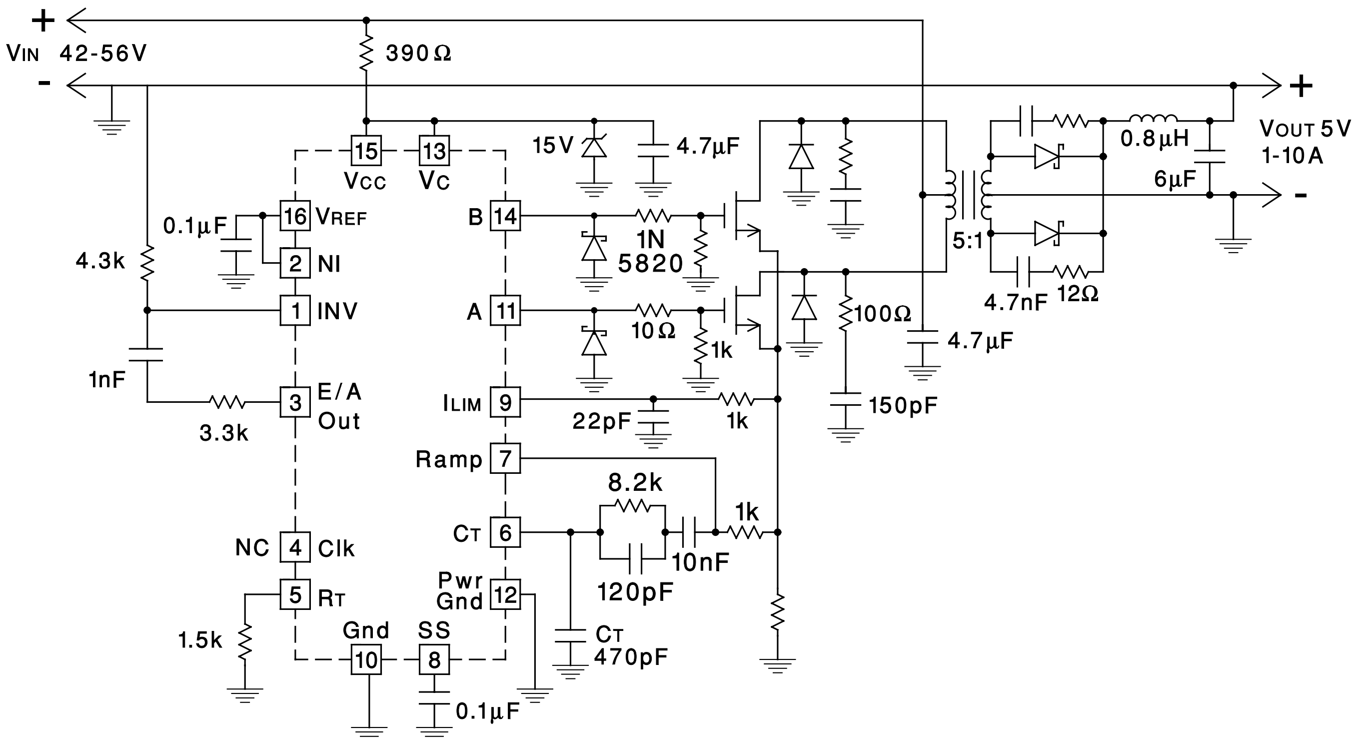


UDG-92032-2

This test fixture is useful for exercising many of the UC1825's functions and measuring their specifications.

As with any wideband circuit, careful grounding and bypass procedures should be followed. The use of a ground plane is highly recommended.

Design Example: 50W, 48V to 5V DC to DC Converter - 1.5MHz Clock Frequency



UDG-92033-3

PACKAGING INFORMATION

Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
5962-87681012A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	Level-NC-NC-NC
5962-8768101EA	ACTIVE	CDIP	J	16	1	TBD	A42 SNPB	Level-NC-NC-NC
5962-8768101QFA	ACTIVE	CFP	W	16	1	TBD	A42 SNPB	Level-NC-NC-NC
5962-8768101V2A	ACTIVE	LCCC	FK	20	1	TBD	Call TI	Level-NC-NC-NC
5962-8768101VEA	ACTIVE	CDIP	J	16	1	TBD	Call TI	Level-NC-NC-NC
UC1825J	ACTIVE	CDIP	J	16	1	TBD	A42 SNPB	Level-NC-NC-NC
UC1825J883B	ACTIVE	CDIP	J	16	1	TBD	A42 SNPB	Level-NC-NC-NC
UC1825JQMLV	ACTIVE	CDIP	J	16		TBD	Call TI	Call TI
UC1825L	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	Level-NC-NC-NC
UC1825L883B	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	Level-NC-NC-NC
UC1825LQMLV	ACTIVE	LCCC	FK	20		TBD	Call TI	Call TI
UC1825W883B	ACTIVE	CFP	W	16	1	TBD	A42 SNPB	Level-NC-NC-NC
UC2825DW	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
UC2825DW/1	PREVIEW	SOIC	DW	16		Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
UC2825DWTR	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
UC2825DWTRG4	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
UC2825J	ACTIVE	CDIP	J	16	1	TBD	A42 SNPB	Level-NC-NC-NC
UC2825N	ACTIVE	PDIP	N	16	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-NC-NC-NC
UC2825NG4	ACTIVE	PDIP	N	16	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-NA-NA-NA
UC2825Q	ACTIVE	PLCC	FN	20	46	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR
UC2825QTR	ACTIVE	PLCC	FN	20	1000	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR
UC3825DW	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
UC3825DWG4	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
UC3825DWTR	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
UC3825DWTRG4	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
UC3825J	ACTIVE	CDIP	J	16	1	TBD	A42 SNPB	Level-NC-NC-NC
UC3825N	ACTIVE	PDIP	N	16	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-NC-NC-NC
UC3825NG4	ACTIVE	PDIP	N	16	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-NC-NC-NC
UC3825Q	ACTIVE	PLCC	FN	20	46	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR
UC3825QTR	ACTIVE	PLCC	FN	20	1000	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR

(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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS) or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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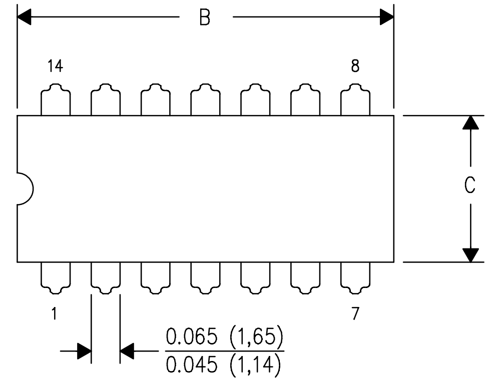
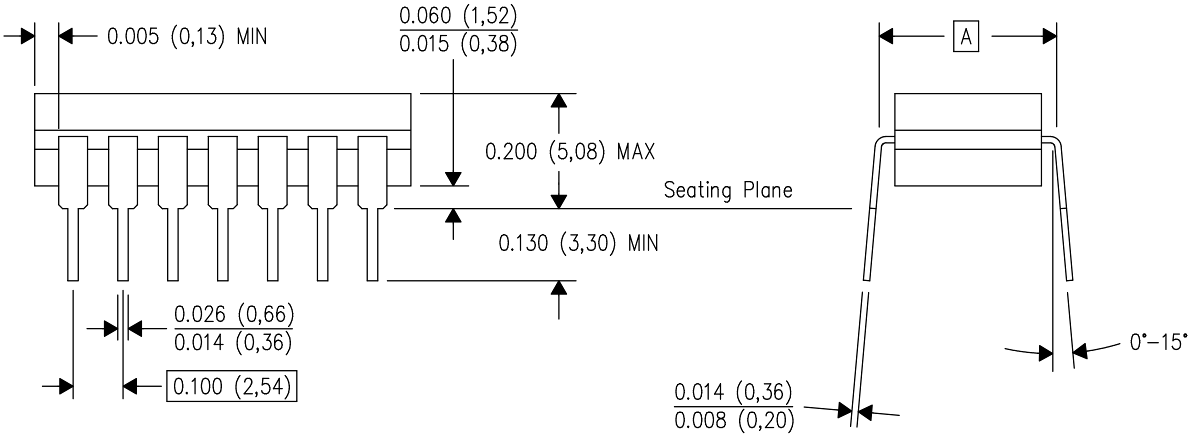
J (R–GDIP–T**) CERAMIC DUAL IN–LINE PACKAGE

