



Informe Técnico
Molino para la obtención de harinas de cereales y leguminosas

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Resumen

En el presente trabajo se presenta el diseño y la construcción del sistema electrónico de un molino que permite la obtención de harinas que se utilizan para la producción de los suplementos alimenticios de origen vegetal que se llevan a cabo en el Laboratorio de Ingeniería de Proceso del Instituto de Ciencias Aplicadas y Tecnología de la UNAM. El sistema cuenta con dos procesos principales: molienda y tamizado, que pueden ser operados de manera independiente o simultánea y con los que se obtienen harinas con un tamaño de partícula menor a 420 micras. La electrónica de operación que establece la comunicación entre el usuario y el equipo se diseñó por medio de una pantalla resistiva de 4 hilos táctil de 2.8" en la que se muestra un menú para la selección de los procesos. Se utilizó un microcontrolador *ATmega328P* para el diseño de la interfaz y el control de los elementos electrónicos del equipo, interpretando las señales que son recibidas por la pantalla táctil a través del menú de selección. La motivación del desarrollo de este proyecto es garantizar que el material utilizado para la producción de las formulaciones nutrimentales de los suplementos alimenticios cumpla con un tamaño de partícula homogéneo, además de asegurar el correcto tratamiento previo a los cereales y leguminosas.

Índice

INTRODUCCIÓN

1. Variables de interés.....	5
2. Diagrama de bloques del prototipo	5
2.1 Bloque de interfaz de usuario	6
2.1.1 Pantalla táctil.....	6
2.1.2 Tarjeta ARDUINO UNO	7
2.1.2 Push button	7
2.2 Bloque de controlador.....	7
2.3 Bloque de alimentación 1.....	7
2.4 Bloque de alimentación 2.....	7
2.5 Bloque de circuito de control	8
2.5.1 Relevador SRD-05VDC-SL-C	9
2.5.2 Transistor BC547	9
2.6 Bloque de motores	9
2.6.1 Motor 1.....	10
2.6.2 Motor 2.....	10
2.6.3 Ventilador de enfriamiento	10
3. Pruebas y resultados	11
3.1 Procesamiento de avena	11
3.2 Procesamiento de lenteja.....	12
3.3 Procesamiento de frijol	12
3.4 Procesamiento de garbanzo.....	13
3.5 Procesamiento de haba.....	13
3.6 Harina resultante.....	14

Conclusiones.....	14
Apéndice A (Lista de componentes).....	15
Apéndice B (Circuito impreso).....	17
Apéndice C (Hojas de datos)	18
Apéndice D (Programa)	111
4. Bibliografía.....	1127

INTRODUCCIÓN

Los suplementos alimenticios de origen natural que se desarrollan en el grupo de Ingeniería de Proceso del Instituto de Ciencias Aplicadas y Tecnología (ICAT, de la UNAM) están destinados para los pacientes con síndrome de malabsorción con la finalidad de que adquieran los nutrientes necesarios para su salud. Para la producción de los suplementos alimenticios se utilizan harinas de distintos cereales y leguminosas con un tamaño de partícula controlado para la elaboración de las formulaciones nutrimentales específicas. Con la finalidad de obtener las harinas para las formulaciones, es necesario disponer de un sistema que realice los procesos de molienda y de tamizado de los granos asegurando un tamaño de partícula homogéneo.

Durante el proceso de molienda se produce la trituración de los granos de cereales y leguminosas por medio de dos discos dentados de acero inoxidable. Una vez que el material de trabajo es molido, se deposita en un arreglo de tamices vibratorios de diferente abertura para discriminar el material granuloso de mayor tamaño, entregando al final del proceso la harina con tamaño de partícula homogéneo. Dentro de los equipos que existen a nivel comercial e industrial no se han encontrado sistemas que cumplan con los procesos de molienda y tamizado en la misma configuración, por lo que el prototipo desarrollado en el ICAT puede competir con las configuraciones existentes ofreciendo la operación de los procesos de manera automática e independiente según las necesidades del usuario produciendo las harinas que se utilizan para la elaboración de los suplementos alimenticios. Cabe mencionar que existe un trabajo previo presentado y una publicación como extenso en el congreso de instrumentación organizado por la SOMI en 2017 (Santana, Bazán y Córdova 2017) donde se presentó un prototipo de prueba explicando los principales elementos así como su funcionamiento y los resultados que se obtuvieron. Dicho trabajo sirvió como base para el desarrollo final del equipo presentado a lo largo del presente informe.

1. Variables de interés

Las variables de interés que se consideraron para el desarrollo del prototipo fueron: el tamaño de partícula de las harinas y el tiempo de producción de las harinas, ambas se muestran en la tabla 1.

Tabla 1. Variables de interés

Variable	Valor
Tamaño de partícula	420 micras
Tiempo de producción	10 a 15 minutos

El tiempo de producción varía según el material de trabajo que se ingresa en el sistema.

2. Diagrama de bloques del prototipo

En la figura 1 se muestra el diagrama de los elementos que conforman al prototipo (Apéndice A). El control de los tiempos de operación del molino y de los tamices se programó en un microcontrolador *ATmega328P* (Massimo y Michael 2014, pp. 53-70) y recibe las señales provenientes de la interfaz de usuario en el menú de selección por parte del operador, realizando los procesos de manera manual o automática.

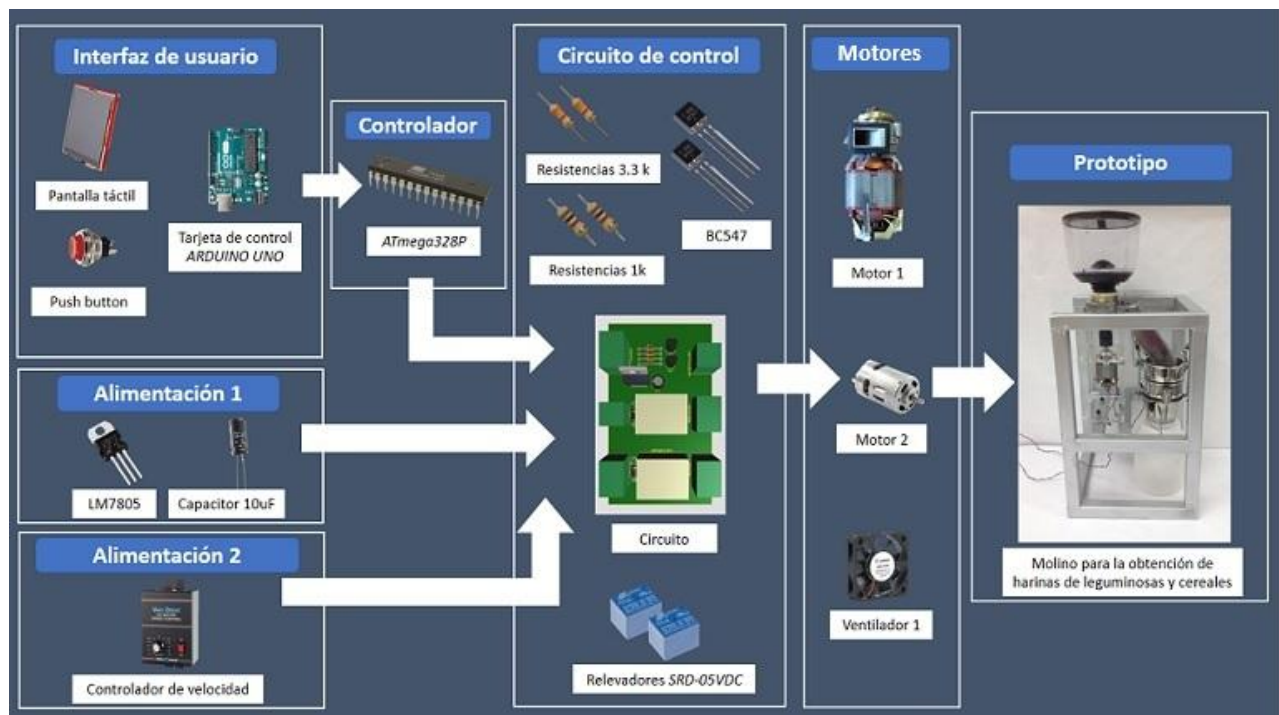


Figura 1. Diagrama de bloques de los elementos que conforman al prototipo.

2.1 Bloque de interfaz de usuario

En la figura 1 se pueden apreciar los elementos que se utilizaron para el desarrollo de la interfaz de usuario donde se seleccionan los procesos que se requieren según el material ingresado. En la figura 2 se muestran las diferentes etapas de la interfaz, el menú principal contiene dos opciones: el botón “info” donde se brinda un pequeño manual de operación y el botón “Procesar” el cual contiene las opciones del material que el prototipo puede procesar de manera automática, así como dos opciones con los nombres “Moler” y “Tamizar” mediante el cual se pueden realizar los procesos de manera manual a través de un control on/off.

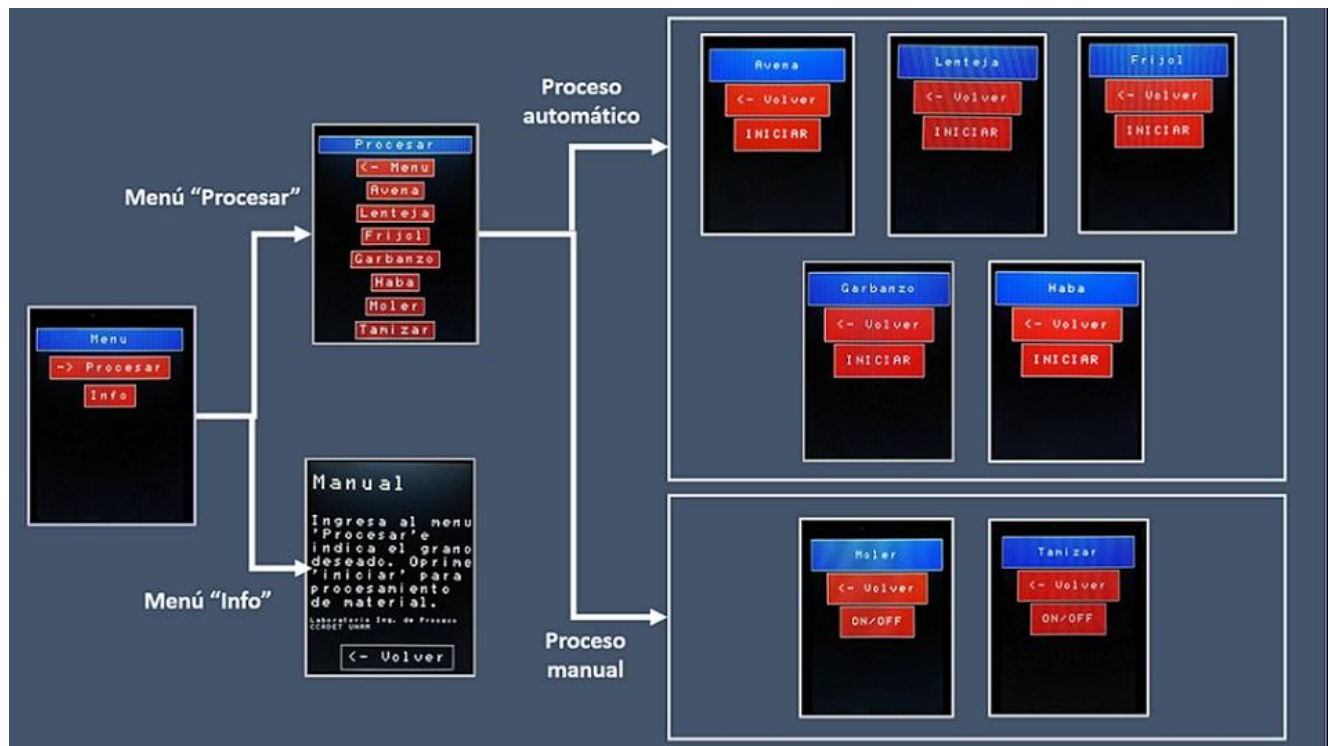


Figura 2. Elementos de la interfaz de usuario.

2.1.1 Pantalla táctil

Se utilizó una pantalla resistiva de 4 hilos táctil de 2.8" que es compatible con la tarjeta *ARDUINO UNO* (TFT Touch Shield, 2004). El transistor de película delgada (TFT por sus siglas en inglés) se basa en el controlador *ST7781R* con datos de 8 bits e interfaz de control de 4 bits. Cuenta con una resolución de 240 x 320 píxeles y 262,000 colores, con luz de fondo LED.

2.1.2 Tarjeta ARDUINO UNO

La tarjeta ARDUINO UNO se puede programar mediante una conexión USB a una computadora, cuenta con 14 pines digitales de entrada/salida (6 pueden ser usadas como salidas PWM), 6 analógicas, un cristal de cuarzo de 16 MHz, un botón de reinicio y un conector de alimentación. La tarjeta se utilizó para el desarrollo de la interfaz aprovechando la compatibilidad de la pantalla táctil, además de establecer la programación del microcontrolador ATmega328P. (Apéndice D).

2.1.2 Push button

Se utilizó un push button normalmente abierto como botón de emergencia. Al ser presionado se detienen los procesos del prototipo en caso de detectar algún tipo de falla durante su operación, evitando así los daños que se puedan ocasionar en los elementos que lo conforman.

2.2 Bloque de controlador

El microcontrolador *ATmega328P* (García 2018, pp. 1-190) interpreta las señales que recibe a través del menú de selección en la pantalla TFT activando los actuadores durante el tiempo preestablecido en la programación en el modo automático o en el modo manual. La tensión de funcionamiento del microcontrolador es de 5-12 VDC y cuenta con salidas de voltaje de 3.3 y 5 VDC con corriente máxima de 50 mA.

2.3 Bloque de alimentación 1

La alimentación del sistema electrónico de baja potencia (microcontrolador, pantalla, motor de los tamices y ventilador de refrigeración) es suministrada por un regulador de voltaje, el cual restringe el voltaje proveniente de una fuente de alimentación de 12 VDC a 5 VDC, asegurando la correcta tensión de operación de los elementos electrónicos de baja potencia.

2.4 Bloque de alimentación 2

La alimentación del sistema electrónico de alta potencia es suministrada del tomacorriente AC a 127 V tomada directamente de la línea de suministro doméstico y energiza al controlador de

velocidades que brinda una tensión de operación en DC en el motor del molino de 42 V a 71.3 V y un consumo de corriente de 1.13 A hasta 1.62 A.

2.5 Bloque de circuito de control

El circuito de control mostrado en la figura 3 (Apéndice B) está diseñado para establecer la comunicación entre las señales provenientes del microcontrolador, además de aislar los elementos electrónicos de baja potencia para evitar algún daño provocado por los elementos electrónicos de alta potencia. Consta de tres entradas; Alimentación 1, para los elementos electrónicos de baja potencia. Alimentación 2, que brinda la energía y establece la potencia del motor del molino. Señales enviadas desde la pantalla a través del microcontrolador, para la activación y desactivación de los motores. En el Apéndice C se presenta la información técnica de los elementos electrónicos que conforman al prototipo.

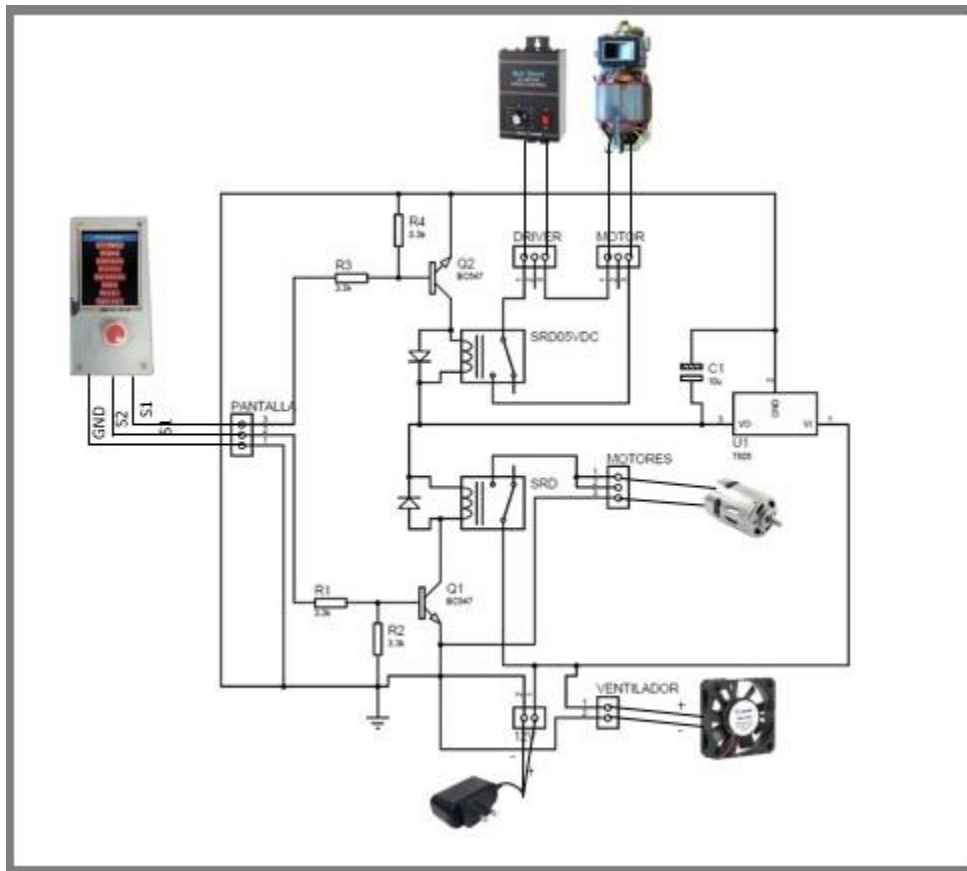


Figura 3. Esquema de conexión del circuito general de control.

2.5.1 Relevador SRD-05VDC-SL-C

Opera como interruptor en la alimentación de los motores y protege la electrónica de baja potencia. En la figura 4 se puede apreciar la conexión con un diodo 1N4001 de protección. Es activado por las señales que se envían desde el microcontrolador. Cada relevador cuenta con 5 pines de conexión, una bobina activada a 5 V y un rango de 10 A/250-110 VDC en el contacto normalmente abierto, mientras que en el contacto normalmente cerrado tiene un rango de 10 A/30 VDC. Su expectativa de vida es de hasta 100,000 accionamientos.