14 LEADS SHOWN



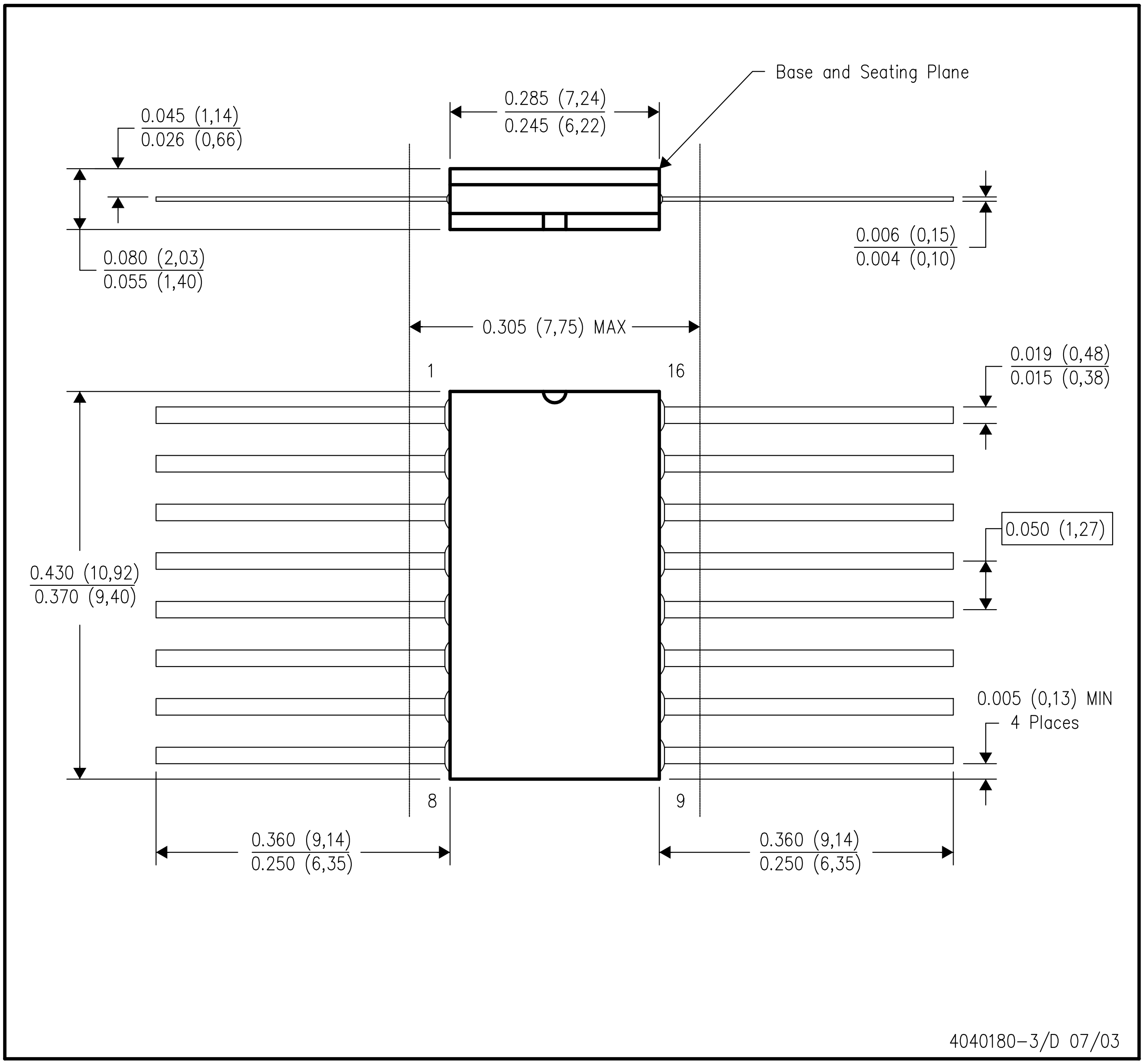
PINS ** / DIM	14	16	18	20
A	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC
B MAX	0.785 (19,94)	.840 (21,34)	0.960 (24,38)	1.060 (26,92)
B MIN	——	——	——	——
C MAX	0.300 (7,62)	0.300 (7,62)	0.310 (7,87)	0.300 (7,62)
C MIN	0.245 (6,22)	0.245 (6,22)	0.220 (5,59)	0.245 (6,22)



4040083/F 03/03

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package is hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
- E. Falls within MIL STD 1835 GDIP1–T14, GDIP1–T16, GDIP1–T18 and GDIP1–T20.

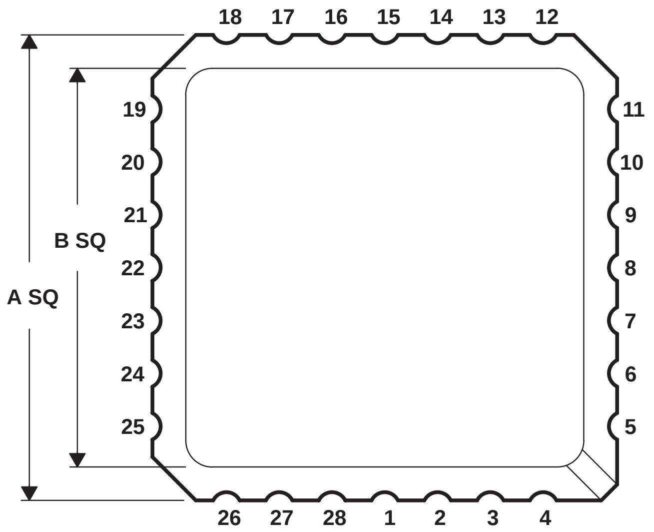
W (R–GDFP–F16) CERAMIC DUAL FLATPACK



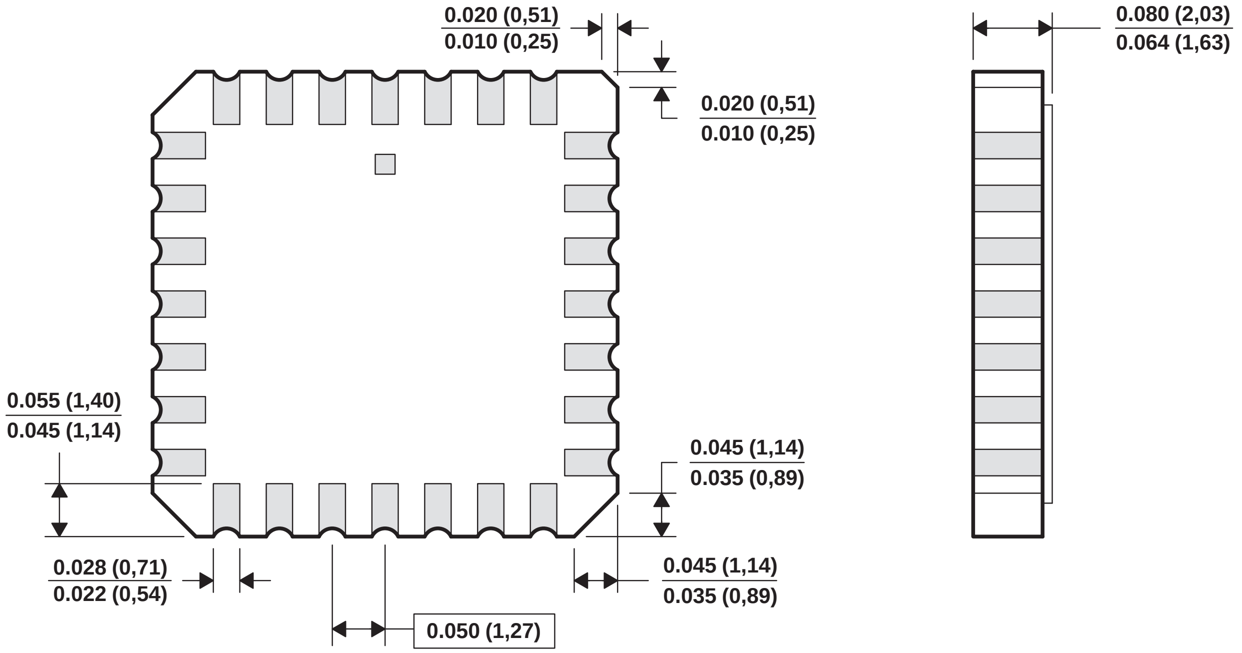
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a ceramic lid using glass frit.
D. Index point is provided on cap for terminal identification only.
E. Falls within MIL STD 1835 GDFP1–F16 and JEDEC MO–092AC

FK (S-CQCC-N**) LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.739 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)

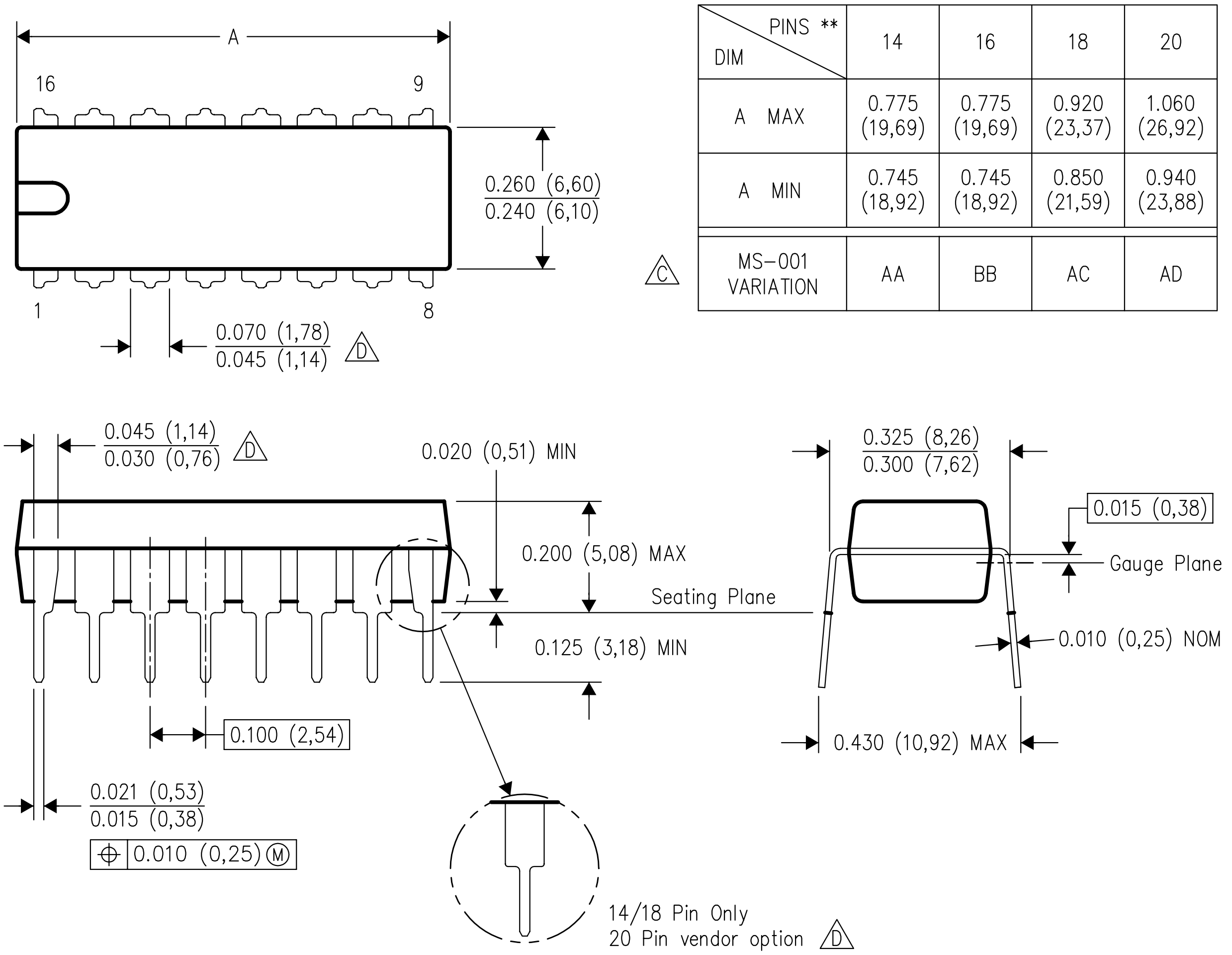


4040140 / D 10/96

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a metal lid.
- D. The terminals are gold plated.
- E. Falls within JEDEC MS-004

N (R–PDIP–T**) PLASTIC DUAL–IN–LINE PACKAGE

16 PINS SHOWN



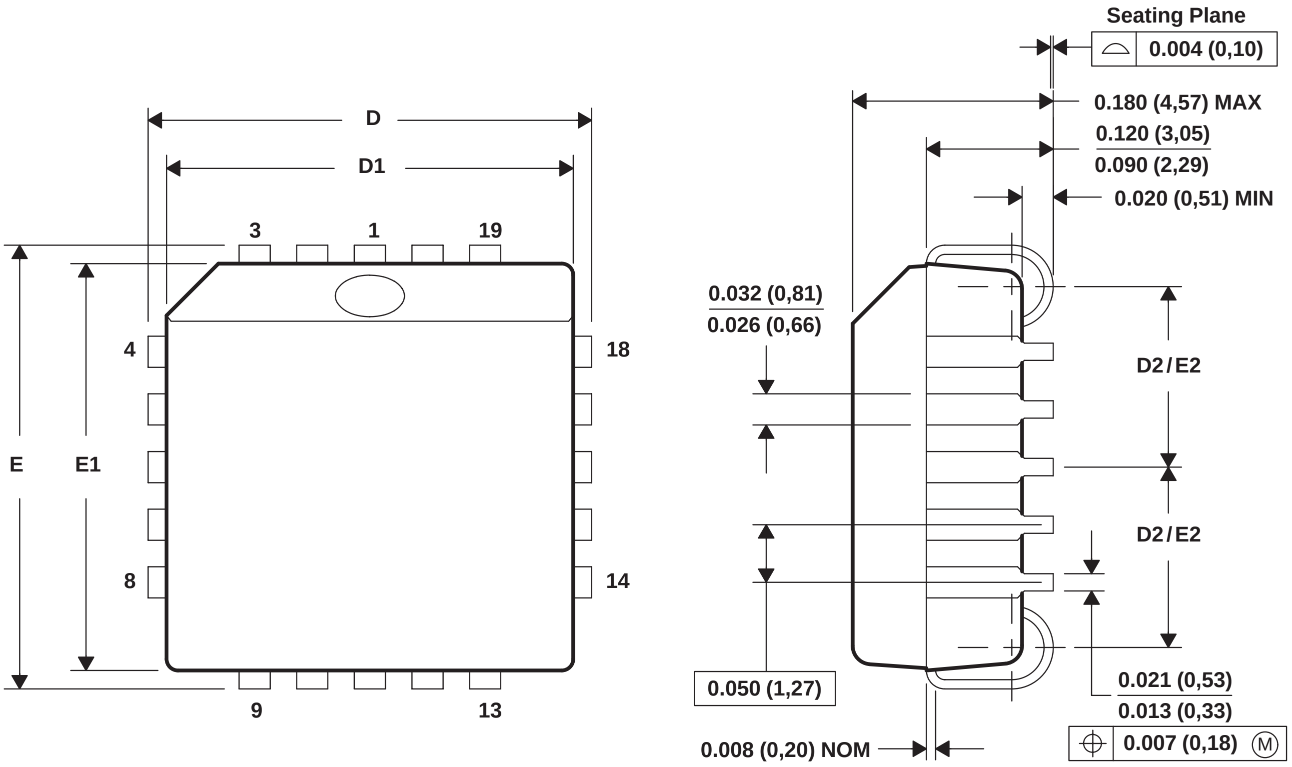
DIM \ PINS **	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS–001 VARIATION	AA	BB	AC	AD

4040049/E 12/2002

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Falls within JEDEC MS–001, except 18 and 20 pin minimum body length (Dim A).
- D. The 20 pin end lead shoulder width is a vendor option, either half or full width.