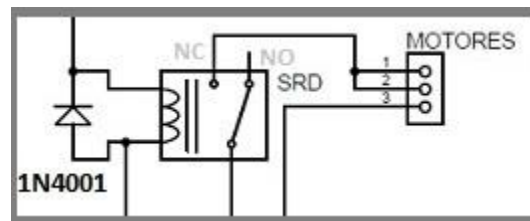


Figura 4. Relevador SRD-05VDC-SL-C

2.5.2 Transistor BC547

Se utilizó el transistor *BC547* para la activación de los relevadores. Es polarizado gracias a la señal que recibe desde el microcontrolador, permitiendo el paso de la corriente necesaria para la energización de la bobina de los relevadores que activan la alimentación de los motores del sistema. Véase la figura 5.

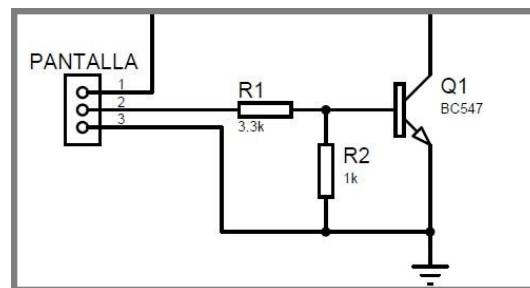


Figura 5. Accionamiento del relevador con el BC547.

2.6 Bloque de motores

Los procesos de molienda y de tamizado cuentan con un motor que permite realizar la trituración de los granos y la discriminación de partículas respectivamente. Los motores son accionados por el circuito de control y dependen de las funciones seleccionadas por el usuario

en el menú de la pantalla táctil. Dentro de la configuración del prototipo se cuenta con un ventilador de enfriamiento para el motor del molino, que ayuda a disipar el calor que se genera por el trabajo y ayuda a retrasar el sobrecalentamiento.

2.6.1 Motor 1

El motor DC se utiliza para el sistema de molienda, su alimentación es de 40 VDC a 75 VDC y tiene un consumo de corriente máxima de 1.8 A. Cuenta con una flecha de 6 mm de diámetro y 23 mm de largo que se encuentra conectada en la cámara de molienda donde se produce la trituración del material.

2.6.2 Motor 2

El sistema de tamizado cuenta con un motor con masa excéntrica que produce las vibraciones en los tamices para realizar la separación de los materiales granulosos no deseados. El diámetro de la flecha es de 2 mm y en su extremo se encuentra una masa de 3 g. Se alimenta a 12 VDC y consume 250 mA de corriente.

2.6.3 Ventilador de enfriamiento

El ventilador de enfriamiento se alimenta a 12 VDC, se encuentra posicionado cerca del motor del molino y previene el sobrecalentamiento del motor prolongando su tiempo de operación.

3. Pruebas y resultados

El prototipo se caracterizó realizando pruebas con avena, frijol, lenteja, garbanzo y haba. Cada material fue evaluado para conocer las limitantes de los elementos que conforman al prototipo y a partir de las mismas se definieron los tiempos de operación para realizar los procesos de molienda y tamizado de manera automática. En la tabla 2 se presentan las características de operación definidas para el correcto funcionamiento del prototipo.

Tabla 2. Características de operación del equipo

	Avena	Lenteja	Frijol	Garbanzo	Haba
Requiere tratamiento previo	No	Sí	Sí	Sí	Sí
Tamaño de ingreso (máx.)	10x7x2	6x6x2	12x6x6	8x7x8	10x6x4
Requiere tamizado	No	Sí	Sí	Sí	Sí
Ajuste de muelas (vueltas)	5 $\frac{3}{4}$	5 $\frac{3}{4}$	5 $\frac{3}{4}$	5 $\frac{1}{2}$	5 $\frac{1}{2}$
# Nivel en driver	60	60	70	70	70
Presenta sobrecalentamiento de motor en molienda	Sí	Sí	Sí	Sí	Sí
Tiempo de operación (minutos) por cada 180gr	12.5	10	8.5	7.5	7.5
Presenta atascamiento por tamaño mayor al de ingreso	Sí	Sí	Sí	Sí	Sí

3.1 Procesamiento de avena

La avena es el único material de trabajo que no requiere un tratamiento previo, puede ser procesado por el molino en crudo. El sistema tarda 12.5 minutos por cada 180 g de material introducido. Además, no se requiere el sistema de tamizado ya que a la salida del molino el tamaño de partícula es menor al permisible por los tamices, por lo que se obtiene la harina de avena directamente del proceso de molienda. En la figura 6 se muestra el grano de avena antes y después de ser procesado.



Figura 6. Avena antes y después de ser procesada.

3.2 Procesamiento de lenteja

La lenteja debe ser cocida y secada previamente para ser ingresada al molino, esto con la finalidad de que cumpla con ciertas propiedades nutrimentales para las formulaciones indicadas por el usuario. El sistema tarda 10 minutos por cada 180 g de material introducido y se requiere del proceso de tamizado. En la figura 7 se muestra el grano de lenteja antes y después de ser procesado.



Figura 7. Lenteja antes y después de ser procesada.

3.3 Procesamiento de frijol

El frijol debe ser cocido y secado previamente para ser ingresado al molino, esto con la finalidad de que cumpla con ciertas propiedades nutrimentales para las formulaciones indicadas por el usuario, además de reducir la dureza del grano provocando mejores resultados durante el proceso de molienda. El sistema tarda 8.5 minutos por cada 180 g de material introducido y se requiere del proceso de tamizado. En la figura 8 se muestra el grano de frijol antes y después de ser procesado.



Figura 8. Frijol antes y después de ser procesado.

3.4 Procesamiento de garbanzo

El garbanzo debe ser cocido, secado y fracturado previamente para ser ingresado al molino, esto con la finalidad de que cumpla con ciertas propiedades nutrimentales para las formulaciones indicadas por el usuario, reduciendo la dureza de los granos además de minimizar el tamaño para el ingreso del material asegurando mejores resultados durante el proceso de molienda. El sistema tarda 7.5 minutos por cada 180 g de material introducido y se requiere del proceso de tamizado. En la figura 9 se muestra el grano de garbanzo antes y después de ser procesado.



Figura 9. Garbanzo antes y después de ser procesado.

3.5 Procesamiento de haba

El haba debe ser cocida, secada y fracturada previamente para ser ingresada al molino, esto con la finalidad de que cumpla con ciertas propiedades nutrimentales para las formulaciones indicadas por el usuario, reduciendo la dureza de los granos además de minimizar el tamaño para el ingreso del material asegurando mejores resultados durante el proceso de molienda. El sistema tarda 7.5 minutos por cada 180 g de material introducido y se requiere del proceso de tamizado. En la figura 10 se muestra el grano de haba antes y después de ser procesado.



Figura 10. Haba antes y después de ser procesada.

3.6 Harina resultante

En la tabla 3 se muestran los porcentajes obtenidos de harina en el sistema de tamizado por cada 50 g de masa depositado en el sistema. Como se ha mencionado a lo largo del presente, la avena no requiere del proceso de tamizado al ser el único material que cumple con las características del tamaño de partícula para las formulaciones después de ser procesada por el molino.

Tabla 3. Porcentaje de harina obtenido con el sistema de tamizado.

	Entrada [g]	Harina [g]	Residuos [g]	% Harina Obtenido
Lenteja	50	37	13	74
Frijol	50	40	10	80
Garbanzo	50	40	10	80
Haba	50	43	7	86

Conclusiones

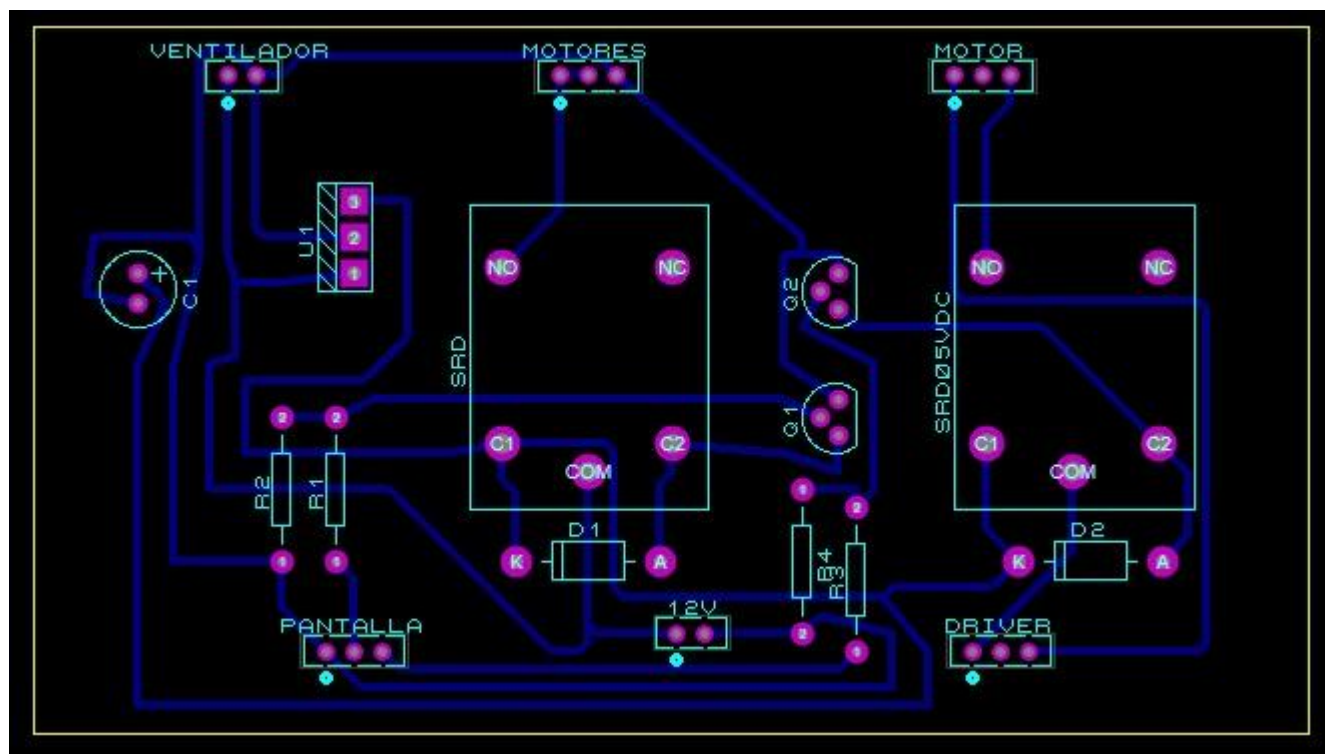
De acuerdo a las pruebas realizadas con los diferentes materiales se logró demostrar que el prototipo es capaz de producir hasta 750 g de harina de avena, lenteja, frijol, garbanzo y haba con un tamaño de partícula menor a 420 micras, procesando granos con un tamaño máximo de 12 mm de largo por 7 mm de ancho y 8 mm de grosor. Granos de mayor tamaño permiten el atascamiento y fallas en los elementos que conforman al prototipo. El equipo opera únicamente material en seco y se recomienda dar un descanso de 10 minutos entre cada operación para permitir el enfriamiento del motor del molino. El desarrollo de este proyecto brinda la ventaja de contar con un equipo propio que no existe en el mercado o la industria con tecnología propia y que en un futuro puede abrir el camino hacia la fabricación de equipos nuevos para la producción de harinas. Otra de las ventajas del prototipo es que se cuenta con las opciones de operación automática e independiente para el procesamiento de los materiales, facilitando la realización de pruebas con cereales y leguminosas distintos a los trabajados. Como siguiente paso se propone buscar distintas alternativas para corregir los problemas mencionados así como la implementación de elementos que benefician el rendimiento del prototipo.

Apéndice A

LISTA DE COMPONENTES

Cantidad	Componente	Características
1	Interruptor general	127 V / 10 A
2	Diodo rectificador	1N4001
2	Relevador en estado sólido	SRD-05VDC-SL-C
2	Transistor	BC547
2	Resistencia	3.3 K OHMS
2	Resistencia	1 K OHM
1	Regulador de voltaje	7805
1	Capacitor electrolítico	100uF / 25 V
4	Conector Hembra	Molex vertical 3 pines
4	Conector Macho	Molex vertical 3 pines
2	Conector Hembra	Molex vertical 2 pines
2	Conector Macho	Molex vertical 2 pines
1	Microcontrolador	ATmega328P

1	Tarjeta de control	ARDUINO UNO
1	Pantalla táctil	TFT 2.8" V1.0 Seeed Studio
1	Motor DC	120 V / 60 Hz
1	Motor DC	12 V
1	Controlador de velocidades	VARI-DRIVE KBWM-120
1	Ventilador	12 VDC
1	Adaptador	OUTPUT: 9 VDC
1	Cable	Cal. 14 (NEGRO) 10 m
1	Cable	Cal. 14 (ROJO) 10 m
1	Cable	Cal. 14 (AZUL) 10 m
1	Push button RED	N/A de montaje
1	Placa fenólica	5 cm x 10 cm
4	Fijador para PCB	12 mm



INSTALLATION AND OPERATING INSTRUCTIONS

VARI-DRIVETM

NEMA 1 / IP20 SCR Variable Speed DC Motor Controls

Model KBWM-120 rated 1/100 - 1/3 HP (90 Volts DC) @ 115 Volts AC, 50/60 Hz
Model KBWM-240 rated 1/50 - 3/4 HP (180 Volts DC) @ 208/230 Volts AC, 50/60 Hz



See Page 2





See Safety Warning on Page 1

The information contained in this manual is intended to be accurate. However, the manufacturer retains the right to make changes in design which may not be included herein.



PENTA KB POWERTM

A COMPLETE LINE OF MOTOR DRIVES

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TABLE OF CONTENTS

Section	Page
i. Simplified Operating Instructions	1
ii. Safety Warning	1
I. Introduction	2
II. Control Setup	5
III. Mounting	6
IV. Wiring	6
V. Operation	8
VI. Trimpot Adjustments and Control Functions	8
VII. Limited Warranty	14

Tables

1. General Performance Specifications	2
2. Electrical Ratings	3
3. Plug-in Horsepower Resistor® Chart	5
4. Armature Fuse Selection Chart	5
5. Terminal Block Wiring Information	6
6. Field Connection (Shunt Wound Motors Only)	7

Figures

1. Control Layout	3
2. Mechanical Specifications	4
3. Motor Voltage Selection (J2) (Model KBWM-240 Only)	6
4. AC Line and Armature Connection	6
5A. Full Voltage Field	7
5B. Half Voltage Field	7
6A. Accel Trimpot Adjustment	9
6B. Decel Trimpot Adjustment	9
7. Internal Connection Diagram	11

I. KBWM-120, 240 SIMPLIFIED OPERATING INSTRUCTIONS

IMPORTANT – You must read these simplified operating instructions before proceeding. These instructions are to be used as a reference only and are not intended to replace the detailed instructions provided herein. You must read the Safety Warning before proceeding.

A. Power Connection – Wire AC line to terminals L1 and L2. Be sure the model number corresponds to the correct input voltage.

MODEL NO. & VOLTAGE RATING

Model Number	AC Line Voltage VAC 50/60 Hz	Armature Voltage (VDC)
KBWM-120	115	0 – 90
KBWM-240	208/230	0 – 90*, 180

B. Permanent Magnet (PM) Motor Connection (Two-Wire Type) – Wire the motor armature leads to terminals A(+) and A(-). Be sure the motor voltage corresponds to the control voltage rating and model number.

*See “G” below.

Note: Although control is specifically designed for PM motors it can also be used for shunt wound motors. (See Section IV D, page. 7.)

C. Ground – Be sure to earth ground the control by attaching a ground wire to the green stud located between the Bx knockouts.

D. Plug-in Horsepower Resistor®** – The correct Plug-in Horsepower Resistor® must be installed for optimum performance. (See Section II A, p. 5.)

E. Armature Fuse** – The correct value armature fuse must be installed for maximum protection. (See Section II C, p. 5.)

F. Trimpot Settings – All trimpots have been set according to Figure 1, page 3 and Section VI, page 8.

G. Jumper J2 is provided on Model KBWM-240 only and is factory set to “180V” position. For step-down operation (208/230 Volts AC line input and 0-90 Volts DC output), set J2 to the “90V” position. See Figure 3, on page 6.

**This control will not operate without installing the proper size Plug-in Horsepower Resistor® and armature fuse – supplied separately.

II. SAFETY WARNING! Please read carefully

This product should be installed and serviced by a qualified technician, electrician, or electrical maintenance person familiar with its operation and the hazards involved. Proper installation, which includes wiring, mounting in proper enclosure, fusing or other over current protection, and grounding can reduce the chance of electrical shocks, fires, or explosion in this product or products used with this product, such as electric motors, switches, coils, solenoids, and/or relays. Eye protection must be worn and insulated adjustment tools must be used when working with control under power. This product is constructed of materials (plastics, metals, carbon, silicon, etc.) which may be a potential hazard. Proper shielding, grounding and filtering of this product can reduce the emission of radio frequency interference (RFI) which may adversely affect sensitive electronic equipment. If further information is required on this product, contact the Sales Department. It is the responsibility of the equipment manufacturer and individual installer to supply this Safety Warning to the ultimate end user of this product. (SW effective 9/2000).

This control contains electronic Start/Stop circuits that can be used to start and stop the control. However these circuits are never to be used as safety disconnects since they are not fail-safe. Use only the AC line for this purpose.

Be sure to follow all instructions carefully. Fire and/or electrocution can result due to improper use of this product.

CE This product complies with all CE directives pertinent at the time of manufacture. Contact factory for detailed installation and Declaration of Conformity. Installation of a CE approved RFI filter (KBRF-200A [P/N 9945C] or equivalent) is required. Additional shielded motor cable and/or AC line cables may be required along with a signal isolator (KBSI-240D [P/N 9431] or equivalent).

I. INTRODUCTION

The KBWM™ Vari-Drive™ adjustable speed SCR control for DC motors offers proven reliability in a rugged all-metal NEMA-1 / IP20 enclosure. The Vari-Drives™ are equipped with the ultimate KBMM™ speed control module. They are specifically designed for fractional horsepower permanent magnet (PM) DC motors. Two models are offered. The KBWM-120 is designed for 115 VAC input and is rated 1/100-1/3 HP at 90 VDC. The KBWM-240 is designed for 208/230 VAC input and is rated 1/50 – 3/4 HP @ 180 VDC. **Note:** Model KBWM-240 can also be used on 90 Volt DC motors. See Section IID, on page 6.

KB's exclusive Plug-in Horsepower Resistor®* automatically presets the drive's IR Comp. for maximum performance and CL circuits for safe operation on various motors. Although factory calibrated, internal trimpots for MIN, MAX, IR, CL, ACCEL and DECEL can be used to fine-tune the KBWM™ for specific applications. Connections to the control are via a barrier terminal block. By changing the orientation of the front cover, the wiring can be brought in either from the bottom or the top of the control.

Motor failure due to demagnetization is eliminated by the patented ultra-fast Direct-Fed™ current limit circuit. The controls contain AC line and armature* fusing, which provide protection against catastrophic failure. Auto-Inhibit®, a KB exclusive, allows the drive to be turned on and off rapidly using the AC line without damage to the control and/or motor. The internal CL LED is a diagnostic indicator that lights when the motor is overloaded.

A conveniently located front panel lighted rocker switch controls AC line input power to the drive.

*Plug-in Horsepower Resistor® and armature fuse supplied separately.

TABLE 1 – GENERAL PERFORMANCE SPECIFICATIONS

Parameter	Specification
Speed Range Ratio	50:1
Armature Feedback Load Regulation (0 - Full Load, 50:1 Speed Range) (% Base Speed)	1**
Line Voltage Regulation at Full Load, ± 10% Line Variation (% Base Speed)	1/2**
Control Linearity (% Speed vs. Dial Rotation)	2
CL/Torque Range (% Full Load)	0 – 200
ACCEL Time Range (0 – Full Speed) (Secs.)	0.2 – 10
DECEL Time Range (Full – 0 Speed) (Secs.)	0.2 – 10
MIN Speed Trimpot Range (% Full Speed)	0 – 30**
MAX Speed Trimpot Range (% Full Speed)	50 – 110**
IR Comp. Trimpot Range (at Specified Full Load) (Volts)	0 – 24
Maximum Allowable Ambient Temperature at Full Rating (°C / °F)	50/122

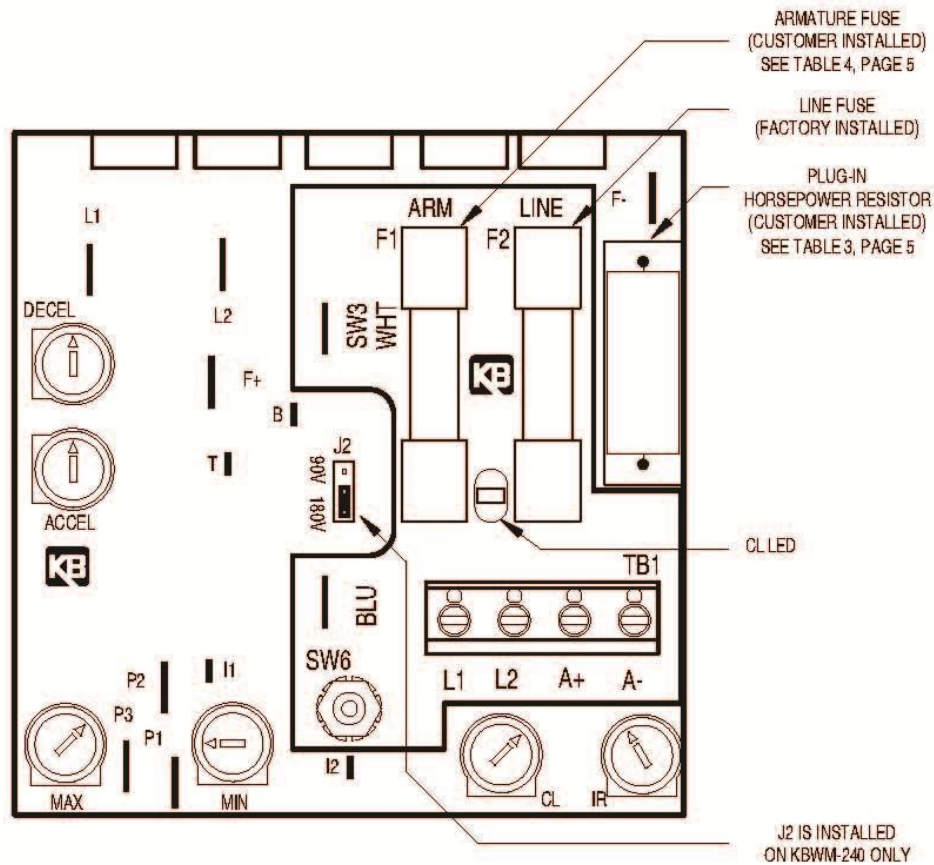
**Performance is for SCR rated PM motors only. Lower performance can be expected with other motor types. Factory setting is for 3% load regulation. To obtain superior regulation, see Section VI F on page 10.

TABLE 2 – ELECTRICAL RATINGS

Model No.	Part No.	Input Voltage (VAC - 50/60 Hz)	Max. AC Load Current (RMS Amps)	Armature Voltage (VDC)	Max. DC Load Current (DC Amps)	Max. Horsepower HP, (kW)
KBWM-120	9380	115	5.0	0 – 90	3.5	1/3, (0.25)
KBWM-240	9381	208/230	5.0	0 – 180	3.5	3/4, (0.50)
			5.0	0 – 90*	3.5	1/3, (0.25)

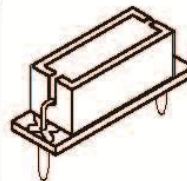
*Note – Step-down Operation: Motor may have reduced brush life. Consult motor manufacturer.

FIGURE 1 – CONTROL LAYOUT
(Illustrates Approximate Factory Setting of Trimpots and Jumper)



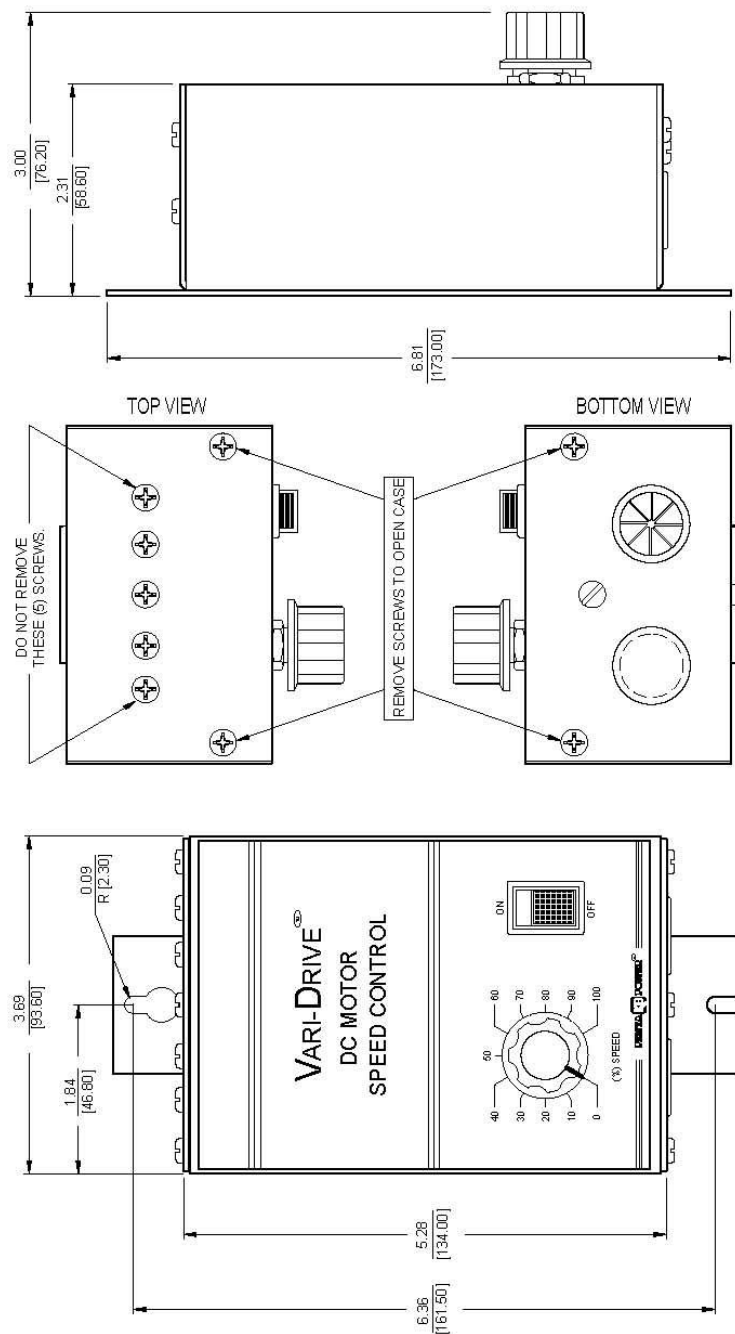
PLUG-IN HORSEPOWER RESISTOR

A Plug-In Horsepower Resistor® must be installed to match the drive to the motor horsepower and armature current. See Table 4, page 5 for the correct value. Plug-In Horsepower Resistors® are stocked by your distributor.



CAUTION: Be sure Plug-In Horsepower Resistor® is inserted completely into mating sockets.

FIGURE 2 – MECHANICAL SPECIFICATIONS (Inches / [mm])



II. CONTROL SETUP

Remove the four (4) 6x32 screws (two on top and two on the bottom) from the enclosure. Slide open the control by separating the front and rear covers. See Figure 2, page 4.

- A. Plug-in Horsepower Resistor®** – (Must be obtained from your distributor as a separate part.) The Plug-in Horsepower Resistor® is designed to match the control and motor without having to recalibrate the IR Comp. and CL for most applications. (Note: For recalibration of IR Comp. and CL see Section VI E, F on pages 9 and 10.) Using the Plug-in Horsepower Resistor® chart, choose the closest value based on motor horsepower and/or armature current. (See Table 3.)

TABLE 3 – PLUG-IN HORSEPOWER RESISTOR® CHART

90 VDC	180 VDC	Approx. Motor Current (DC Amps)	Plug-in Horsepower Resistor® Value (Ohms)	Individual Plug-in Horsepower® Resistor Part No.
Motor Horsepower Range				
1/100	1/50	0.1	1.0	9833
1/50	1/25	0.2	0.51	9834
1/30, 1/25	1/15	0.35	0.35	9835
1/20	1/10	0.5	0.25	9836
1/15, 1/12	1/6	0.8	0.18	9837
1/10, 1/8, 1/6	1/4	1.3	0.1	9838
1/4	1/2	2.5	0.05	9839
1/3	3/4	3.3	0.035	9840

Notes:

1. Motor horsepower and armature current must be specified in order to select correct Plug-in Horsepower Resistor®.
2. For motor horsepower not indicated, use the lower ohm value Plug-in Horsepower Resistor®.

- B. AC Line Fuse** – The KBWM™ contains a 5-Amp AC line fuse used to protect the control against catastrophic failure. If fuse blows, the control may be miswired, the motor is shorted or grounded, or the speed control module is defective. Replace with Littelfuse 326, Buss ABC or equivalent. Note: Bypassing or eliminating the fuse will void warranty.

CAUTION: Most electrical codes require that each ungrounded conductor contain fusing. Separate branch fusing or circuit breakers may be required on 208/230 VAC line.

- C. Armature Fuse** — The KBWM™ has provision for installing an armature fuse that helps protect the motor and control from damage due to overload. Armature fuses are 3 AG type and are available from your distributor.

Note: An armature fuse must be installed or control will not operate. Fuse value is calculated based on 1.7 times the DC current rating of the motor. See Table 4.

**TABLE 4 – ARMATURE FUSE
SELECTION CHART**

90 VDC	180 VDC	Approx. Motor Current (DC Amps)	Fuse Rating (AC Amps)
Motor Horsepower Range			
1/100	1/50	0.1	1/5
1/50	1/25	0.2	3/10
1/30	1/15	0.3	1/2
1/20	1/10	0.5	3/4
1/15	1/8	0.7	1
1/10	1/5	1.0	1½
1/8	1/4	1.3	2
1/6	1/3	1.7	3
1/4	1/2	2.5	4
1/3	3/4	3.3	5

Note: Specific applications may require a different fuse value than indicated. This is based on several factors such as ambient temperature.

D. **Jumper J2** is provided on Model KBWM-240 only and is factory set to "180V" position. For step-down operation (208/230 Volts AC line input and 0-90 Volts DC output), set J2 to the "90V" position. See Figure 3.

FIGURE 3 – MOTOR VOLTAGE SELECTION (MODEL KBWM-240 ONLY)

J2 Set for 180 Volt DC Motors (Factory Setting)	J2 Set for 90 Volt DC Motors (Step-Down)
	

III. MOUNTING

The KBWM™ is mounted via the rear cover mounting strap. Before attempting to wire the control, locate the mounting holes using the rear cover as a template or use the dimensions as shown in the outline drawing. (See Figure 2, page 4.) Be sure the control is mounted on a flat surface in a location where it will not be exposed to contaminants such as water, metal chips, solvents or excessive vibration and/or temperature extremes. Note: Allow adequate clearance around control to permit motor and AC power cables to enter through the Bx knockouts on bottom of enclosure.

When mounting in an airtight enclosure, the air space should be large enough to provide adequate heat dissipation. It is recommended that an enclosure with minimum dimensions of 12"H x 12"W x 6"D (300mm x 300mm x 150mm) be used. The maximum allowable ambient temperature at full rating is 50 °C (122 °F). Consult the Sales Department if more information is required.

Note: The KBWM™ can be oriented so that the AC power and motor wiring can be brought in from the top of the control. Mount the rear cover so that the Bx knockouts are located on the top by rotating the rear cover 180°. The front cover is then installed right side up using the four (4) 6x32 screws previously removed from the top and bottom of the enclosure.

After wiring the front cover, install the mating rear cover with the four (4) 6x32 screws previously removed from the top and bottom of enclosures.

IV. WIRING

Be sure the AC power is "off" before wiring control. Read Safety Warning on page 1 before attempting to use this control.

TABLE 5 – TERMINAL BLOCK WIRING INFORMATION

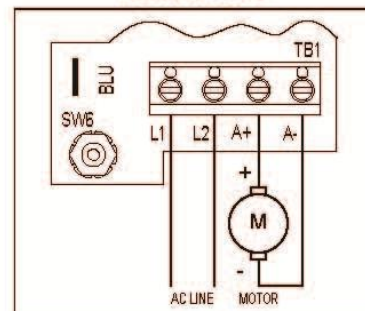
Terminal Block Designation	Connection Designation	Supply Wire Gauge		Maximum Tightening Torque (in-lbs)
		Minimum	Maximum	
TB1	L1, L2, A+, A-	22	14	3.5



WARNING! To avoid erratic operation, do not bundle AC line and motor wires with potentiometer, voltage following, enable, inhibit or other signal wiring. Use shielded cables on all signal wiring over 12" (30 cm) – The shield should be earth grounded on the control side only. Wire the control in accordance with the National Electrical Code requirements and other codes that may apply to your area.

A. AC Line – Wire the AC power to terminals L1 and L2. Be sure that the control model corresponds to the correct AC line input voltage. Model KBWM-120 is for 115 VAC 50/60 Hz and model KBWM-240 is for 208/230 VAC 50/60 Hz. See Figure 4.

FIGURE 4 – AC LINE & ARMATURE CONNECTION



Caution: If control is wired to a transformer, it is advisable to switch the secondary to disconnect power. If the primary is switched, additional snubber capacitors may have to be added across terminals L1 and L2 to prevent power bridge damage.

Separate branch fusing or circuit breaker may be required on 208/230 VAC applications. (See Section IV E, on page 8.)

- B. Motor Armature** – Wire the motor armature wires to terminals A+ and A-. Be sure the motor voltage corresponds to the control voltage rating. See Figure 4, on page 6. Note: If motor runs in opposite direction to what is required, turn power off and reverse armature leads.



WARNING! Do not wire a switch or relay in series with the armature leads. Armature switching can cause catastrophic failure of motor and/or control. If reversing or dynamic braking is required, consult the Sales Department.

- C. Ground (earth)** – Be sure to ground motor and control to green ground stud located between the Bx knockouts. See Figure 7, on page 11.

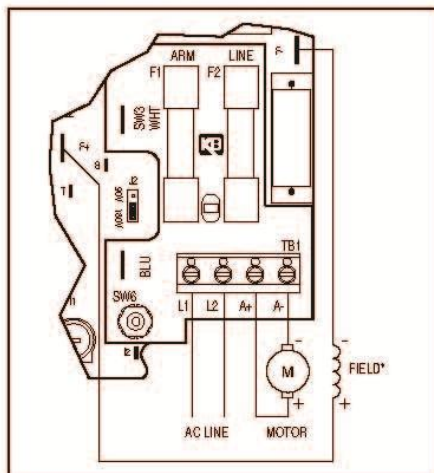
- D. Field (Shunt motors only)** – Do not use F+ and F- terminals for any other motor type. The KBWM™ control is primarily designed for permanent magnet (PM) motors. However, a shunt motor can also be controlled by wiring the shunt field directly to the 1/4" quick-disconnect terminals located on the main speed control module. See Figures 5A and 5B for the F+ and F- terminal locations. Attach motor field using insulated 1/4" Q-D female terminals. For Standard PM (2-wire) motors, the Field is not used.

CAUTION: Shunt-wound motors may be damaged if field remains connected without motor rotating for an extended period of time.