FN (S-PQCC-J**) PLASTIC J-LEADED CHIP CARRIER

20 PIN SHOWN

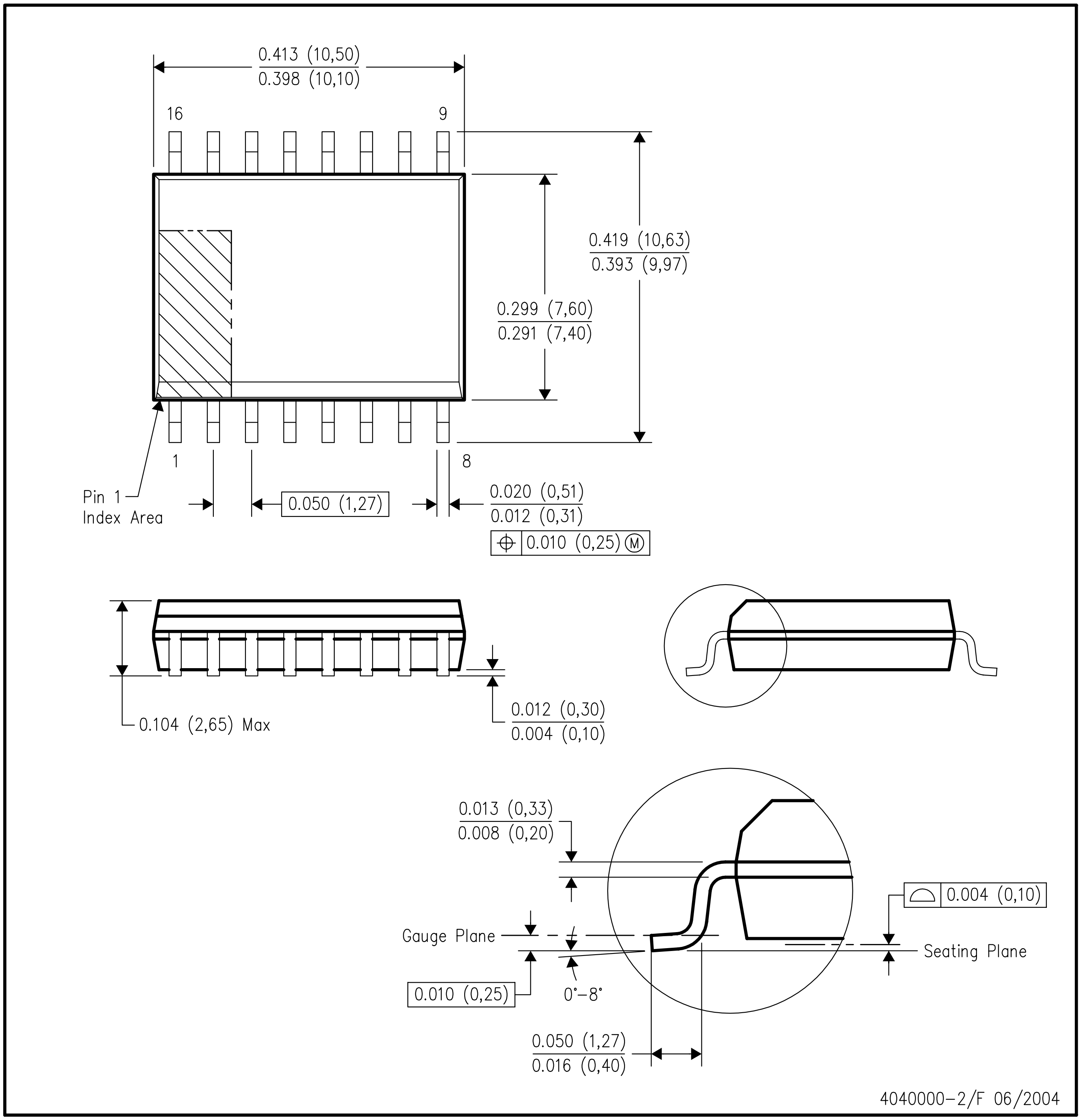


NO. OF PINS **	D / E		D1 / E1		D2 / E2	
	MIN	MAX	MIN	MAX	MIN	MAX
20	0.385 (9,78)	0.395 (10,03)	0.350 (8,89)	0.356 (9,04)	0.141 (3,58)	0.169 (4,29)
28	0.485 (12,32)	0.495 (12,57)	0.450 (11,43)	0.456 (11,58)	0.191 (4,85)	0.219 (5,56)
44	0.685 (17,40)	0.695 (17,65)	0.650 (16,51)	0.656 (16,66)	0.291 (7,39)	0.319 (8,10)
52	0.785 (19,94)	0.795 (20,19)	0.750 (19,05)	0.756 (19,20)	0.341 (8,66)	0.369 (9,37)
68	0.985 (25,02)	0.995 (25,27)	0.950 (24,13)	0.958 (24,33)	0.441 (11,20)	0.469 (11,91)
84	1.185 (30,10)	1.195 (30,35)	1.150 (29,21)	1.158 (29,41)	0.541 (13,74)	0.569 (14,45)

4040005 / B 03/95

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Falls within JEDEC MS-018

DW (R-PDSO-G16) PLASTIC SMALL-OUTLINE PACKAGE



NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
- D. Falls within JEDEC MS-013 variation AA.

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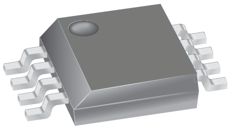
ACS712

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

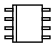
Features and Benefits

- 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
- 50 kHz bandwidth
- Total output error 1.5% at T_A = 25°C, and 4% at –40°C to 85°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

Package: 8 pin SOIC (suffix LC)



Approximate Scale 1:1



Description

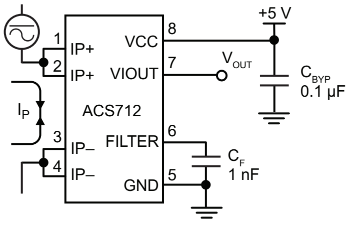
The Allegro® ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, automotive, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switched-mode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

Continued on the next page…

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_{OP} (°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.

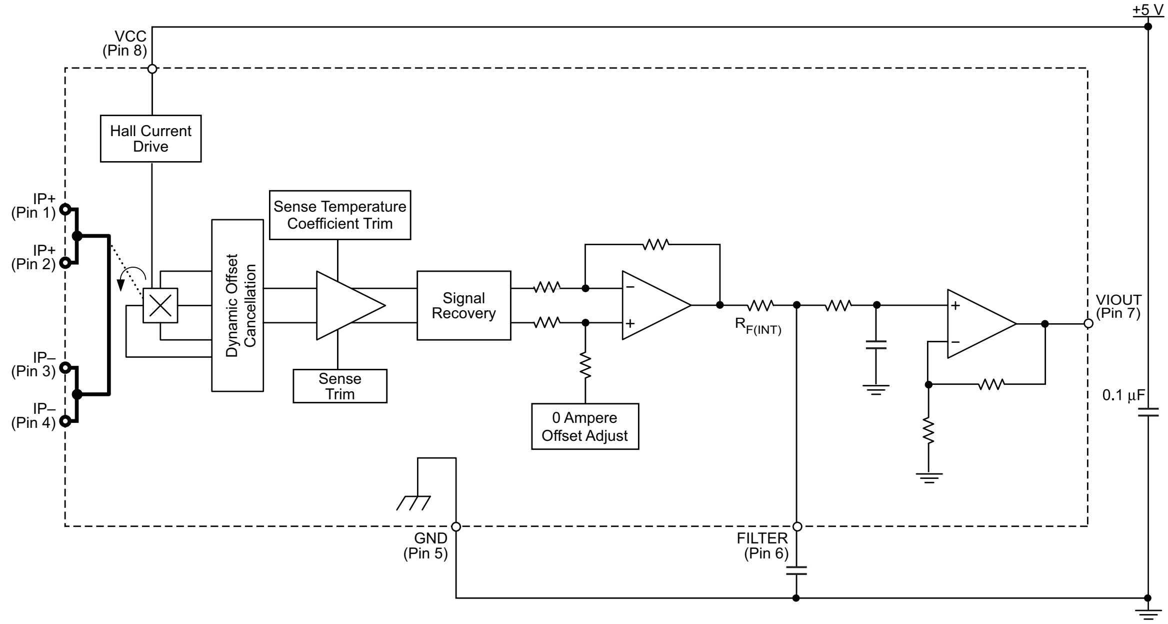
Absolute Maximum Ratings

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
Output Current Source	$I_{IOUT(Source)}$		3	mA
Output Current Sink	$I_{IOUT(Sink)}$		10	mA
Overcurrent Transient Tolerance	I_P	100 total pulses, 250 ms duration each, applied at a rate of 1 pulse every 100 seconds.	60	A
Maximum Transient Sensed Current	I_R(max)	Junction Temperature, $T_J < T_J$(max)	60	A
Nominal Operating Ambient Temperature	T_A	Range E	–40 to 85	ºC
Maximum Junction	T_J(max)		165	ºC
Storage Temperature	T_{stg}		–65 to 170	ºC

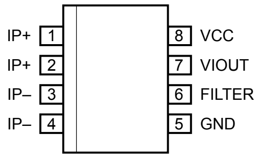
TÜV America
Certificate Number:
U8V 06 05 54214 010

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_{OP}, 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	6	8	11	mA
Output Zener Clamp Voltage	V_Z	I_{CC} = 11 mA, T_A = 25°C	6	8.3	–	V
Output Resistance	R_{IOUT}	I_{IOUT} = 1.2 mA, T_A=25°C	–	1	2	Ω
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
RMS Isolation Voltage	V_{ISORMS}	Pins 1-4 and 5-8; 60 Hz, 1 minute, T_A=25°C	2100	–	–	V
DC Isolation Voltage	V_{ISODC}	Pins 1-4 and 5-8; 1 minute, T_A=25°C	–	5000	–	V
Propagation Time	t_{PROP}	I_P = I_P(max), T_A = 25°C, C_{OUT} = open	–	3	–	μs
Response Time	$t_{RESPONSE}$	I_P = I_P(max), T_A = 25°C, C_{OUT} = open	–	7	–	μs
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	50	–	–	kHz
Nonlinearity	E_{LIN}	Over full range of I_P	–	±1	±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
Magnetic Offset Error	V_{ERROM}	I_P = 0 A, after excursion of 5 A	–	0	–	mV
Clamping Voltage	V_{CH}		Typ. –110	V_{CC} × 0.9375	Typ. +110	mV
	V_{CL}		Typ. –110	V_{CC} × 0.0625	Typ. +110	mV
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_{OP}, 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_{OP}	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 mm^2 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.