TABLE 6 – FIELD CONNECTION (Shunt Wound Motors Only)

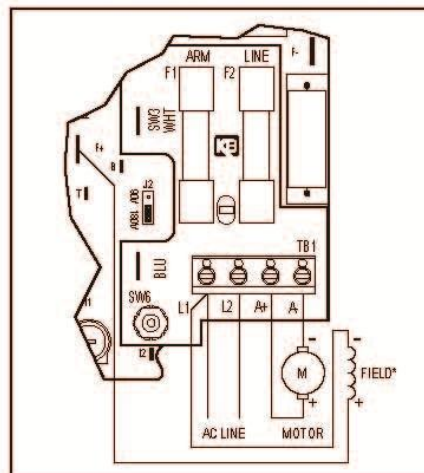
AC Line Voltage VAC	Motor Voltage	Field Voltage (Volts DC)	Field Connection
115	0 – 90	100	F+, F-
115	0 – 90	50	F+, L1
208/230	0 – 180	200	F+, F-
208/230	0 – 180	100	F+, L1
208/230	0 – 90	100	F+, L1

FIGURE 5A – FULL VOLTAGE FIELD



*Shunt motors only

FIGURE 5B – HALF VOLTAGE FIELD



E. Fusing – As indicated in Section IIB, the KBWM™ contains a single AC line fuse on 208/230 VAC applications. In the USA and other countries where the 208/230 volt is derived from two (2) “hot” leads, both AC lines should be connected to a separate dual circuit breaker. Do not fuse neutral or grounded connections.

F. AC Line Switch – The KBWM™ contains a double pole AC line switch which opens both legs of the AC line.

V. OPERATION

After wiring is complete, recheck connections to be sure they are correct. Also be sure correct armature fuse and Plug-in Horsepower Resistor® are installed. Turn main power on. Internal lamp in power switch should be lighted indicating control is receiving AC line voltage. Gradually increase main speed dial setting. Motor should rotate in proportion to dial setting.

Note: if motor runs in opposite direction to what is required, turn power off and reverse armature leads.



WARNING! If control is operated with cover off, be sure to wear safety glasses and use insulated tools if any adjustments are to be made.

CL LED – A red light-emitting diode (LED) can be found on the speed control PC board. It lights when the current limit circuit activates, indicating an overload condition. This is normal when the motor accelerates to full speed or when a transient peak load condition exists. However, if the LED lights continuously, a severe overload condition may exist. A DC ammeter should be installed in series with either armature lead to observe motor current during actual operation. (See Safety Warning on page 1.) If the actual DC current exceeds the motor rating, a higher horsepower motor should be used. If actual current is equal to or less than the rated motor current, the CL adjustment may be incorrect, or the Plug-in Horsepower Resistor® value may be too high. Refer to the CL trimpot adjustment procedure and the Plug-in Horsepower Resistor® chart on page 5.

VI. TRIMPOT ADJUSTMENTS AND CONTROL FUNCTIONS



WARNING! If adjustments are made under power, insulated adjustment tools must be used and eye protection must be worn.

The KBWM™ has been factory adjusted to provide 0 - full speed using the speed control knob. Minimum (MIN) and Maximum (MAX) speed trimpots are provided to change the speed settings. The acceleration (ACCEL) trimpot is provided to allow for a smooth start over an adjustable time period each time the AC power is applied or the Main Speed Potentiometer is rotated. The DECEL trimpot controls the amount of ramp-down time when the Main Speed Potentiometer is adjusted to a lower speed. The Current Limit (CL, or torque output) adjustment is factory set to approximately 1.5 times the motor rating. The IR Compensation (IR) is factory adjusted to provide excellent motor regulation under normal operation.

Note: For the IR Comp. and CL trimpot settings to be correct, the proper Plug-in Horsepower Resistor® must be installed. (See Table 3 on page 5.) Do not attempt to change the settings of the trimpots unless absolutely necessary since they are factory adjusted to near optimum settings.

The following procedure, presented in order of adjustment sequence, should be used when readjusting all trimpot functions:

A. Acceleration Start – The ACCEL is factory set at approximately 2 seconds. To readjust to different times, set the knob to the desired position as shown in Figure 6A.

B. Deceleration – The DECEL is factory set to provide a ramp-down time of 2 seconds. To change the ramp-down time, adjust the DECEL trimpot as indicated in Figure 6B.

C. Minimum Speed Adjustment – If a higher than zero minimum speed is needed, readjust the minimum speed by turning the speed control knob to zero setting (full CCW position). Then adjust the MIN speed trimpot to the desired setting.

Note: The minimum speed adjustment will affect the maximum speed setting. Therefore, it is necessary to readjust the maximum speed after the minimum speed.

D. Maximum Speed Adjustment – Turn Speed Control Knob to full speed (full CW position). Adjust MAX speed trimpot to new desired setting.

Note: Do not attempt to adjust the maximum speed above the rated motor RPM since unstable motor operation may occur. For moderate changes in the maximum speed, there will only be a slight effect on the minimum speed setting.

E. Current Limit (CL/Torque Adjustment) – CL circuitry is provided to protect the motor and control against overloads. The CL also limits the inrush current to a safe level during startup. The CL is factory set to approximately 1.5 times the full load rating of the motor. (CL trimpot is nominally set to approximately 65% of full CW rotation.) **Note:** Proper size Plug-in Horsepower Resistor® must be installed.

To set the CL to factory specifications adjust as follows:

1. Set speed control knob at approximately 30 - 50% CW rotation. Set CL trimpot to full CCW position.
2. Connect a DC ammeter in series with the armature lead.
3. Lock shaft of motor (be sure CL pot is in full CCW position). Apply power and rotate CL pot CW until DC ammeter reads 1.5 times motor rating. (Do not exceed 2 times motor rating.) Do not leave motor in locked rotor position for more than a few seconds or damage may occur. **Note:** The CL LED will illuminate when the control is in current limit.

FIGURE 6A – ACCEL TRIMPOT ADJUSTMENT

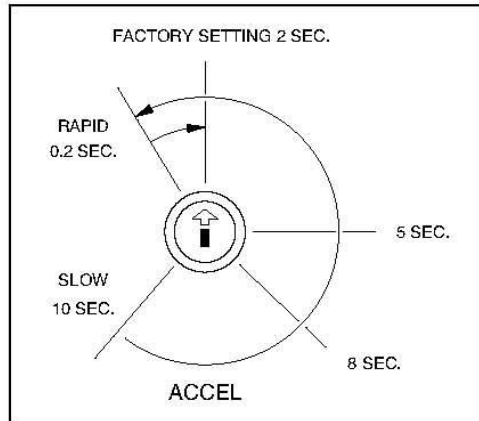
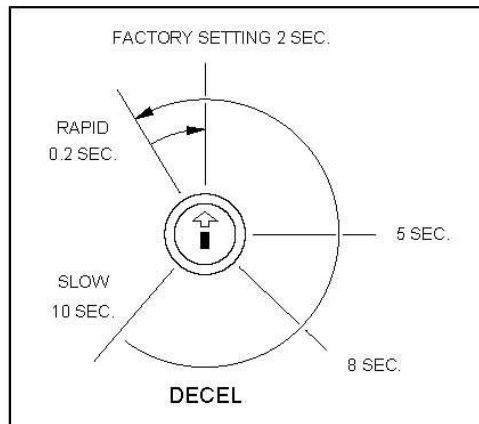


FIGURE 6B – DECEL TRIMPOT ADJUSTMENT



Note: If only an AC ammeter is available, it can be installed in series with AC input line. Follow above instructions; however, set AC amperage at 0.75 motor rating.

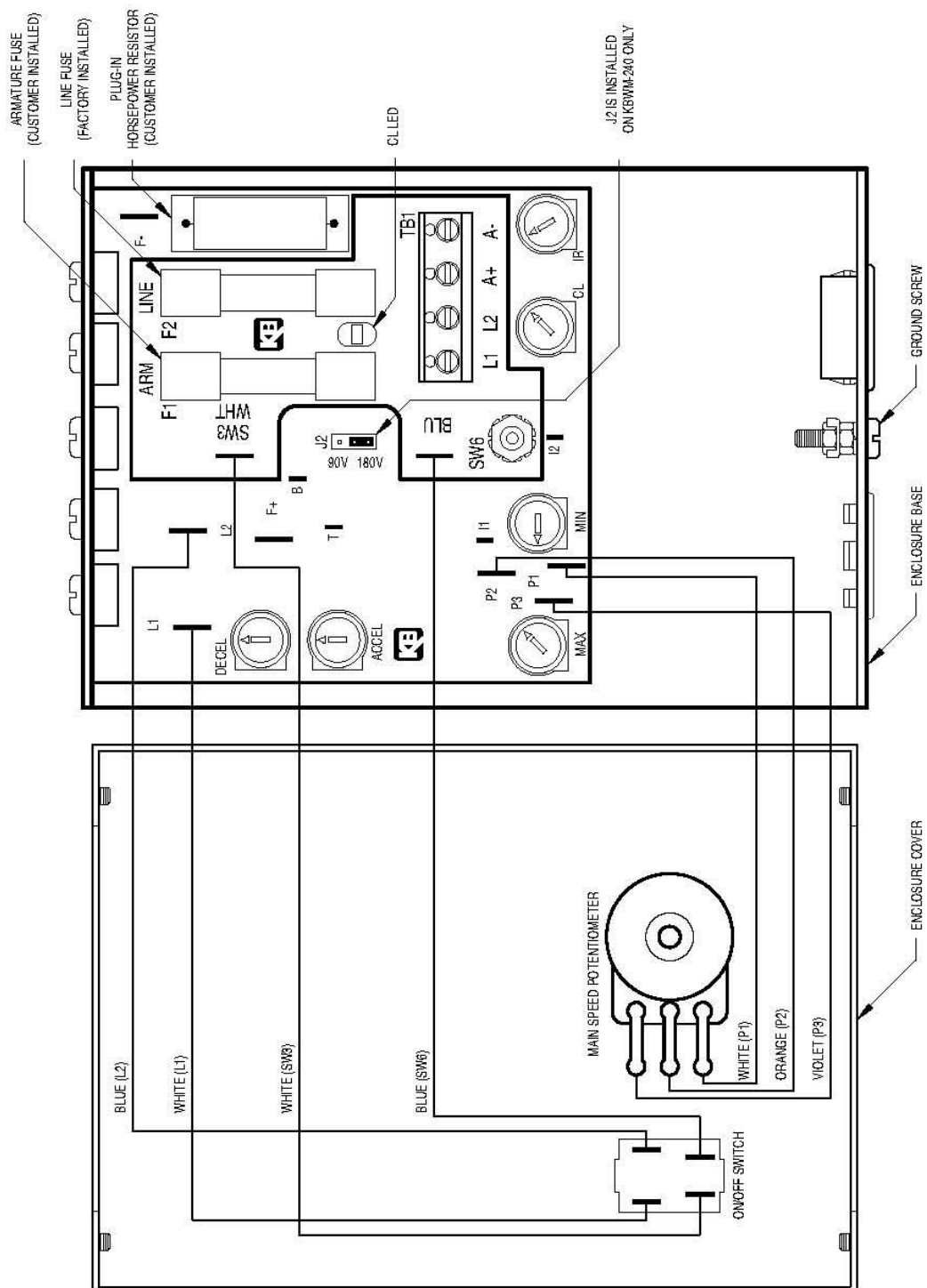
F. IR Compensation Adjustment – IR compensation is provided to improve load regulation. If the load presented to the motor does not vary substantially, the IR adjustment may be set at a minimum level (approximately 1/4 of full setting). The control is factory adjusted to approximately 3% regulation. If superior performance is needed (less than 1% speed change of base speed from 0 - full load), then the IR Comp. should be adjusted as follows:

Note: Excessive IR Comp. will cause control to become unstable, which causes motor cogging.

1. Set IR Comp. trimpot at approximately 25% of CW rotation. Run motor unloaded at approximately 1/3 speed and record RPM.
2. Run motor with maximum load and adjust IR Comp. trimpot so that the motor speed under load equals the unloaded speed per step 1.
3. Remove load and recheck unloaded RPM. If unloaded RPM has shifted, repeat procedure for more exact regulation.

The control is now compensated to provide minimal speed change under large variations of applied load.

FIGURE 7 – INTERNAL CONNECTION DIAGRAM



VII. LIMITED WARRANTY

For a period of 18 months from the date of original purchase, KB Electronics, Inc. will repair or replace, without charge, devices which our examination proves to be defective in material or workmanship. This warranty is valid if the unit has not been tampered with by unauthorized persons, misused, abused, or improperly installed and has been used in accordance with the instructions and/or ratings supplied. The foregoing is in lieu of any other warranty or guarantee, expressed or implied. KB Electronics, Inc. is not responsible for any expense, including installation and removal, inconvenience, or consequential damage, including injury to any person, caused by items of our manufacture or sale. Some states do not allow certain exclusions or limitations found in this warranty and therefore they may not apply to you. In any event, the total liability of KB Electronics, Inc., under any circumstance, shall not exceed the full purchase price of this product. (rev 2/2000)



KB Electronics, Inc.

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www.kbelectronics.com

(A40275) – Rev. C – 6/2001

SONGLE RELAY

	RELAY ISO9002	SRD
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1. MAIN FEATURES

- Switching capacity available by 10A in spite of small size design for highdensity P.C. board mounting technique.
- UL,CUL,TUV recognized.
- Selection of plastic material for high temperature and better chemical solution performance.
- Sealed types available.
- Simple relay magnetic circuit to meet low cost of mass production.

2. APPLICATIONS

- Domestic appliance, office machine, audio, equipment, automobile, etc.
(Remote control TV receiver, monitor display, audio equipment high rushing current use application.)

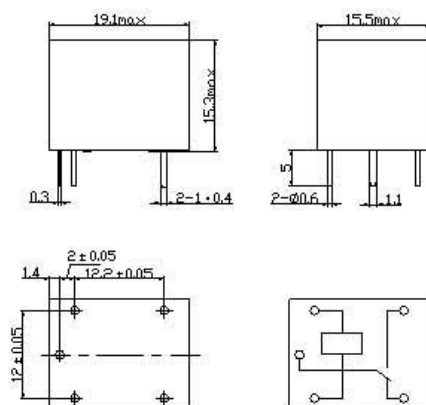
3. ORDERING INFORMATION

SRD	XX VDC	S	L	C
Model of relay	Nominal coil voltage	Structure	Coil sensitivity	Contact form
SRD	03、05、06、09、12、24、48VDC	S:Sealed type	L:0.36W	A:1 form A
		F:Flux free type	D:0.45W	B:1 form B
				C:1 form C

4. RATING

CCC	FILE NUMBER:CH0052885-2000	7A/240VDC
CCC	FILE NUMBER:CH0036746-99	10A/250VDC
UL/CUL	FILE NUMBER: E167996	10A/125VAC 28VDC
TUV	FILE NUMBER: R9933789	10A/240VAC 28VDC

5. DIMENSION (unit:mm) DRILLING (unit:mm) WIRING DIAGRAM



6. COIL DATA CHART (AT20°C)

Coil Sensitivity	Coil Voltage Code	Nominal Voltage (VDC)	Nominal Current (mA)	Coil Resistance (Ω) $\pm 10\%$	Power Consumption (W)	Pull-In Voltage (VDC)	Drop-Out Voltage (VDC)	Max-Allowable Voltage (VDC)
SRD (High Sensitivity)	03	03	120	25	abt. 0.36W	75%Max.	10% Min.	120%
	05	05	71.4	70				
	06	06	60	100				
	09	09	40	225				
	12	12	30	400				
	24	24	15	1600				
SRD (Standard)	48	48	7.5	6400	abt. 0.45W	75% Max.	10% Min.	110%
	03	03	150	20				
	05	05	89.3	55				
	06	06	75	80				
	09	09	50	180				
	12	12	37.5	320				
	24	24	18.7	1280	abt. 0.51W			
	48	48	10	4500				

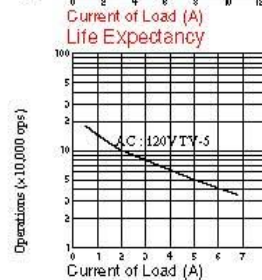
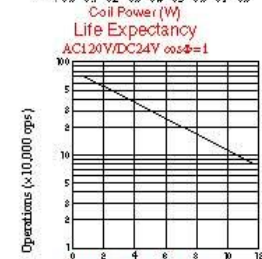
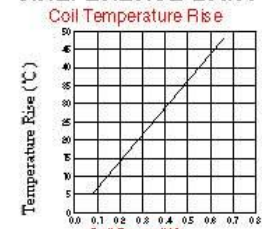
7. CONTACT RATING

Item	Type	SRD	
		FORM C	FORM A
Contact Capacity		7A 28VDC	10A 28VDC
Resistive Load ($\cos\Phi=1$)		10A 125VAC	10A 240VAC
		7A 240VAC	
Inductive Load		3A 120VAC	5A 120VAC
($\cos\Phi=0.4$ L/R=7msec)		3A 28VDC	5A 28VDC
Max. Allowable Voltage		250VAC/110VDC	250VAC/110VDC
Max. Allowable Power Force		800VAC/240W	1200VA/300W
Contact Material		AgCdO	AgCdO

8. PERFORMANCE (at initial value)

Item	Type	SRD	
Contact Resistance		100m Ω Max.	
Operation Time		10msec Max.	
Release Time		5msec Max.	
Dielectric Strength			
Between coil & contact		1500VAC 50/60HZ (1 minute)	
Between contacts		1000VAC 50/60HZ (1 minute)	
Insulation Resistance		100 M Ω Min. (500VDC)	
Max. ON/OFF Switching			
Mechanically		300 operation/min	
Electrically		30 operation/min	
Ambient Temperature		-25°C to +70°C	
Operating Humidity		45 to 85% RH	
Vibration			
Endurance		10 to 55Hz Double Amplitude 1.5mm	
Error Operation		10 to 55Hz Double Amplitude 1.5mm	
Shock			
Endurance		100G Min.	
Error Operation		10G Min.	
Life Expectancy			
Mechanically		10 ⁷ operations. Min. (no load)	
Electrically		10 ⁵ operations. Min. (at rated coil voltage)	
Weight		abt. 10grs.	

9. REFERENCE DATA



Features

- High Performance, Low Power AVR[®] 8-Bit Microcontroller
- Advanced RISC Architecture
 - 131 Powerful Instructions – Most Single Clock Cycle Execution
 - 32 x 8 General Purpose Working Registers
 - Fully Static Operation
 - Up to 20 MIPS Throughput at 20 MHz
 - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
 - 4/8/16/32K Bytes of In-System Self-Programmable Flash program memory (ATmega48PA/88PA/168PA/328P)
 - 256/512/512/1K Bytes EEPROM (ATmega48PA/88PA/168PA/328P)
 - 512/1K/1K/2K Bytes Internal SRAM (ATmega48PA/88PA/168PA/328P)
 - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
 - Data retention: 20 years at 85°C/100 years at 25°C⁽¹⁾
 - Optional Boot Code Section with Independent Lock Bits
 - In-System Programming by On-chip Boot Program
 - True Read-While-Write Operation
 - Programming Lock for Software Security
- Peripheral Features
 - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
 - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
 - Real Time Counter with Separate Oscillator
 - Six PWM Channels
 - 8-channel 10-bit ADC in TQFP and QFN/MLF package
 - Temperature Measurement
 - 6-channel 10-bit ADC in PDIP Package
 - Temperature Measurement
 - Programmable Serial USART
 - Master/Slave SPI Serial Interface
 - Byte-oriented 2-wire Serial Interface (Philips I²C compatible)
 - Programmable Watchdog Timer with Separate On-chip Oscillator
 - On-chip Analog Comparator
 - Interrupt and Wake-up on Pin Change
- Special Microcontroller Features
 - Power-on Reset and Programmable Brown-out Detection
 - Internal Calibrated Oscillator
 - External and Internal Interrupt Sources
 - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby
- I/O and Packages
 - 23 Programmable I/O Lines
 - 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF
- Operating Voltage:
 - 1.8 - 5.5V for ATmega48PA/88PA/168PA/328P
- Temperature Range:
 - -40°C to 85°C
- Speed Grade:
 - 0 - 20 MHz @ 1.8 - 5.5V
- Low Power Consumption at 1 MHz, 1.8V, 25°C for ATmega48PA/88PA/168PA/328P:
 - Active Mode: 0.2 mA
 - Power-down Mode: 0.1 µA
 - Power-save Mode: 0.75 µA (Including 32 kHz RTC)



8-bit AVR[®]
Microcontroller
with 4/8/16/32K
Bytes In-System
Programmable
Flash

ATmega48PA
ATmega88PA
ATmega168PA
ATmega328P

Summary

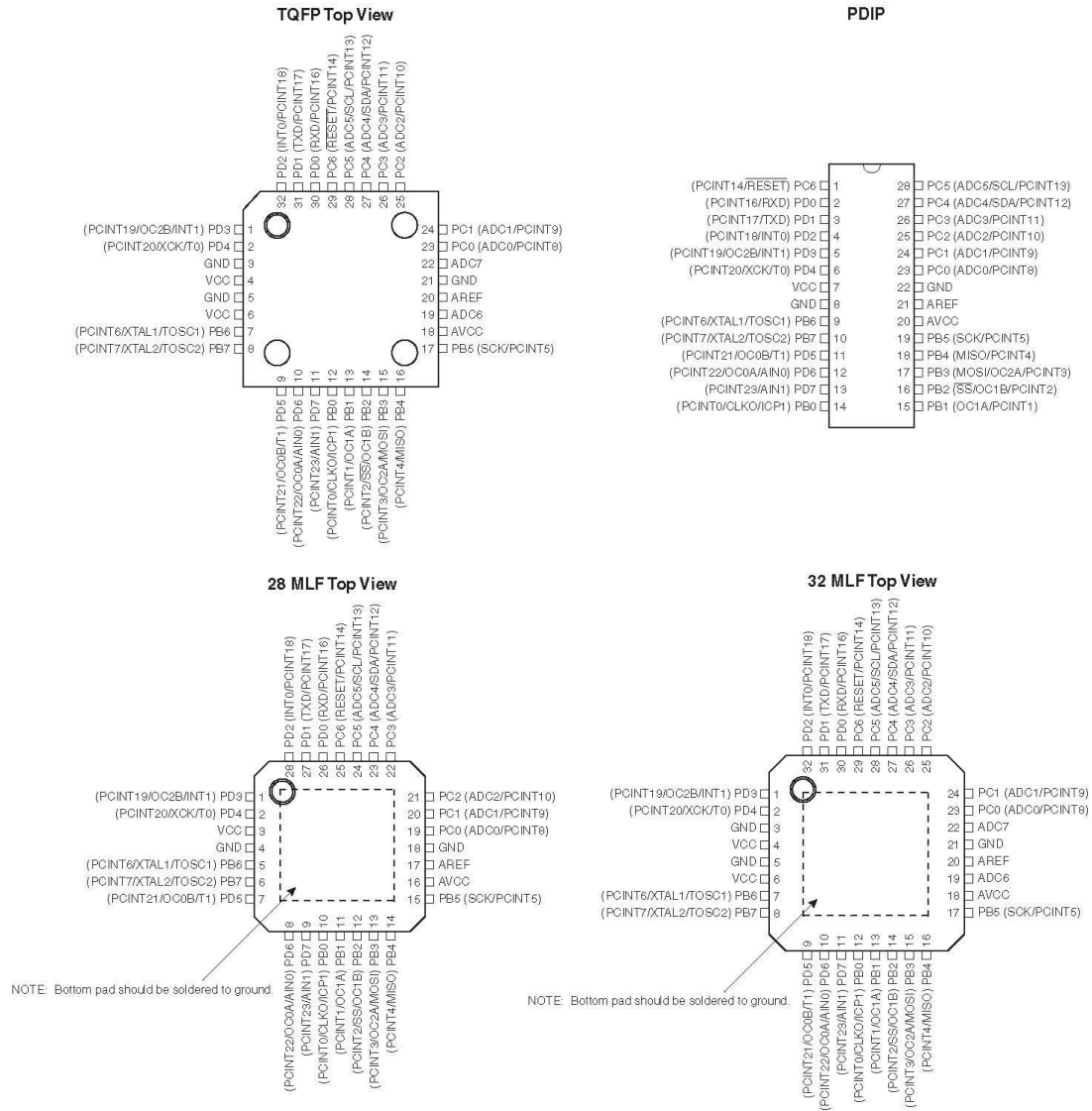
Rev. 8161CS-AVR-05/09



ATmega48PA/88PA/168PA/328P

1. Pin Configurations

Figure 1-1. Pinout ATmega48PA/88PA/168PA/328P



1.1 Pin Descriptions**1.1.1 VCC**

Digital supply voltage.

1.1.2 GND

Ground.

1.1.3 Port B (PB7:0) XTAL1/XTAL2/TOSC1/TOSC2

Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Depending on the clock selection fuse settings, PB6 can be used as input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

Depending on the clock selection fuse settings, PB7 can be used as output from the inverting Oscillator amplifier.

If the Internal Calibrated RC Oscillator is used as chip clock source, PB7..6 is used as TOSC2..1 input for the Asynchronous Timer/Counter2 if the AS2 bit in ASSR is set.

The various special features of Port B are elaborated in ["Alternate Functions of Port B" on page 76](#) and ["System Clock and Clock Options" on page 26](#).

1.1.4 Port C (PC5:0)

Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The PC5..0 output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

1.1.5 PC6/RESET

If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin. Note that the electrical characteristics of PC6 differ from those of the other pins of Port C.

If the RSTDISBL Fuse is unprogrammed, PC6 is used as a Reset input. A low level on this pin for longer than the minimum pulse length will generate a Reset, even if the clock is not running. The minimum pulse length is given in [Table 28-3 on page 308](#). Shorter pulses are not guaranteed to generate a Reset.

The various special features of Port C are elaborated in ["Alternate Functions of Port C" on page 79](#).

1.1.6 Port D (PD7:0)

Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

ATmega48PA/88PA/168PA/328P

The various special features of Port D are elaborated in "[Alternate Functions of Port D](#)" on page 82.

1.1.7 AV_{CC}

AV_{CC} is the supply voltage pin for the A/D Converter, PC3:0, and ADC7:6. It should be externally connected to V_{CC} , even if the ADC is not used. If the ADC is used, it should be connected to V_{CC} through a low-pass filter. Note that PC6..4 use digital supply voltage, V_{CC} .

1.1.8 AREF

AREF is the analog reference pin for the A/D Converter.

1.1.9 ADC7:6 (TQFP and QFN/MLF Package Only)

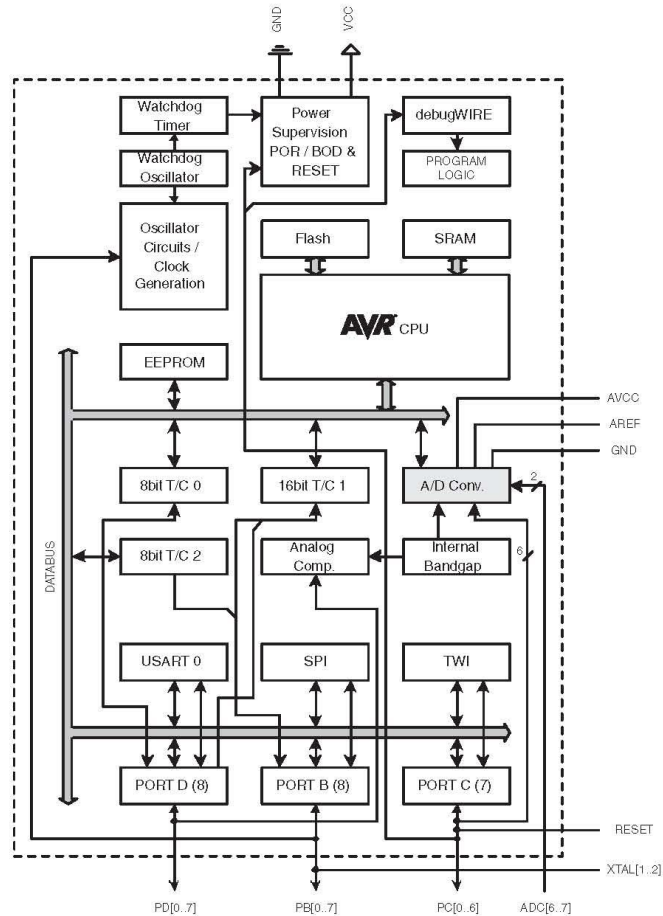
In the TQFP and QFN/MLF package, ADC7:6 serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels.

2. Overview

The ATmega48PA/88PA/168PA/328P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega48PA/88PA/168PA/328P achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

2.1 Block Diagram

Figure 2-1. Block Diagram



The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting

ATmega48PA/88PA/168PA/328P

architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

The ATmega48PA/88PA/168PA/328P provides the following features: 4/8/16/32K bytes of In-System Programmable Flash with Read-While-Write capabilities, 256/512/512/1K bytes EEPROM, 512/1K/1K/2K bytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte-oriented 2-wire Serial Interface, an SPI serial port, a 6-channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages), a programmable Watchdog Timer with internal Oscillator, and five software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, USART, 2-wire Serial Interface, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or hardware reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low power consumption.

The device is manufactured using Atmel's high density non-volatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, by a conventional non-volatile memory programmer, or by an On-chip Boot program running on the AVR core. The Boot program can use any interface to download the application program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega48PA/88PA/168PA/328P is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATmega48PA/88PA/168PA/328P AVR is supported with a full suite of program and system development tools including: C Compilers, Macro Assemblers, Program Debugger/Simulators, In-Circuit Emulators, and Evaluation kits.

2.2 Comparison Between ATmega48PA, ATmega88PA, ATmega168PA and ATmega328P

The ATmega48PA, ATmega88PA, ATmega168PA and ATmega328P differ only in memory sizes, boot loader support, and interrupt vector sizes. [Table 2-1](#) summarizes the different memory and interrupt vector sizes for the three devices.

Table 2-1. Memory Size Summary

Device	Flash	EEPROM	RAM	Interrupt Vector Size
ATmega48PA	4K Bytes	256 Bytes	512 Bytes	1 instruction word/vector
ATmega88PA	8K Bytes	512 Bytes	1K Bytes	1 instruction word/vector
ATmega168PA	16K Bytes	512 Bytes	1K Bytes	2 instruction words/vector
ATmega328P	32K Bytes	1K Bytes	2K Bytes	2 instruction words/vector

ATmega88PA, ATmega168PA and ATmega328P support a real Read-While-Write Self-Programming mechanism. There is a separate Boot Loader Section, and the SPM instruction can only execute from there. In ATmega48PA, there is no Read-While-Write support and no separate Boot Loader Section. The SPM instruction can execute from the entire Flash.

3. Resources

A comprehensive set of development tools, application notes and datasheets are available for download on <http://www.atmel.com/avr>.

4. Data Retention

Reliability Qualification results show that the projected data retention failure rate is much less than 1 PPM over 20 years at 85°C or 100 years at 25°C.

5. Register Summary

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0xFF)	Reserved	—	—	—	—	—	—	—	—	
(0xFE)	Reserved	—	—	—	—	—	—	—	—	
(0xFD)	Reserved	—	—	—	—	—	—	—	—	
(0xFC)	Reserved	—	—	—	—	—	—	—	—	
(0xFB)	Reserved	—	—	—	—	—	—	—	—	
(0xFA)	Reserved	—	—	—	—	—	—	—	—	
(0xF9)	Reserved	—	—	—	—	—	—	—	—	
(0xF8)	Reserved	—	—	—	—	—	—	—	—	
(0xF7)	Reserved	—	—	—	—	—	—	—	—	
(0xF6)	Reserved	—	—	—	—	—	—	—	—	
(0xF5)	Reserved	—	—	—	—	—	—	—	—	
(0xF4)	Reserved	—	—	—	—	—	—	—	—	
(0xF3)	Reserved	—	—	—	—	—	—	—	—	
(0xF2)	Reserved	—	—	—	—	—	—	—	—	
(0xF1)	Reserved	—	—	—	—	—	—	—	—	
(0xF0)	Reserved	—	—	—	—	—	—	—	—	
(0xEF)	Reserved	—	—	—	—	—	—	—	—	
(0xEE)	Reserved	—	—	—	—	—	—	—	—	
(0xED)	Reserved	—	—	—	—	—	—	—	—	
(0xEC)	Reserved	—	—	—	—	—	—	—	—	
(0xEB)	Reserved	—	—	—	—	—	—	—	—	
(0xEA)	Reserved	—	—	—	—	—	—	—	—	
(0xE9)	Reserved	—	—	—	—	—	—	—	—	
(0xE8)	Reserved	—	—	—	—	—	—	—	—	
(0xE7)	Reserved	—	—	—	—	—	—	—	—	
(0xE6)	Reserved	—	—	—	—	—	—	—	—	
(0xE5)	Reserved	—	—	—	—	—	—	—	—	
(0xE4)	Reserved	—	—	—	—	—	—	—	—	
(0xE3)	Reserved	—	—	—	—	—	—	—	—	
(0xE2)	Reserved	—	—	—	—	—	—	—	—	
(0xE1)	Reserved	—	—	—	—	—	—	—	—	
(0xE0)	Reserved	—	—	—	—	—	—	—	—	
(0xDF)	Reserved	—	—	—	—	—	—	—	—	
(0xDE)	Reserved	—	—	—	—	—	—	—	—	
(0xDD)	Reserved	—	—	—	—	—	—	—	—	
(0xDC)	Reserved	—	—	—	—	—	—	—	—	
(0xDB)	Reserved	—	—	—	—	—	—	—	—	
(0xDA)	Reserved	—	—	—	—	—	—	—	—	
(0xD9)	Reserved	—	—	—	—	—	—	—	—	
(0xD8)	Reserved	—	—	—	—	—	—	—	—	
(0xD7)	Reserved	—	—	—	—	—	—	—	—	
(0xD6)	Reserved	—	—	—	—	—	—	—	—	
(0xD5)	Reserved	—	—	—	—	—	—	—	—	
(0xD4)	Reserved	—	—	—	—	—	—	—	—	
(0xD3)	Reserved	—	—	—	—	—	—	—	—	
(0xD2)	Reserved	—	—	—	—	—	—	—	—	
(0xD1)	Reserved	—	—	—	—	—	—	—	—	
(0xD0)	Reserved	—	—	—	—	—	—	—	—	
(0xCF)	Reserved	—	—	—	—	—	—	—	—	
(0xCE)	Reserved	—	—	—	—	—	—	—	—	
(0xCD)	Reserved	—	—	—	—	—	—	—	—	
(0xCC)	Reserved	—	—	—	—	—	—	—	—	
(0xCB)	Reserved	—	—	—	—	—	—	—	—	
(0xCA)	Reserved	—	—	—	—	—	—	—	—	
(0xC9)	Reserved	—	—	—	—	—	—	—	—	
(0xC8)	Reserved	—	—	—	—	—	—	—	—	
(0xC7)	Reserved	—	—	—	—	—	—	—	—	
(0xC6)	UDR0	USART I/O Data Register								189
(0xC5)	UBRR0H					USART Baud Rate Register High				193
(0xC4)	UBRR0L	USART Baud Rate Register Low								193
(0xC3)	Reserved	—	—	—	—	—	—	—	—	
(0xC2)	UCSR0C	UMSEL01	UMSEL00	UPM01	UPM00	USBS0	UCSZ01/AUDORD0	UCSZ00/UCPHA0	UCPOL0	191/206