x05A PERFORMANCE CHARACTERISTICS T_{OP} = –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[2]	$Sens_{TA}$	Over full range of I_P, T_A = 25°C	–	185	–	mV/A
	$Sens_{TOP}$	Over full range of I_P	178	–	193	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A= 25°C, 185 mV/A programmed Sensitivity, C_F=4.7 nF, C_{OUT} = open, 20 kHz bandwidth	–	45	–	mV
		Peak-to-peak, T_A = 25°C, 185 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	20	–	mV
		Peak-to-peak, T_A = 25°C, 185 mV/A programmed Sensitivity, C_F = 1 nF, C_{OUT} = open, 50 kHz bandwidth	–	75	–	mV
Electrical Offset Voltage	V_{OE}	I_P = 0 A	–40	–	40	mV
Total Output Error[3]	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_{OP}, provided that the Maximum Junction Temperature, $T_{J(max)}$, is not exceeded.

[2] At –40°C Sensitivity may shift as much 9% outside of the datasheet limits.

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

x20A PERFORMANCE CHARACTERISTICS T_{OP} = –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[2]	$Sens_{TA}$	Over full range of I_P, T_A = 25°C	–	100	–	mV/A
	$Sens_{TOP}$	Over full range of I_P	97	–	103	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A= 25°C, 100 mV/A programmed Sensitivity, C_F=4.7 nF, C_{OUT} = open, 20 kHz bandwidth	–	24	–	mV
		Peak-to-peak, T_A = 25°C, 100 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	10	–	mV
		Peak-to-peak, T_A = 25°C, 100 mV/A programmed Sensitivity, C_F = 1 nF, C_{OUT} = open, 50 kHz bandwidth	–	40	–	mV
Electrical Offset Voltage	V_{OE}	I_P = 0 A	–30	–	30	mV
Total Output Error[3]	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_{OP}, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.

[2] At –40°C Sensitivity may shift as much 9% outside of the datasheet limits.

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

x30A PERFORMANCE CHARACTERISTICS T_{OP} = –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[2]	$Sens_{TA}$	Over full range of I_P, T_A = 25°C	–	66	–	mV/A
	$Sens_{TOP}$	Over full range of I_P	64	–	68	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A= 25°C, 66 mV/A programmed Sensitivity, C_F=4.7 nF, C_{OUT} = open, 20 kHz bandwidth	–	20	–	mV
		Peak-to-peak, T_A = 25°C, 66 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	7	–	mV
		Peak-to-peak, T_A = 25°C, 66 mV/A programmed Sensitivity, C_F = 1 nF, C_{OUT} = open, 50 kHz bandwidth	–	35	–	mV
Electrical Offset Voltage	V_{OE}	I_P = 0 A	–30	–	30	mV
Total Output Error[3]	E_{TOT}	I_P = ±30 A, T_A = 25°C	–	±1.5	–	%

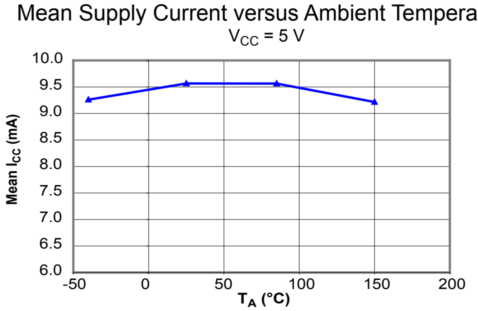
[1] Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_{OP}, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.

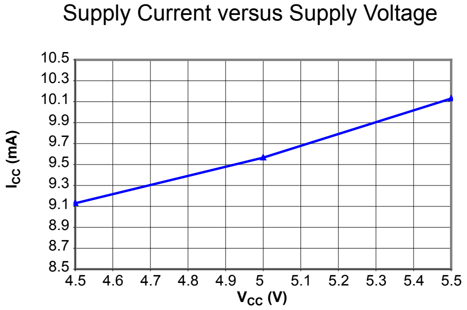
[2] At –40°C Sensitivity may shift as much 9% outside of the datasheet limits.

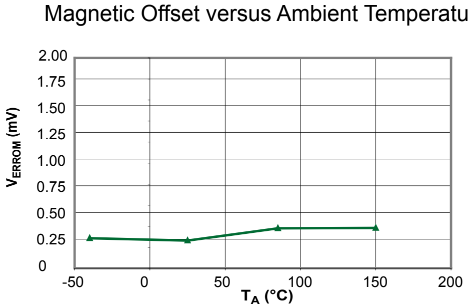
[3] Percentage of I_P, with I_P = 30 A. Output filtered.

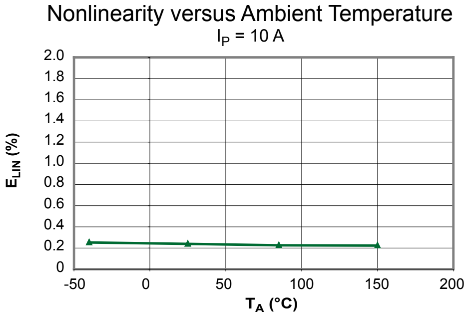
Characteristic Performance

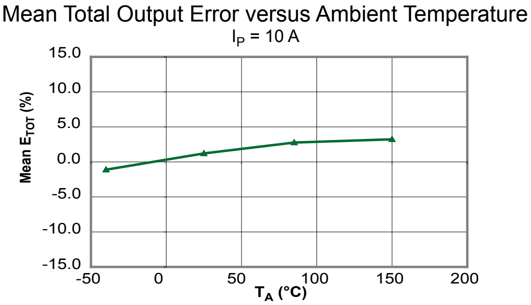
I_P = 5 A, Sens = 185 mV/A unless otherwise specified

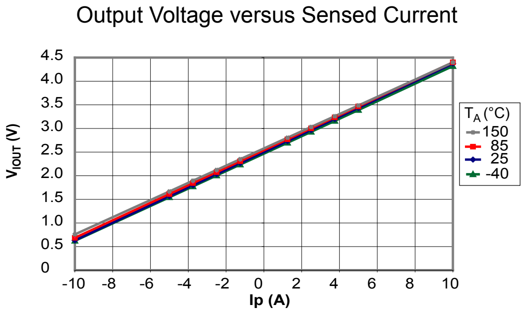


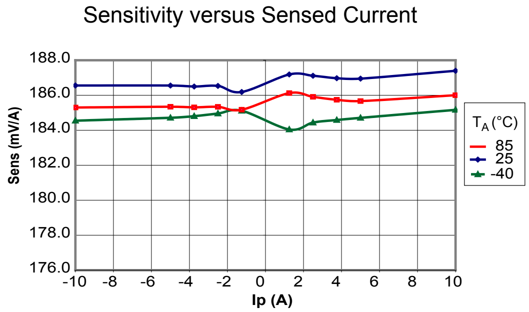










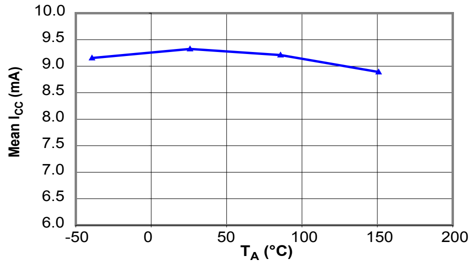


Characteristic Performance

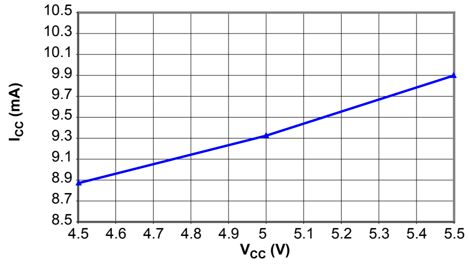
I_P = 30 A, Sens = 66 mV/A unless otherwise specified