ATmega48PA/88PA/168PA/328P

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0xC1)	UCSR0B	RXCIE0	TXCIE0	UDRIE0	RXEN0	TXEN0	UCSZ02	RXB80	TXB80	190
(0xC0)	UCSR0A	RXC0	TXC0	UDRE0	FE0	DOR0	UPF0	U2X0	MPCM0	189
(0xBF)	Reserved	—	—	—	—	—	—	—	—	
(0xBE)	Reserved	—	—	—	—	—	—	—	—	
(0xBD)	TWAMR	TWAM6	TWAM5	TWAM4	TWAM3	TWAM2	TWAM1	TWAM0	—	239
(0xBC)	TWCR	TWINT	TWEA	TWSTA	TWSTO	TWWC	TWEN	—	TWIE	236
(0xBB)	TWDR	2-wire Serial Interface Data Register								238
(0xBA)	TWAR	TWA6	TWA5	TWA4	TWA3	TWA2	TWA1	TWA0	TWGCE	239
(0xB9)	TWSR	TWS7	TWS6	TWS5	TWS4	TWS3	—	TWPS1	TWPS0	238
(0xB8)	TWBR	2-wire Serial Interface Bit Rate Register								236
(0xB7)	Reserved	—	—	—	—	—	—	—	—	
(0xB6)	ASSR	—	EXCLK	AS2	TCN2UB	OCR2AUB	OCR2BUB	TCR2AUB	TCR2BUB	158
(0xB5)	Reserved	—	—	—	—	—	—	—	—	
(0xB4)	OCR2B	Timer/Counter2 Output Compare Register B								156
(0xB3)	OCR2A	Timer/Counter2 Output Compare Register A								156
(0xB2)	TCNT2	Timer/Counter2 (8-bit)								156
(0xB1)	TCR2B	FOC2A	FOC2B	—	—	WGM22	CS22	CS21	CS20	155
(0xB0)	TCR2A	COM2A1	COM2A0	COM2B1	COM2B0	—	—	WGM21	WGM20	152
(0xAF)	Reserved	—	—	—	—	—	—	—	—	
(0xAE)	Reserved	—	—	—	—	—	—	—	—	
(0xAD)	Reserved	—	—	—	—	—	—	—	—	
(0xAC)	Reserved	—	—	—	—	—	—	—	—	
(0xAB)	Reserved	—	—	—	—	—	—	—	—	
(0xAA)	Reserved	—	—	—	—	—	—	—	—	
(0xA9)	Reserved	—	—	—	—	—	—	—	—	
(0xA8)	Reserved	—	—	—	—	—	—	—	—	
(0xA7)	Reserved	—	—	—	—	—	—	—	—	
(0xA6)	Reserved	—	—	—	—	—	—	—	—	
(0xA5)	Reserved	—	—	—	—	—	—	—	—	
(0xA4)	Reserved	—	—	—	—	—	—	—	—	
(0xA3)	Reserved	—	—	—	—	—	—	—	—	
(0xA2)	Reserved	—	—	—	—	—	—	—	—	
(0xA1)	Reserved	—	—	—	—	—	—	—	—	
(0xA0)	Reserved	—	—	—	—	—	—	—	—	
(0x9F)	Reserved	—	—	—	—	—	—	—	—	
(0x9E)	Reserved	—	—	—	—	—	—	—	—	
(0x9D)	Reserved	—	—	—	—	—	—	—	—	
(0x9C)	Reserved	—	—	—	—	—	—	—	—	
(0x9B)	Reserved	—	—	—	—	—	—	—	—	
(0x9A)	Reserved	—	—	—	—	—	—	—	—	
(0x99)	Reserved	—	—	—	—	—	—	—	—	
(0x98)	Reserved	—	—	—	—	—	—	—	—	
(0x97)	Reserved	—	—	—	—	—	—	—	—	
(0x96)	Reserved	—	—	—	—	—	—	—	—	
(0x95)	Reserved	—	—	—	—	—	—	—	—	
(0x94)	Reserved	—	—	—	—	—	—	—	—	
(0x93)	Reserved	—	—	—	—	—	—	—	—	
(0x92)	Reserved	—	—	—	—	—	—	—	—	
(0x91)	Reserved	—	—	—	—	—	—	—	—	
(0x90)	Reserved	—	—	—	—	—	—	—	—	
(0x8F)	Reserved	—	—	—	—	—	—	—	—	
(0x8E)	Reserved	—	—	—	—	—	—	—	—	
(0x8D)	Reserved	—	—	—	—	—	—	—	—	
(0x8C)	Reserved	—	—	—	—	—	—	—	—	
(0x8B)	OCR1BH	Timer/Counter1 - Output Compare Register B High Byte								132
(0x8A)	OCR1BL	Timer/Counter1 - Output Compare Register B Low Byte								132
(0x89)	OCR1AH	Timer/Counter1 - Output Compare Register A High Byte								132
(0x88)	OCR1AL	Timer/Counter1 - Output Compare Register A Low Byte								132
(0x87)	ICR1H	Timer/Counter1 - Input Capture Register High Byte								133
(0x86)	ICR1L	Timer/Counter1 - Input Capture Register Low Byte								133
(0x85)	TCNT1H	Timer/Counter1 - Counter Register High Byte								132
(0x84)	TCNT1L	Timer/Counter1 - Counter Register Low Byte								132
(0x83)	Reserved	—	—	—	—	—	—	—	—	
(0x82)	TCR1C	FOC1A	FOC1B	—	—	—	—	—	—	131
(0x81)	TCR1B	ICNC1	ICES1	—	WGM13	WGM12	CS12	CS11	CS10	130
(0x80)	TCR1A	COM1A1	COM1A0	COM1B1	COM1B0	—	—	WGM11	WGM10	128

ATmega48PA/88PA/168PA/328P

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0x7F)	DIDR1	—	—	—	—	—	—	AIN1D	AIN0D	244
(0x7E)	DIDR0	—	—	ADCS0	ADC4D	ADC3D	ADC2D	ADC1D	ADC0D	261
(0x7D)	Reserved	—	—	—	—	—	—	—	—	
(0x7C)	ADMUX	REFS1	REFS0	ADLAR	—	MUX3	MUX2	MUX1	MUX0	257
(0x7B)	ADCSRB	—	ACME	—	—	—	ADTS2	ADTS1	ADTS0	260
(0x7A)	ADCSRA	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0	258
(0x79)	ADCH	ADC Data Register High byte								260
(0x78)	ADCL	ADC Data Register Low byte								260
(0x77)	Reserved	—	—	—	—	—	—	—	—	
(0x76)	Reserved	—	—	—	—	—	—	—	—	
(0x75)	Reserved	—	—	—	—	—	—	—	—	
(0x74)	Reserved	—	—	—	—	—	—	—	—	
(0x73)	Reserved	—	—	—	—	—	—	—	—	
(0x72)	Reserved	—	—	—	—	—	—	—	—	
(0x71)	Reserved	—	—	—	—	—	—	—	—	
(0x70)	TIMSK2	—	—	—	—	—	OCIE2B	OCIE2A	TOIE2	157
(0x6F)	TIMSK1	—	—	IOIE1	—	—	OCIE1B	OCIE1A	TOIE1	193
(0x6E)	TIMSK0	—	—	—	—	—	OCIE0B	OCIE0A	TOIE0	105
(0x6D)	PCMSK2	PCINT23	PCINT22	PCINT21	PCINT20	PCINT19	PCINT18	PCINT17	PCINT16	68
(0x6C)	PCMSK1	—	PCINT14	PCINT13	PCINT12	PCINT11	PCINT10	PCINT9	PCINT8	68
(0x6B)	PCMSK0	PCINT7	PCINT6	PCINT5	PCINT4	PCINT3	PCINT2	PCINT1	PCINT0	68
(0x6A)	Reserved	—	—	—	—	—	—	—	—	
(0x69)	EICRA	—	—	—	—	ISC11	ISC10	ISC01	ISC00	65
(0x68)	PCICR	—	—	—	—	—	PCIE2	PCIE1	PCIE0	
(0x67)	Reserved	—	—	—	—	—	—	—	—	
(0x66)	OSCCAL	Oscillator Calibration Register								37
(0x65)	Reserved	—	—	—	—	—	—	—	—	
(0x64)	PRR	PRTW1	PRTIM2	PRTIM0	—	PRTIM1	PRSPI	PRUSART0	PRADC	42
(0x63)	Reserved	—	—	—	—	—	—	—	—	
(0x62)	Reserved	—	—	—	—	—	—	—	—	
(0x61)	CLKPR	CLKPCE	—	—	—	CLKPS3	CLKPS2	CLKPS1	CLKPS0	37
(0x60)	WDTCR	WDIF	WDIE	WDP3	WDCE	WDE	WDP2	WDP1	WDP0	54
0x3F (0x5F)	SREG	I	T	H	S	V	N	Z	C	9
0x3E (0x5E)	SPH	—	—	—	—	—	(SP10) ⁵	SP9	SP8	12
0x3D (0x5D)	SPL	SP7	SP6	SP5	SP4	SP3	SP2	SP1	SP0	12
0x3C (0x5C)	Reserved	—	—	—	—	—	—	—	—	
0x3B (0x5B)	Reserved	—	—	—	—	—	—	—	—	
0x3A (0x5A)	Reserved	—	—	—	—	—	—	—	—	
0x39 (0x59)	Reserved	—	—	—	—	—	—	—	—	
0x38 (0x58)	Reserved	—	—	—	—	—	—	—	—	
0x37 (0x57)	SPMCSR	SPMIE	(RWWSB) ⁵	—	(RWWSRE) ⁵	BLBSET	PGWRT	PGERS	SELFPRGEN	284
0x36 (0x56)	Reserved	—	—	—	—	—	—	—	—	
0x35 (0x55)	MCUCR	—	BODS	BODSE	PUD	—	—	IVSEL	IVCE	44/62/86
0x34 (0x54)	MCUSR	—	—	—	—	WDRF	BORF	EXTRF	PORF	54
0x33 (0x53)	SMCR	—	—	—	—	SM2	SM1	SM0	SE	40
0x32 (0x52)	Reserved	—	—	—	—	—	—	—	—	
0x31 (0x51)	Reserved	—	—	—	—	—	—	—	—	
0x30 (0x50)	ACSR	ACD	ACBG	ACO	ACI	ACIE	ACIC	ACIS1	ACIS0	242
0x2F (0x4F)	Reserved	—	—	—	—	—	—	—	—	
0x2E (0x4E)	SPDR	SPI Data Register								169
0x2D (0x4D)	SPSR	SPIF	WCOL	—	—	—	—	—	SPI2X	168
0x2C (0x4C)	SPCR	SPIE	SPE	DORD	MSTR	CPOL	CPHA	SPR1	SPR0	167
0x2B (0x4B)	GPOR2	General Purpose I/O Register 2								25
0x2A (0x4A)	GPOR1	General Purpose I/O Register 1								25
0x29 (0x49)	Reserved	—	—	—	—	—	—	—	—	
0x28 (0x48)	OCROB	Timer/Counter0 Output Compare Register B								
0x27 (0x47)	OCROA	Timer/Counter0 Output Compare Register A								
0x26 (0x46)	TCNT0	Timer/Counter0 (8-bit)								
0x25 (0x45)	TCCR0B	FOC0A	FOC0B	—	—	WGM02	CS02	CS01	CS00	
0x24 (0x44)	TCCR0A	COM0A1	COM0A0	COM0B1	COM0B0	—	—	WGM01	WGM00	
0x23 (0x43)	GTCCR	TSM	—	—	—	—	—	PSRASY	PSRSYNC	137/159
0x22 (0x42)	EEARH	(EEPROM Address Register High Byte) ⁵								21
0x21 (0x41)	EEARL	EEPROM Address Register Low Byte								21
0x20 (0x40)	EEDR	EEPROM Data Register								21
0x1F (0x3F)	EEDR	—	—	EEP01	EEP00	EE01E	EE00E	EE01E	EE00E	21
0x1E (0x3E)	GPOR0	General Purpose I/O Register 0								25

ATmega48PA/88PA/168PA/328P

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
0x1D (0x3D)	EIMSK	—	—	—	—	—	—	INT1	INT0	66
0x1C (0x3C)	EIFR	—	—	—	—	—	—	INTF1	INTF0	66
0x1B (0x3B)	PCIFR	—	—	—	—	—	PCIF2	PCIF1	PCIF0	
0x1A (0x3A)	Reserved	—	—	—	—	—	—	—	—	
0x19 (0x39)	Reserved	—	—	—	—	—	—	—	—	
0x18 (0x38)	Reserved	—	—	—	—	—	—	—	—	
0x17 (0x37)	TIFR2	—	—	—	—	—	OCF2B	OCF2A	TOV2	157
0x16 (0x36)	TIFR1	—	—	ICF1	—	—	OCF1B	OCF1A	TOV1	134
0x15 (0x35)	TIFR0	—	—	—	—	—	OCF0B	OCF0A	TOV0	
0x14 (0x34)	Reserved	—	—	—	—	—	—	—	—	
0x13 (0x33)	Reserved	—	—	—	—	—	—	—	—	
0x12 (0x32)	Reserved	—	—	—	—	—	—	—	—	
0x11 (0x31)	Reserved	—	—	—	—	—	—	—	—	
0x10 (0x30)	Reserved	—	—	—	—	—	—	—	—	
0x0F (0x2F)	Reserved	—	—	—	—	—	—	—	—	
0x0E (0x2E)	Reserved	—	—	—	—	—	—	—	—	
0x0D (0x2D)	Reserved	—	—	—	—	—	—	—	—	
0x0C (0x2C)	Reserved	—	—	—	—	—	—	—	—	
0x0B (0x2B)	PORTD	PORTD7	PORTD6	PORTD5	PORTD4	PORTD3	PORTD2	PORTD1	PORTD0	87
0x0A (0x2A)	DDRD	DDD7	DDD6	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0	87
0x09 (0x29)	PIND	PIND7	PIND6	PIND5	PIND4	PIND3	PIND2	PIND1	PIND0	87
0x08 (0x28)	PORTC	—	PORTC6	PORTC5	PORTC4	PORTC3	PORTC2	PORTC1	PORTC0	86
0x07 (0x27)	DDRC	—	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0	86
0x06 (0x26)	PINC	—	PINC6	PINC5	PINC4	PINC3	PINC2	PINC1	PINC0	86
0x05 (0x25)	PORTB	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0	86
0x04 (0x24)	DDRB	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0	86
0x03 (0x23)	PINB	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0	86
0x02 (0x22)	Reserved	—	—	—	—	—	—	—	—	
0x01 (0x21)	Reserved	—	—	—	—	—	—	—	—	
0x00 (0x20)	Reserved	—	—	—	—	—	—	—	—	

- Note:
- For compatibility with future devices, reserved bits should be written to zero if accessed. Reserved I/O memory addresses should never be written.
 - I/O Registers within the address range 0x00 - 0x1F are directly bit-accessible using the SBI and CBI instructions. In these registers, the value of single bits can be checked by using the SBIS and SBIC instructions.
 - Some of the Status Flags are cleared by writing a logical one to them. Note that, unlike most other AVRs, the CBI and SBI instructions will only operate on the specified bit, and can therefore be used on registers containing such Status Flags. The CBI and SBI instructions work with registers 0x00 to 0x1F only.
 - When using the I/O specific commands IN and OUT, the I/O addresses 0x00 - 0x3F must be used. When addressing I/O Registers as data space using LD and ST instructions, 0x20 must be added to these addresses. The ATmega48PA/88PA/168PA/328P is a complex microcontroller with more peripheral units than can be supported within the 64 location reserved in Opcode for the IN and OUT instructions. For the Extended I/O space from 0x60 - 0xFF in SRAM, only the ST/STS/STD and LD/LDS/LDD instructions can be used.
 - Only valid for ATmega88PA.

6. Instruction Set Summary

Mnemonics	Operands	Description	Operation	Flags	#Clocks
ARITHMETIC AND LOGIC INSTRUCTIONS					
ADD	Rd, Rr	Add two Registers	$Rd \leftarrow Rd + Rr$	Z, C, N, V, H	1
ADC	Rd, Rr	Add with Carry two Registers	$Rd \leftarrow Rd + Rr + C$	Z, C, N, V, H	1
ADIW	Rd, K	Add Immediate to Word	$Rd_{16:8} \leftarrow Rd_{16:8} + K$	Z, C, N, V, S	2
SUB	Rd, Rr	Subtract two Registers	$Rd \leftarrow Rd - Rr$	Z, C, N, V, H	1
SUBI	Rd, K	Subtract Constant from Register	$Rd \leftarrow Rd - K$	Z, C, N, V, H	1
SBC	Rd, Rr	Subtract with Carry two Registers	$Rd \leftarrow Rd - Rr - C$	Z, C, N, V, H	1
SBCI	Rd, K	Subtract with Carry Constant from Reg	$Rd \leftarrow Rd - K - C$	Z, C, N, V, H	1
SBIW	Rd, K	Subtract Immediate from Word	$Rd_{16:8} \leftarrow Rd_{16:8} - K$	Z, C, N, V, S	2
AND	Rd, Rr	Logical AND Registers	$Rd \leftarrow Rd \cdot Rr$	Z, N, V	1
ANDI	Rd, K	Logical AND Register and Constant	$Rd \leftarrow Rd \cdot K$	Z, N, V	1
OR	Rd, Rr	Logical OR Registers	$Rd \leftarrow Rd \vee Rr$	Z, N, V	1
ORI	Rd, K	Logical OR Register and Constant	$Rd \leftarrow Rd \vee K$	Z, N, V	1
EOR	Rd, Rr	Exclusive OR Registers	$Rd \leftarrow Rd \oplus Rr$	Z, N, V	1
COM	Rd	One's Complement	$Rd \leftarrow 0xFF - Rd$	Z, C, N, V	1
NEG	Rd	Two's Complement	$Rd \leftarrow 0x00 - Rd$	Z, C, N, V, H	1
SBR	Rd, K	Set Bit(s) in Register	$Rd \leftarrow Rd \vee K$	Z, N, V	1
CBR	Rd, K	Clear Bit(s) in Register	$Rd \leftarrow Rd \cdot (0xFF - K)$	Z, N, V	1
INC	Rd	Increment	$Rd \leftarrow Rd + 1$	Z, N, V	1
DEC	Rd	Decrement	$Rd \leftarrow Rd - 1$	Z, N, V	1
TST	Rd	Test for Zero or Minus	$Rd \leftarrow Rd \cdot Rd$	Z, N, V	1
CLR	Rd	Clear Register	$Rd \leftarrow Rd \oplus Rd$	Z, N, V	1
SER	Rd	Set Register	$Rd \leftarrow 0xFF$	None	1
MUL	Rd, Rr	Multiply Unsigned	$R1:R0 \leftarrow Rd \times Rr$	Z, C	2
MULS	Rd, Rr	Multiply Signed	$R1:R0 \leftarrow Rd \times Rr$	Z, C	2
MULSU	Rd, Rr	Multiply Signed with Unsigned	$R1:R0 \leftarrow Rd \times Rr$	Z, C	2
FMUL	Rd, Rr	Fractional Multiply Unsigned	$R1:R0 \leftarrow (Rd \times Rr) \lll 1$	Z, C	2
FMULS	Rd, Rr	Fractional Multiply Signed	$R1:R0 \leftarrow (Rd \times Rr) \lll 1$	Z, C	2
FMULSU	Rd, Rr	Fractional Multiply Signed with Unsigned	$R1:R0 \leftarrow (Rd \times Rr) \lll 1$	Z, C	2
BRANCH INSTRUCTIONS					
RJMP	k	Relative Jump	$PC \leftarrow PC + k + 1$	None	2
IJMP		Indirect Jump to (Z)	$PC \leftarrow Z$	None	2
JMP ⁽¹⁾	k	Direct Jump	$PC \leftarrow k$	None	3
RCALL	k	Relative Subroutine Call	$PC \leftarrow PC + k + 1$	None	3
ICALL		Indirect Call to (Z)	$PC \leftarrow Z$	None	3
CALL ⁽¹⁾	k	Direct Subroutine Call	$PC \leftarrow k$	None	4
RET		Subroutine Return	$PC \leftarrow STACK$	None	4
RETI		Interrupt Return	$PC \leftarrow STACK$	I	4
CPSE	Rd, Rr	Compare, Skip if Equal	if $(Rd = Rr)$ $PC \leftarrow PC + 2$ or 3	None	1/2/3
CP	Rd, Rr	Compare	$Rd - Rr$	Z, N, V, C, H	1
CPC	Rd, Rr	Compare with Carry	$Rd - Rr - C$	Z, N, V, C, H	1
CPI	Rd, K	Compare Register with Immediate	$Rd - K$	Z, N, V, C, H	1
SBRC	Rr, b	Skip if Bit in Register Cleared	if $(Rr(b)=0)$ $PC \leftarrow PC + 2$ or 3	None	1/2/3
SBRSC	Rr, b	Skip if Bit in Register is Set	if $(Rr(b)=1)$ $PC \leftarrow PC + 2$ or 3	None	1/2/3
SBIC	P, b	Skip if Bit in I/O Register Cleared	if $(P(b)=0)$ $PC \leftarrow PC + 2$ or 3	None	1/2/3
SBIS	P, b	Skip if Bit in I/O Register is Set	if $(P(b)=1)$ $PC \leftarrow PC + 2$ or 3	None	1/2/3
BRBS	s, k	Branch if Status Flag Set	if $(SREG(s) = 1)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRBC	s, k	Branch if Status Flag Cleared	if $(SREG(s) = 0)$ then $PC \leftarrow PC + k + 1$	None	1/2
BREQ	k	Branch if Equal	if $(Z = 1)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRNE	k	Branch if Not Equal	if $(Z = 0)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRCS	k	Branch if Carry Set	if $(C = 1)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRCC	k	Branch if Carry Cleared	if $(C = 0)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRSH	k	Branch if Same or Higher	if $(C = 0)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRLO	k	Branch if Lower	if $(C = 1)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRMI	k	Branch if Minus	if $(N = 1)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRPL	k	Branch if Plus	if $(N = 0)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRGE	k	Branch if Greater or Equal, Signed	if $(N \oplus V = 0)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRLT	k	Branch if Less Than Zero, Signed	if $(N \oplus V = 1)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRHS	k	Branch if Half Carry Flag Set	if $(H = 1)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRHC	k	Branch if Half Carry Flag Cleared	if $(H = 0)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRIS	k	Branch if I Flag Set	if $(I = 1)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRIC	k	Branch if I Flag Cleared	if $(I = 0)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRVS	k	Branch if Overflow Flag is Set	if $(V = 1)$ then $PC \leftarrow PC + k + 1$	None	1/2
BRVC	k	Branch if Overflow Flag is Cleared	if $(V = 0)$ then $PC \leftarrow PC + k + 1$	None	1/2

ATmega48PA/88PA/168PA/328P

Mnemonics	Operands	Description	Operation	Flags	#Clocks
BRIE	k	Branch if Interrupt Enabled	If (I = 1) then PC ← PC + k + 1	None	1/2
BRID	k	Branch if Interrupt Disabled	If (I = 0) then PC ← PC + k + 1	None	1/2
BIT AND BIT-TEST INSTRUCTIONS					
SBI	P,b	Set Bit in I/O Register	I/O(P,b) ← 1	None	2
CBI	P,b	Clear Bit in I/O Register	I/O(P,b) ← 0	None	2
LSL	Rd	Logical Shift Left	Rd(n+1) ← Rd(n), Rd(0) ← 0	Z,C,N,V	1
LSR	Rd	Logical Shift Right	Rd(n) ← Rd(n+1), Rd(7) ← 0	Z,C,N,V	1
ROL	Rd	Rotate Left Through Carry	Rd(0) ← C, Rd(n+1) ← Rd(n), C ← Rd(7)	Z,C,N,V	1
ROR	Rd	Rotate Right Through Carry	Rd(7) ← C, Rd(n) ← Rd(n+1), C ← Rd(0)	Z,C,N,V	1
ASR	Rd	Arithmetic Shift Right	Rd(n) ← Rd(n+1), n=0..6	Z,C,N,V	1
SWAP	Rd	Swap Nibbles	Rd(3..0) ← Rd(7..4), Rd(7..4) ← Rd(3..0)	None	1
BSET	s	Flag Set	SREG(s) ← 1	SREG(s)	1
BCLR	s	Flag Clear	SREG(s) ← 0	SREG(s)	1
BST	Rr, b	Bit Store from Register to T	T ← Rr(b)	T	1
BLD	Rd, b	Bit load from T to Register	Rd(b) ← T	None	1
SEC		Set Carry	C ← 1	C	1
CLC		Clear Carry	C ← 0	C	1
SEN		Set Negative Flag	N ← 1	N	1
CLN		Clear Negative Flag	N ← 0	N	1
SEZ		Set Zero Flag	Z ← 1	Z	1
CLZ		Clear Zero Flag	Z ← 0	Z	1
SEI		Global Interrupt Enable	I ← 1	I	1
CLI		Global Interrupt Disable	I ← 0	I	1
SES		Set Signed Test Flag	S ← 1	S	1
CLS		Clear Signed Test Flag	S ← 0	S	1
SEV		Set Twos Complement Overflow	V ← 1	V	1
CLV		Clear Twos Complement Overflow	V ← 0	V	1
SET		Set T in SREG	T ← 1	T	1
CLT		Clear T in SREG	T ← 0	T	1
SEH		Set Half Carry Flag in SREG	H ← 1	H	1
CLH		Clear Half Carry Flag in SREG	H ← 0	H	1
DATA TRANSFER INSTRUCTIONS					
MOV	Rd, Rr	Move Between Registers	Rd ← Rr	None	1
MOVW	Rd, Rr	Copy Register Word	Rd+1,Rd ← Rr+1,Rr	None	1
LDI	Rd, K	Load Immediate	Rd ← K	None	1
LD	Rd, X	Load Indirect	Rd ← (X)	None	2
LD	Rd, X+	Load Indirect and Post-Inc.	Rd ← (X), X ← X + 1	None	2
LD	Rd, -X	Load Indirect and Pre-Dec.	X ← X - 1, Rd ← (X)	None	2
LD	Rd, Y	Load Indirect	Rd ← (Y)	None	2
LD	Rd, Y+	Load Indirect and Post-Inc.	Rd ← (Y), Y ← Y + 1	None	2
LD	Rd, -Y	Load Indirect and Pre-Dec.	Y ← Y - 1, Rd ← (Y)	None	2
LDD	Rd, Y+q	Load Indirect with Displacement	Rd ← (Y + q)	None	2
LD	Rd, Z	Load Indirect	Rd ← (Z)	None	2
LD	Rd, Z+	Load Indirect and Post-Inc.	Rd ← (Z), Z ← Z + 1	None	2
LD	Rd, -Z	Load Indirect and Pre-Dec.	Z ← Z - 1, Rd ← (Z)	None	2
LDD	Rd, Z+q	Load Indirect with Displacement	Rd ← (Z + q)	None	2
LDS	Rd, k	Load Direct from SRAM	Rd ← (k)	None	2
ST	X, Rr	Store Indirect	(X) ← Rr	None	2
ST	X+, Rr	Store Indirect and Post-Inc.	(X) ← Rr, X ← X + 1	None	2
ST	-X, Rr	Store Indirect and Pre-Dec.	X ← X - 1, (X) ← Rr	None	2
ST	Y, Rr	Store Indirect	(Y) ← Rr	None	2
ST	Y+, Rr	Store Indirect and Post-Inc.	(Y) ← Rr, Y ← Y + 1	None	2
ST	-Y, Rr	Store Indirect and Pre-Dec.	Y ← Y - 1, (Y) ← Rr	None	2
STD	Y+q, Rr	Store Indirect with Displacement	(Y + q) ← Rr	None	2
ST	Z, Rr	Store Indirect	(Z) ← Rr	None	2
ST	Z+, Rr	Store Indirect and Post-Inc.	(Z) ← Rr, Z ← Z + 1	None	2
ST	-Z, Rr	Store Indirect and Pre-Dec.	Z ← Z - 1, (Z) ← Rr	None	2
STD	Z+q, Rr	Store Indirect with Displacement	(Z + q) ← Rr	None	2
STS	k, Rr	Store Direct to SRAM	(k) ← Rr	None	2
LPM		Load Program Memory	R0 ← (Z)	None	3
LPM	Rd, Z	Load Program Memory	Rd ← (Z)	None	3
LPM	Rd, Z+	Load Program Memory and Post-Inc.	Rd ← (Z), Z ← Z + 1	None	3
SPM		Store Program Memory	(Z) ← R1:R0	None	-
IN	Rd, P	In Port	Rd ← P	None	1
OUT	P, Rr	Out Port	P ← Rr	None	1
PUSH	Rr	Push Register on Stack	STACK ← Rr	None	2

ATmega48PA/88PA/168PA/328P

Mnemonics	Operands	Description	Operation	Flags	#Clocks
POP	Rd	Pop Register from Stack	Rd ← STACK	None	2
MCU CONTROL INSTRUCTIONS					
NOP		No Operation		None	1
SLEEP		Sleep	(see specific descr. for Sleep function)	None	1
WDR		Watchdog Reset	(see specific descr. for WDR/timer)	None	1
BREAK		Break	For On-chip Debug Only	None	N/A

7. Ordering Information

7.1 ATmega48PA

Speed (MHz)	Power Supply	Ordering Code ⁽²⁾	Package ⁽¹⁾	Operational Range
20 ⁽³⁾	1.8 - 5.5	ATmega48PA-AU ATmega48PA-MMH ⁽⁴⁾ ATmega48PA-MU ATmega48PA-PU	32A 28M1 32M1-A 28P3	Industrial (-40°C to 85°C)

- Note:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
 2. Pb-free packaging complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
 3. See "[Speed Grades](#)" on [page 306](#).
 4. NiPdAu Lead Finish.

Package Type	
32A	32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP)
28M1	28-pad, 4 x 4 x 1.0 body, Lead Pitch 0.45 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
32M1-A	32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
28P3	28-lead, 0.300" Wide, Plastic Dual Inline Package (PDIP)

ATmega48PA/88PA/168PA/328P

7.2 ATmega88PA

Speed (MHz)	Power Supply	Ordering Code ⁽²⁾	Package ⁽¹⁾	Operational Range
20 ⁽³⁾	1.8 - 5.5	ATmega88PA-AU ATmega88PA-MMH ⁽⁴⁾ ATmega88PA-MU ATmega88PA-PU	32A 28M1 32M1-A 28P3	Industrial (-40°C to 85°C)

- Note:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
 2. Pb-free packaging complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
 3. See "[Speed Grades](#)" on page 306.
 4. NiPdAu Lead Finish.

Package Type	
32A	32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP)
28M1	28-pad, 4 x 4 x 1.0 body, Lead Pitch 0.45 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
32M1-A	32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
28P3	28-lead, 0.300" Wide, Plastic Dual Inline Package (PDIP)



ATmega48PA/88PA/168PA/328P

7.3 ATmega168PA

Speed (MHz) ⁽³⁾	Power Supply	Ordering Code ⁽²⁾	Package ⁽¹⁾	Operational Range
20	1.8 - 5.5	ATmega168PA-AU ATmega168PA-MMH ⁽⁴⁾ ATmega168PA-MU ATmega168PA-PU	32A 28M1 32M1-A 28P3	Industrial (-40°C to 85°C)

- Note:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
 2. Pb-free packaging complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
 3. See "[Speed Grades](#)" on page 312.
 4. NiPdAu Lead Finish.

Package Type	
32A	32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP)
28M1	28-pad, 4 x 4 x 1.0 body, Lead Pitch 0.45 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
32M1-A	32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
28P3	28-lead, 0.300" Wide, Plastic Dual Inline Package (PDIP)

ATmega48PA/88PA/168PA/328P

7.4 ATmega328P

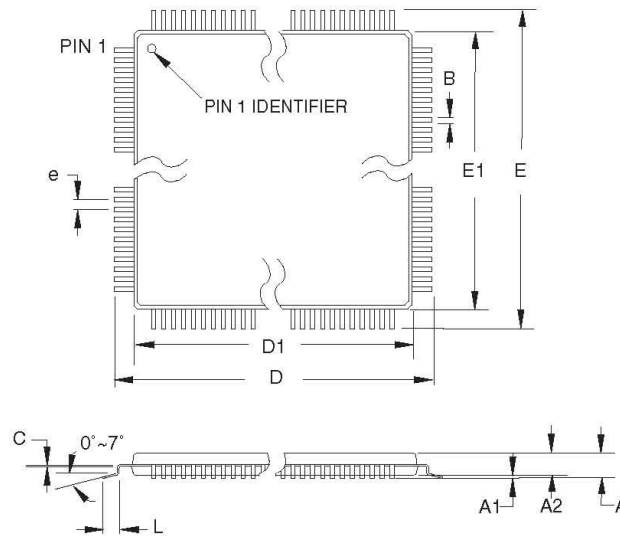
Speed (MHz)	Power Supply	Ordering Code ⁽²⁾	Package ⁽¹⁾	Operational Range
20 ⁽³⁾	1.8 - 5.5	ATmega328P- AU ATmega328P- MU ATmega328P- PU	32A 32M1-A 28P3	Industrial (-40°C to 85°C)

- Note:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
 2. Pb-free packaging complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
 3. See [Figure 28-1 on page 316](#).

Package Type	
32A	32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP)
28P3	28-lead, 0.300" Wide, Plastic Dual Inline Package (PDIP)
32M1-A	32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)

8. Packaging Information

8.1 32A



COMMON DIMENSIONS
(Unit of Measure = mm)

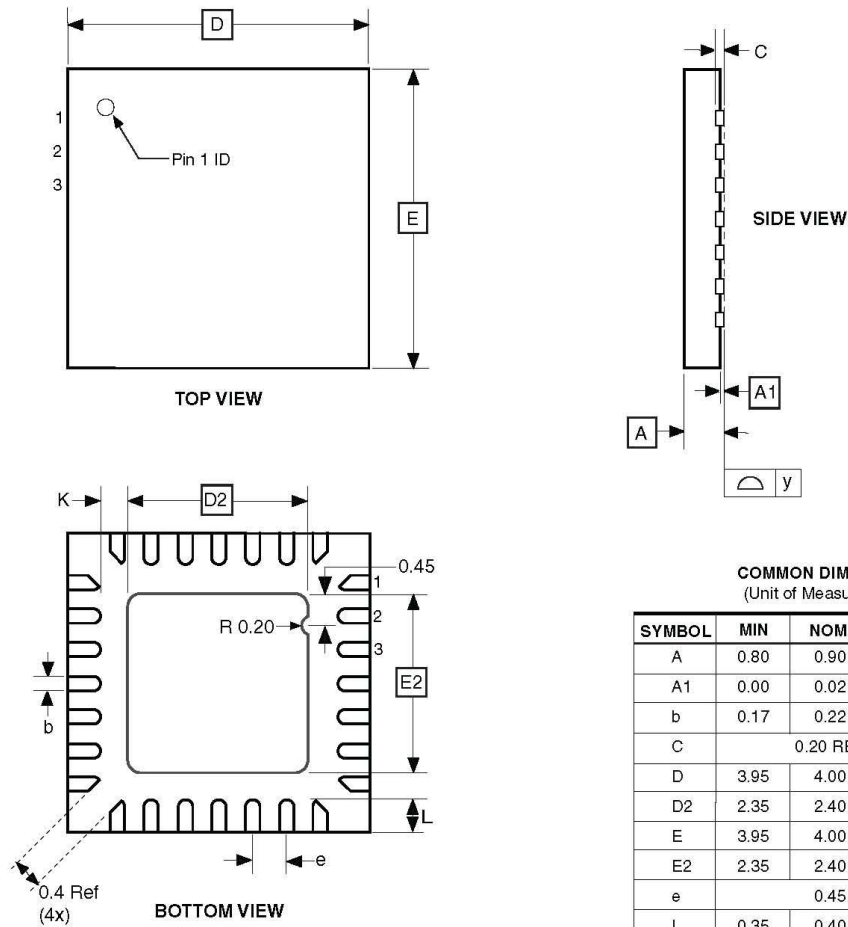
SYMBOL	MIN	NOM	MAX	NOTE
A	—	—	1.20	
A1	0.05	—	0.15	
A2	0.95	1.00	1.05	
D	8.75	9.00	9.25	
D1	6.90	7.00	7.10	Note 2
E	8.75	9.00	9.25	
E1	6.90	7.00	7.10	Note 2
B	0.30	—	0.45	
C	0.09	—	0.20	
L	0.45	—	0.75	
e	0.80 TYP			

- Notes:
1. This package conforms to JEDEC reference MS-026, Variation ABA.
 2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is 0.25 mm per side. Dimensions D1 and E1 are maximum plastic body size dimensions including mold mismatch.
 3. Lead coplanarity is 0.10 mm maximum.