Mean Supply Current versus Ambient Temperature

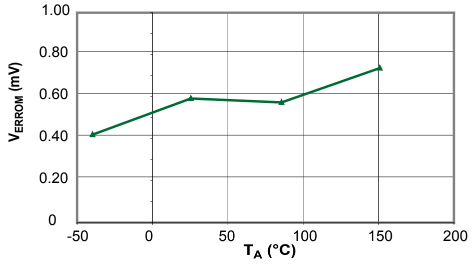
V_{CC} = 5 V



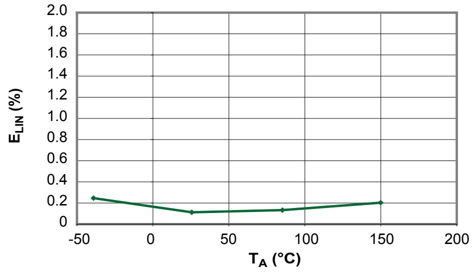
Supply Current versus Supply Voltage



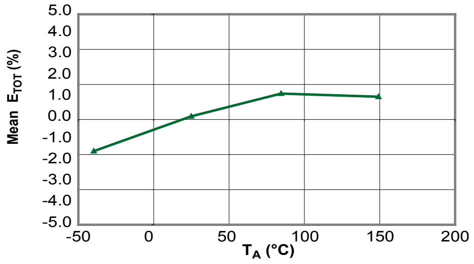
Magnetic Offset Current versus Ambient Temperature



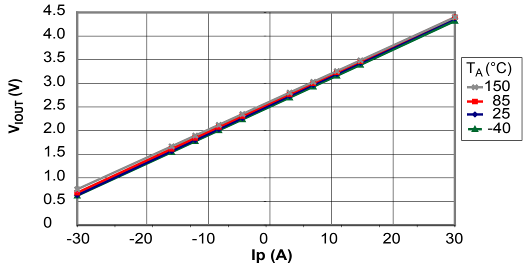
Nonlinearity versus Ambient Temperature



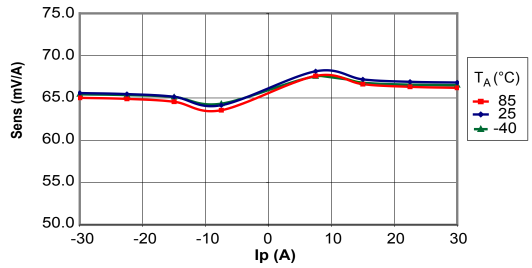
Mean Total Output Error versus Ambient Temperature



Output Voltage versus Sensed Current



Sensitivity versus Sensed Current



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:

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

where $V_{\text{IOUT\_full-scale amperes}}$ = 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:

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

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, $\Delta V_{IOUT(Q)RAT}$ (%).

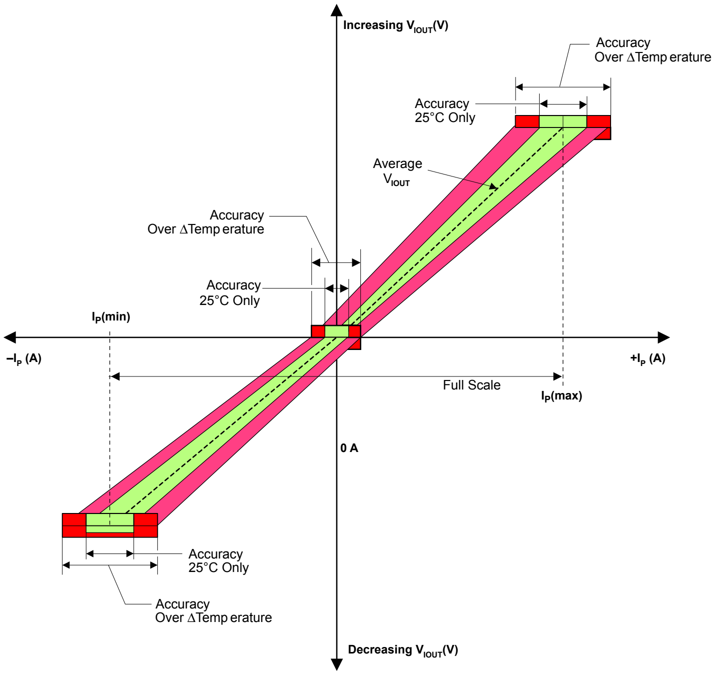
$$100\left(\frac{V_{\text{IOUT(Q)VCC}}\,/\,V_{\text{IOUT(Q)5V}}}{V_{\text{CC}}\,/\,5\text{ V}}\right)$$

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

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

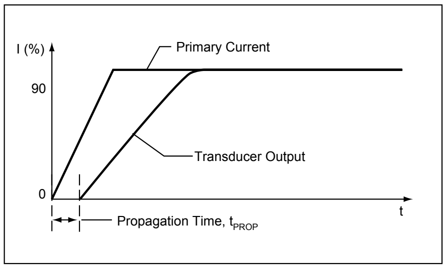
Output Voltage versus Sensed Current

Accuracy at 0 A and at Full-Scale Current

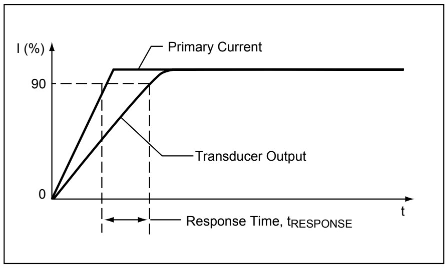


Definitions of Dynamic Response Characteristics

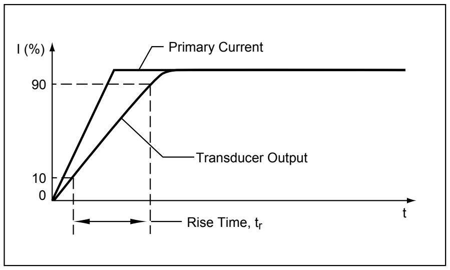
Propagation delay (t_{PROP}). The time required for the sensor output to reflect a change in the primary current signal. Propagation delay is attributed to inductive loading within the linear IC package, as well as in the inductive loop formed by the primary conductor geometry. Propagation delay can be considered as a fixed time offset and may be compensated.



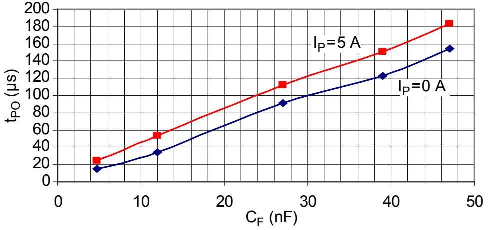
Response time ($t_{RESPONSE}$). The time interval between a) when the primary current signal reaches 90% of its final value, and b) when the sensor reaches 90% of its output corresponding to the applied current.



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.

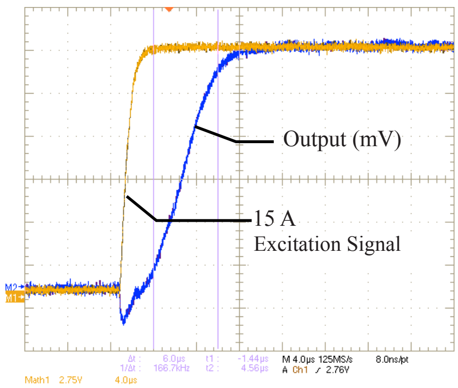


Power on Time versus External Filter Capacitance

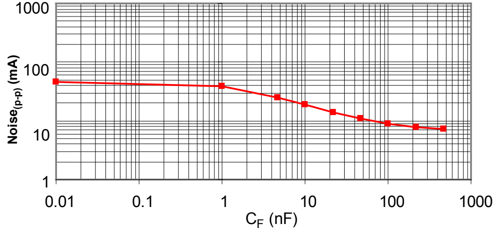


Step Response

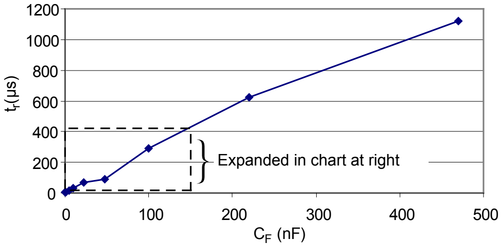
T_A=25°C



Noise versus External Filter Capacitance

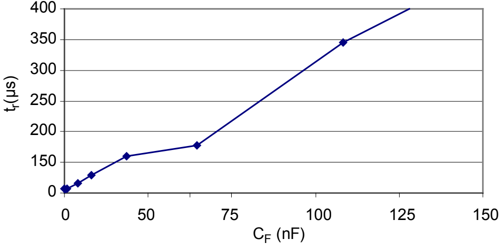


Rise Time versus External Filter Capacitance



C_F (nF)	t_r (µs)
0	6.647
1	7.74
4.7	17.38
10	32.09087
22	68.15
47	88.18
100	291.26
220	623.02
470	1120

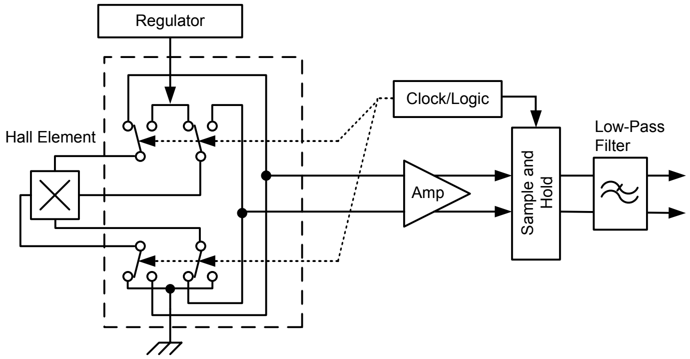
Rise Time versus External Filter Capacitance



Chopper Stabilization Technique

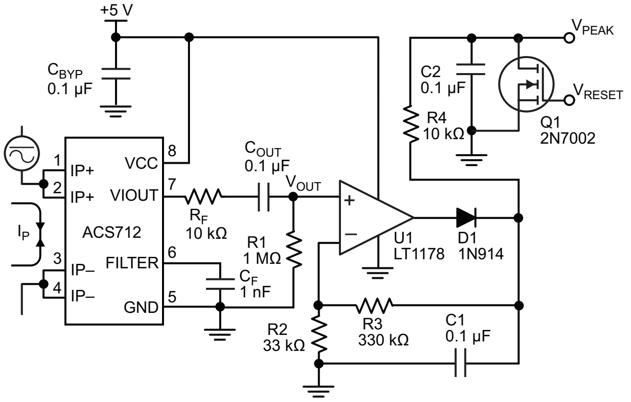
Chopper Stabilization is an innovative circuit technique that is used to minimize the offset voltage of a Hall element and an associated on-chip amplifier. Allegro patented a Chopper Stabilization technique that nearly eliminates Hall IC output drift induced by temperature or package stress effects. 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.

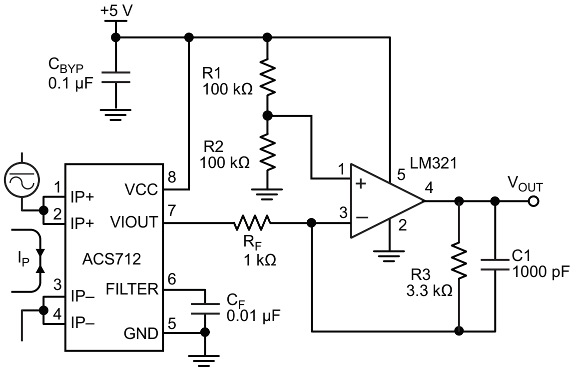


Concept of Chopper Stabilization Technique

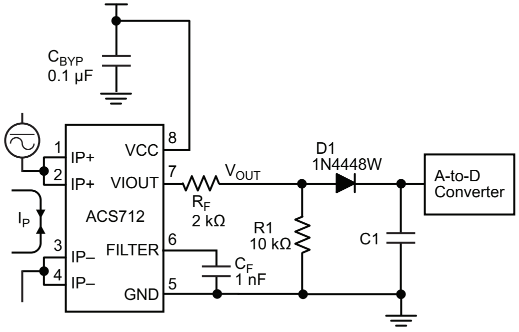
Typical Applications



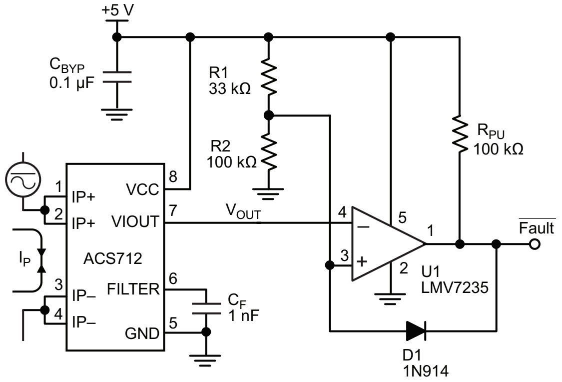
Application 2. Peak Detecting Circuit



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

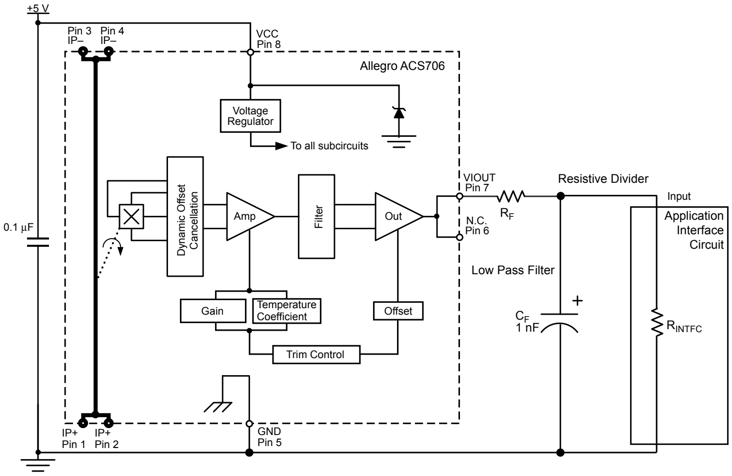
In low-frequency sensing applications, it is often advantageous to add a simple RC filter to the output of the sensor. Such a low-pass filter improves the signal-to-noise ratio, and therefore the resolution, of the sensor output signal. However, the addition of an RC filter to the output of a sensor 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:

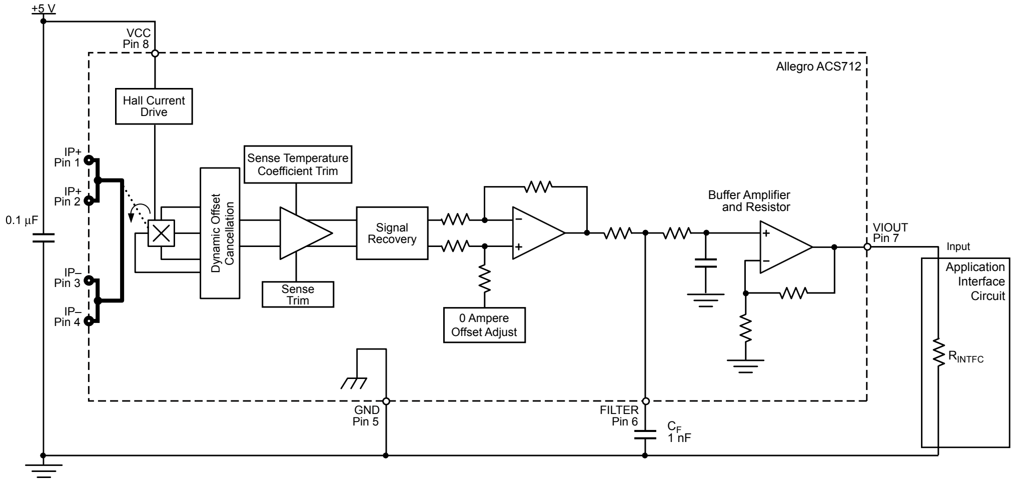
$$\Delta V_{\mathrm{ATT}} = V_{\mathrm{IOUT}} \left(\frac{R_{\mathrm{INTFC}}}{R_{\mathrm{F}} + R_{\mathrm{INTFC}}} \right) .$$

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.

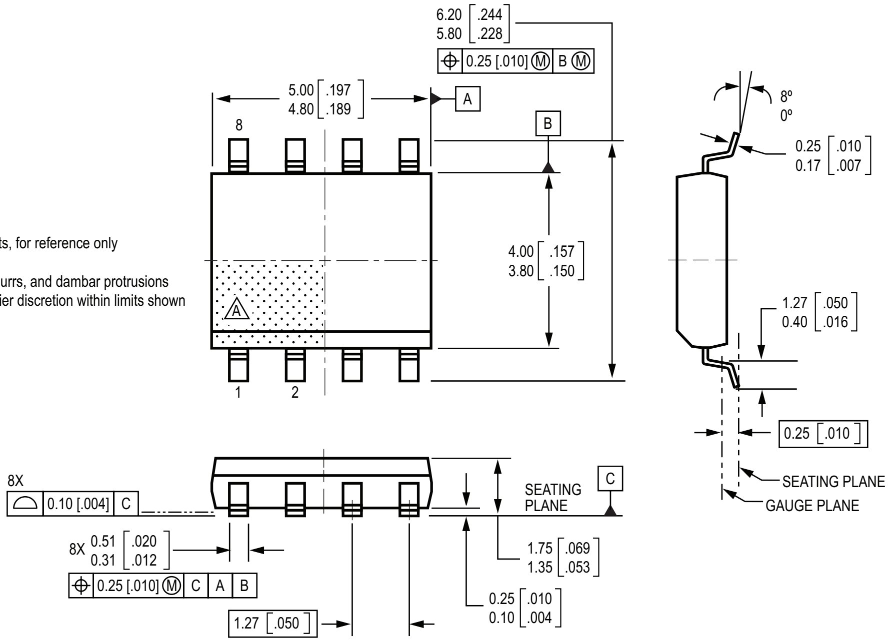


Application 6. When a low pass filter is constructed externally to a standard Hall effect device, a resistive divider may exist between the filter resistor, R_F, and the resistance of the customer interface circuit, R_{INTFC}. This resistive divider will cause excessive attenuation, as given by the transfer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

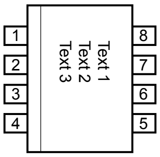
Package LC, 8-pin SOIC



Preliminary dimensions, for reference only
Dimensions in millimeters
U.S. Customary dimensions (in.) in brackets, for reference only
(reference JEDEC MS-012 AA)
Dimensions exclusive of mold flash, gate burrs, and dambar protrusions
Exact case and lead configuration at supplier discretion within limits shown
⚠A Terminal #1 mark area

Package Branding

Two alternative patterns are used



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

ACS712T *R*LC*PPP* *L...L* *YYWW*	ACS	Allegro Current Sensor
	712	Device family number
	T	Indicator of 100% matte tin leadframe plating
	R	Operating ambient temperature range code
	LC	Package type designator
	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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UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Escuela Técnica Superior de Ingeniería del Diseño

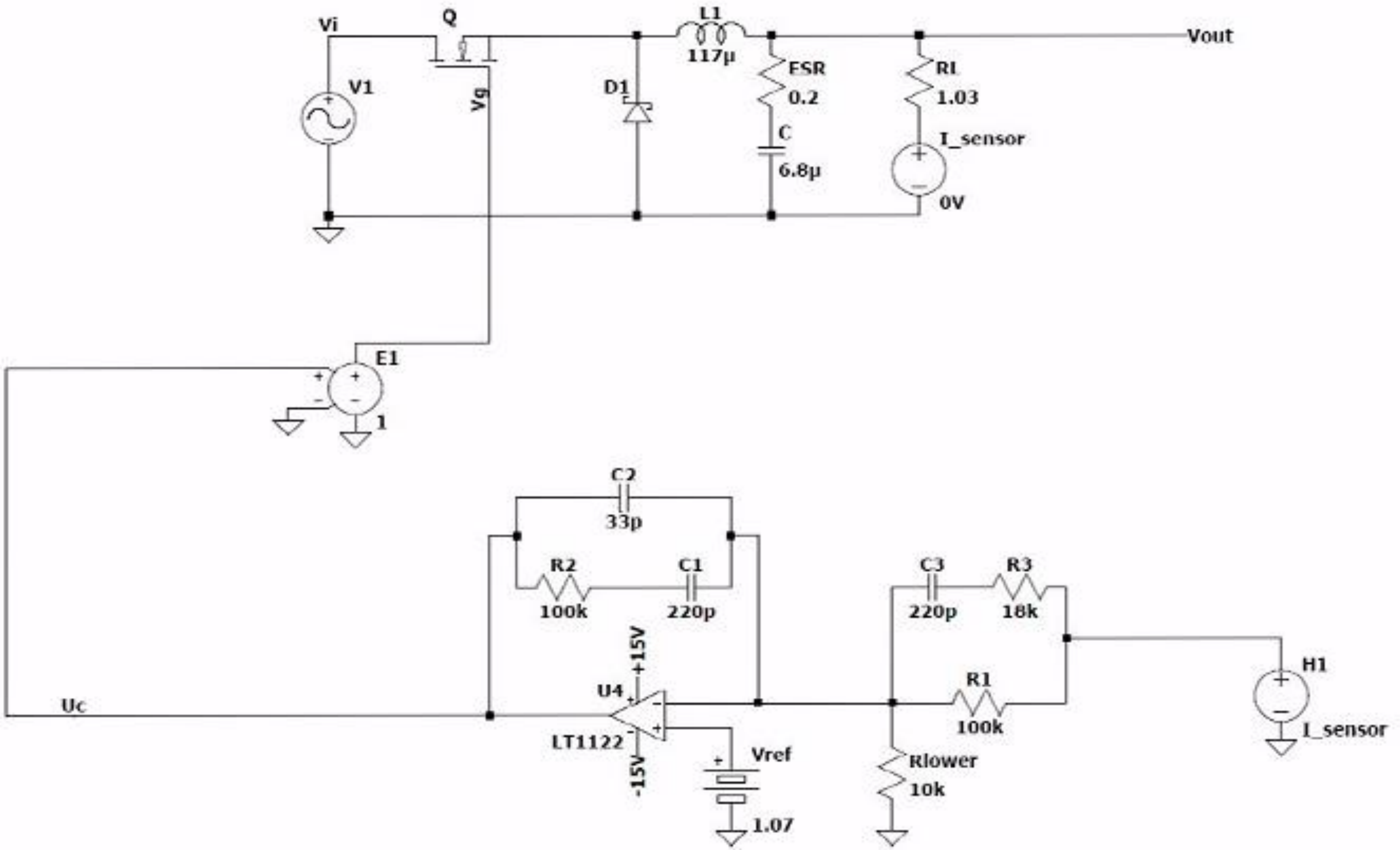
Documento 2: Planos

TRABAJO FINAL DEL
Grado en Ingeniería Electrónica Industrial y Automática

REALIZADO POR
Marc Bosch Perez

TUTORIZADO POR
Carlos Sánchez Diaz

CURSO ACADÉMICO: 2020/2021



FECHA	NOMBRE Y APELLIDOS	TRABAJO FIN DE GRADO
AGOSTO 20	MARC BOSCH PEREZ	
CIRCUITO EN LTSPICE		

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Escuela Técnica Superior de Ingeniería del Diseño

Documento 3: Presupuesto

TRABAJO FINAL DEL

Grado en Ingeniería Electrónica Industrial y Automática

REALIZADO POR

Marc Bosch Perez

TUTORIZADO POR

Carlos Sánchez Diaz

CURSO ACADÉMICO: 2020/2021

Presupuesto

Presupuesto de mano de obra			
Concepto	Horas	Precio unitario (€)	Precio total (€)
Mano de obra de Ingeniería	300	20	6000 €
		Total:	6000 €

Resumen del presupuesto	
Coste mano de obra directa	6000 €
Coste mano de obra indirecto	300 €
Costes indirectos	75,26 €
Total presupuestado	6375,26 €
Iva (21%)	1338,80 €
Total	7714,06 €

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Escuela Técnica Superior de Ingeniería del Diseño

Documento 4: Pliego de condiciones

TRABAJO FINAL DEL
Grado en Ingeniería Electrónica Industrial y Automática

REALIZADO POR
Marc Bosch Perez

TUTORIZADO POR
Carlos Sánchez Diaz

CURSO ACADÉMICO: 2020/2021

Pliego de condiciones

En este documento se redactará las condiciones mínimas para llevar a cabo el proyecto. Como este proyecto es solo un estudio, se ha hecho un documento simplificado.
Este proyecto ha sido creado exclusivamente para uso académico y con fin de ayudar en el proyecto en el cual está trabajando el Doctor Carlos Sánchez Díaz, por lo que quedará prohibida su distribución y comercialización fuera de estos dos ámbitos.

Ejecución

Para los cálculos se ha utilizado el programa Matlab 2019 con la licencia que dispone la propia universidad.

Las simulaciones de este proyecto se han realizado mediante el programa LTspice, con la licencia de la universidad politécnica de Valencia.
Este programa tiene unas limitaciones en cuanto a los componentes a seleccionar, puesto que los componentes seleccionados en este proyecto no tienen una librería en este programa, se ha seleccionado otros componentes de características similares para poder realizar las simulaciones correctamente.

Si el circuito se monta como se muestra en la memoria, eligiendo los componentes seleccionados, el diseñador asegura que los valores que se obtendrán a la salida del convertidor son los correctos para este proyecto.

Control de la ejecución

El diseñador debe revisar que todos los componentes tienen los valores que se han descrito en la memoria, así como, cerciorarse de que todos los componentes están bien conectados para que a la hora de la simulación no se produzca ningún error.

Toma de medidas

Para la toma de medidas solo se necesita poner una sonda de tensión en la salida del circuito de potencia y una sonda amperimétrica en la bobina del circuito. De este modo se visualizará el voltaje y la corriente de salida.

Exención de responsabilidad

Este proyecto asegura que con los valores que se muestran en los cálculos y en las simulaciones, el proyecto es totalmente valido. Si en un futuro montaje los resultados no son los esperados, el estudiante se exime de toda responsabilidad puesto que en las simulaciones los resultados son los correctos.