10/5/2001

 2325 Orchard Parkway San Jose, CA 95131	TITLE 32A , 32-lead, 7 x 7 mm Body Size, 1.0 mm Body Thickness, 0.8 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)	DRAWING NO.	REV.
		32A	B

8.2 28M1



COMMON DIMENSIONS
(Unit of Measure = mm)

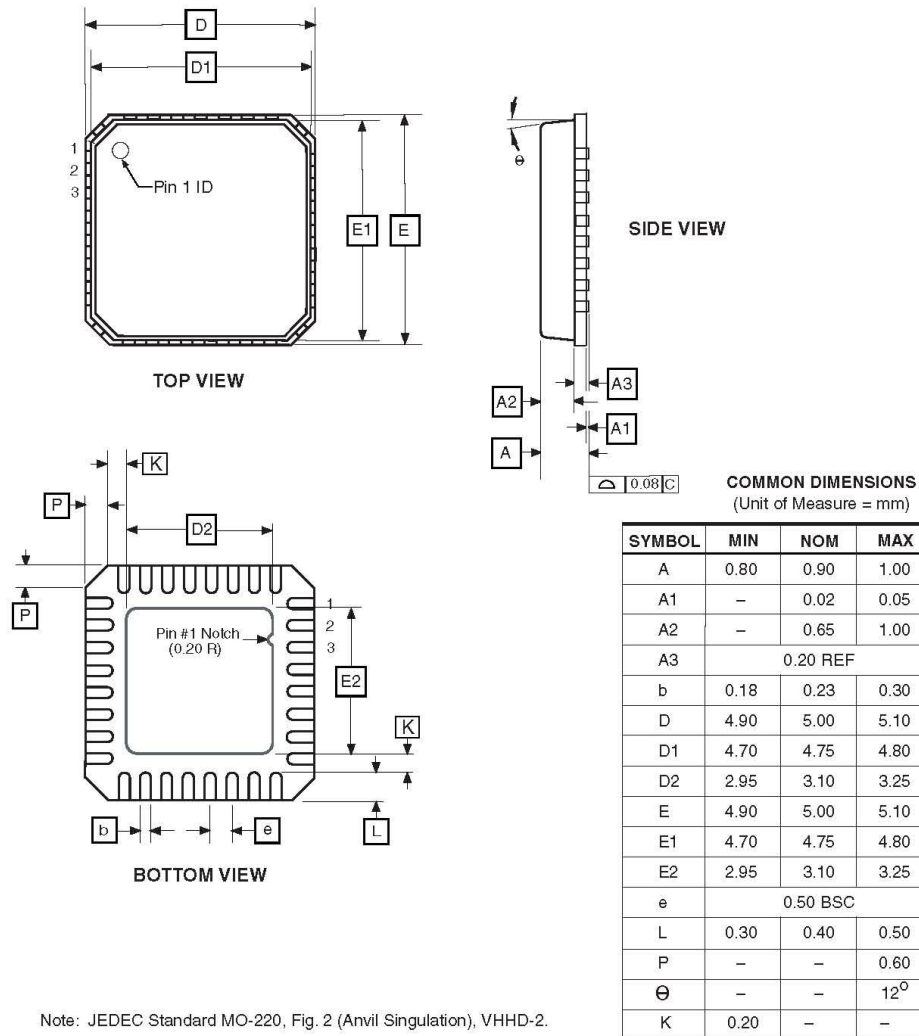
SYMBOL	MIN	NOM	MAX	NOTE
A	0.80	0.90	1.00	
A1	0.00	0.02	0.05	
b	0.17	0.22	0.27	
C	0.20 REF			
D	3.95	4.00	4.05	
D2	2.35	2.40	2.45	
E	3.95	4.00	4.05	
E2	2.35	2.40	2.45	
e	0.45			
L	0.35	0.40	0.45	
y	0.00	—	0.08	
K	0.20	—	—	

Note: The terminal #1 ID is a Laser-marked Feature.

10/24/08

PACKAGE DRAWING CONTACT:		TITLE	GPC	DRAWING NO.	REV.
packagedrawings@atmel.com		28M1, 28-pad, 4 x 4 x 1.0 mm Body, Lead Pitch 0.45 mm, 2.4 x 2.4 mm Exposed Pad, Thermally Enhanced Plastic Very Thin Quad Flat No Lead Package (VQFN)	ZBV	28M1	B

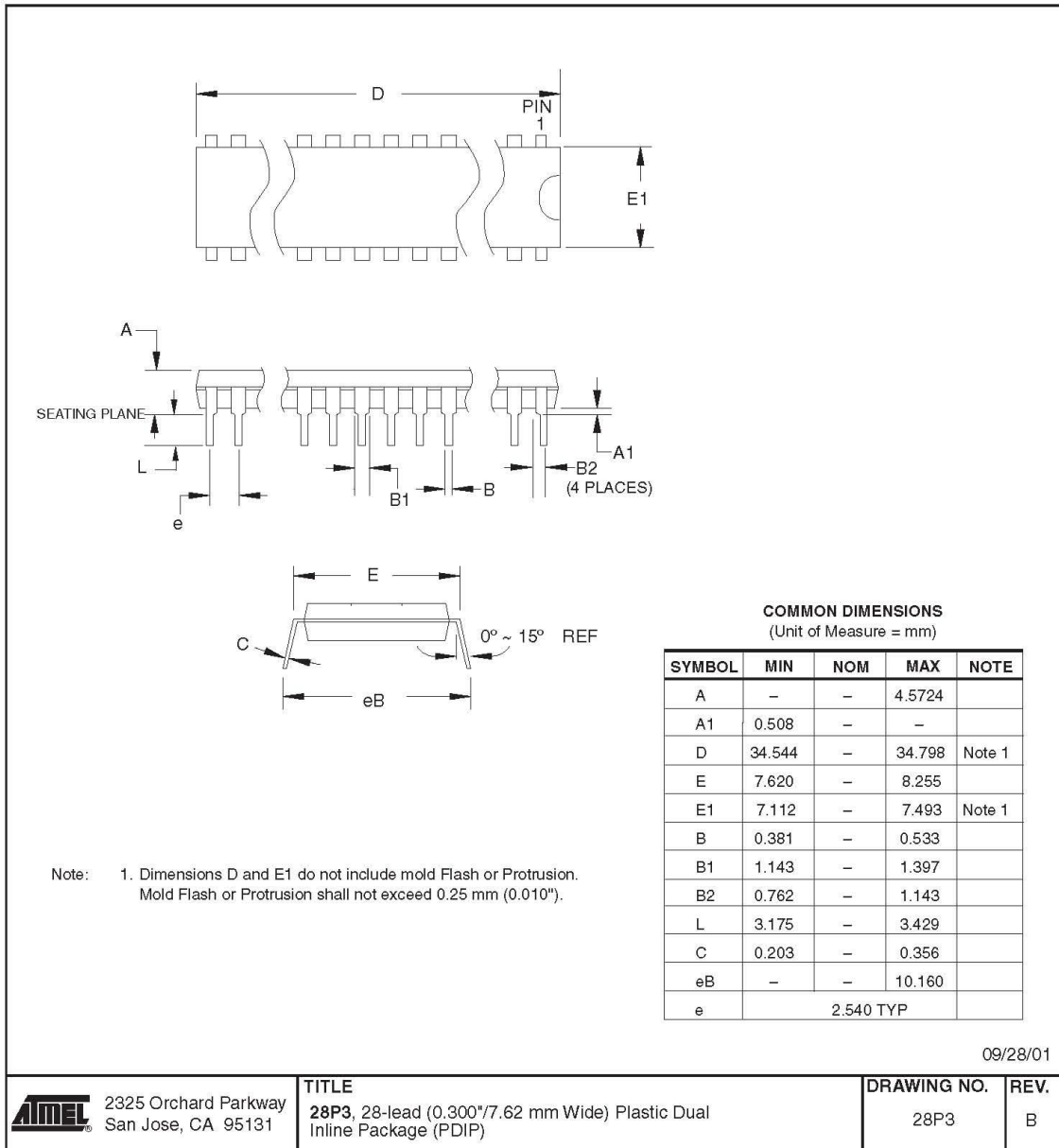
8.3 32M1-A



5/25/06

	2325 Orchard Parkway San Jose, CA 95131	TITLE 32M1-A , 32-pad, 5 x 5 x 1.0 mm Body, Lead Pitch 0.50 mm, 3.10 mm Exposed Pad, Micro Lead Frame Package (MLF)	DRAWING NO.	REV.
			32M1-A	E

8.4 28P3



9. Errata

9.1 Errata ATmega48PA

The revision letter in this section refers to the revision of the ATmega48PA device.

9.1.1 Rev. D

No known errata.

9.2 Errata ATmega88PA

The revision letter in this section refers to the revision of the ATmega88PA device.

9.2.1 Rev. F

No known errata.

9.3 Errata ATmega168PA

The revision letter in this section refers to the revision of the ATmega168PA device.

9.3.1 Rev E

No known errata.

9.4 Errata ATmega328P

The revision letter in this section refers to the revision of the ATmega328P device.

9.4.1 Rev D

No known errata.

9.4.2 Rev C

Not sampled.

9.4.3 Rev B

- **Unstable 32 kHz Oscillator**

- 1. Unstable 32 kHz Oscillator**

The 32 kHz oscillator does not work as system clock.

The 32 kHz oscillator used as asynchronous timer is inaccurate.

Problem Fix/ Workaround

None

9.4.4 Rev A

- **Unstable 32 kHz Oscillator**

- 1. Unstable 32 kHz Oscillator**

The 32 kHz oscillator does not work as system clock.

The 32 kHz oscillator used as asynchronous timer is inaccurate.

Problem Fix/ Workaround

None

10. Datasheet Revision History

Please note that the referring page numbers in this section are referred to this document. The referring revision in this section are referring to the document revision.

10.1 Rev. 8161C – 05/09

1. Updated "Features" on page 1 for ATmega48PA/88PA/168PA/328P.
2. Updated "Overview" on page 5 included the Table 2-1 on page 6.
3. Updated "AVR Memories" on page 16 included "Register Description" on page 21 and inserted Figure 7-1 on page 17.
4. Updated "Register Description" on page 44.
5. Updated "System Control and Reset" on page 46.
6. Updated "Interrupts" on page 57.
7. Updated "External Interrupts" on page 70.
8. Updated "Boot Loader Support – Read-While-Write Self-Programming, ATmega88PA, ATmega168PA and ATmega328P" on page 277.
9. Inserted "ATmega168PA DC Characteristics" on page 315.
10. Inserted "ATmega328P DC Characteristics" on page 316.
11. Inserted "ATmega168PA Typical Characteristics" on page 375.
12. Inserted "ATmega328P Typical Characteristics" on page 399.
13. Inserted Ordering Information for "ATmega168PA" on page 432.
14. Inserted Ordering Information for "ATmega328P" on page 433.
15. Inserted "Errata ATmega328P" on page 438.
16. Editing updates.

10.2 Rev. 8161B – 01/09

1. Updated "Features" on page 1 for ATmega48PA and updated the book accordingly.
2. Updated "Overview" on page 5 included the Table 2-1 on page 6.
3. Updated "AVR Memories" on page 16 included "Register Description" on page 21 and inserted Figure 7-1 on page 17.
4. Updated "Register Description" on page 44.
5. Updated "System Control and Reset" on page 46.
6. Updated "Interrupts" on page 57.
7. Updated "External Interrupts" on page 70.
8. Inserted Typical characteristics for "ATmega48PA Typical Characteristics" on page 327.
9. Updated figure names in Typical characteristics for "ATmega88PA Typical Characteristics" on page 351.
10. Inserted "ATmega48PA DC Characteristics" on page 314.

11. Updated [Table 28-1 on page 317](#) by removing the footnote from Vcc/User calibration
12. Updated [Table 28-7 on page 323](#) by removing Max value (2.5 LSB) from Absolute accuracy, $V_{REF} = 4V$, $V_{CC} = 4V$, ADC clock = 200 kHz.
13. Inserted Ordering Information for "ATmega48PA" on [page 430](#).

10.3 Rev. 8161A – 11/08

1. Initial revision (Based on the ATmega48P/88P/168P/328P datasheet 8025F-AVR-08/08).
2. Changes done compared to ATmega48P/88P/168P/328P datasheet 8025F-AVR-08/08:
 - Updated "DC Characteristics" on [page 313](#) with new typical values for I_{CC} .
 - Updated "Speed Grades" on [page 316](#).
 - New graphics in "Typical Characteristics" on [page 326](#).
 - New "Ordering Information" on [page 430](#).



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8161CS-AVR-05/09

LM78XX/LM78XXA 3-Terminal 1A Positive Voltage Regulator

Features

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

General Description

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

Ordering Information

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

Block Diagram

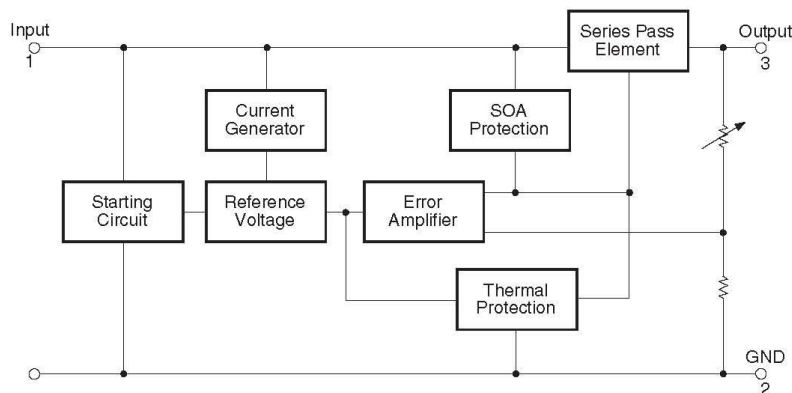


Figure 1.

Pin Assignment

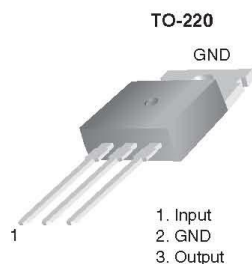


Figure 2.

Absolute Maximum Ratings

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

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

Electrical Characteristics (LM7805)Refer to the test circuits. $-40^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 500\text{mA}$, $V_I = 10\text{V}$, $C_I = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

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

Electrical Characteristics (LM7806) (Continued)Refer to the test circuits. $-40^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 500\text{mA}$, $V_I = 11\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

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

Electrical Characteristics (LM7808) (Continued)Refer to the test circuits. $-40^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 500\text{mA}$, $V_I = 14\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

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

Electrical Characteristics (LM7809) (Continued)Refer to the test circuits. $-40^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 500\text{mA}$, $V_I = 15\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

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

Electrical Characteristics (LM7810) (Continued)Refer to the test circuits. $-40^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 500\text{mA}$, $V_I = 16\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

9. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

10. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7812) (Continued)Refer to the test circuits. $-40^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 500\text{mA}$, $V_I = 19\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:11. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

12. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7815) (Continued)Refer to the test circuits. $-40^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 500\text{mA}$, $V_I = 23\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

13. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

14. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7818) (Continued)Refer to the test circuits. $-40^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 500\text{mA}$, $V_I = 27\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

15. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

16. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7824) (Continued)Refer to the test circuits. $-40^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 500\text{mA}$, $V_I = 33\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

17. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

18. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7805A) (Continued)Refer to the test circuits. $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 1\text{A}$, $V_I = 10\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

19. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

20. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7806A) (Continued)Refer to the test circuits. $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 1\text{A}$, $V_I = 11\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:21. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

22. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7810A) (Continued)Refer to the test circuits. $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 1\text{A}$, $V_I = 16\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

27. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

28. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7812A) (Continued)Refer to the test circuits. $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 1\text{A}$, $V_I = 19\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Note:

29. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

30. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7815A) (Continued)Refer to the test circuits. $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 1\text{A}$, $V_I = 23\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

31. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

32. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7818A) (Continued)Refer to the test circuits. $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 1\text{A}$, $V_I = 27\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

33. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

34. These parameters, although guaranteed, are not 100% tested in production.

Electrical Characteristics (LM7824A) (Continued)Refer to the test circuits. $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$, $I_O = 1\text{A}$, $V_I = 33\text{V}$, $C_I = 0.33\mu\text{F}$, $C_O = 0.1\mu\text{F}$, unless otherwise specified.

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

Notes:

35. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

36. These parameters, although guaranteed, are not 100% tested in production.

Typical Performance Characteristics

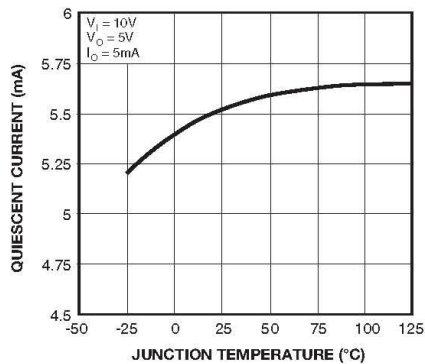


Figure 3. Quiescent Current

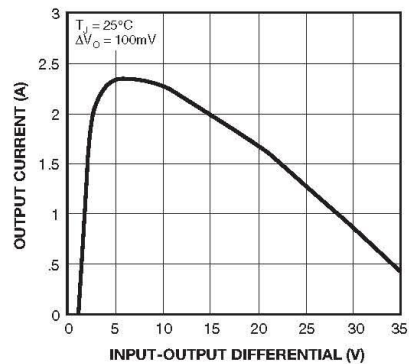


Figure 4. Peak Output Current

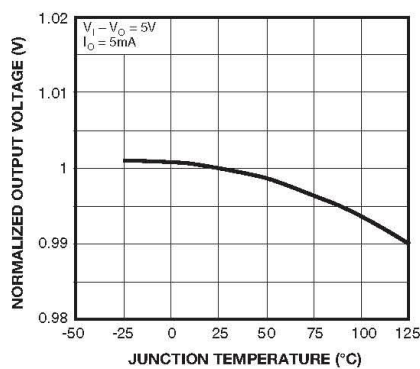


Figure 5. Output Voltage

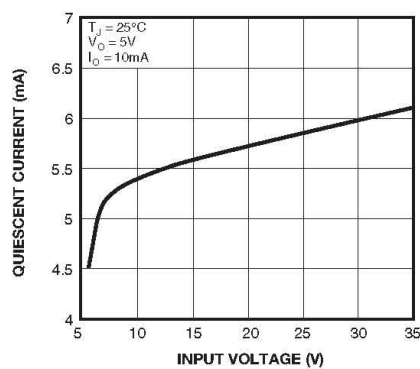


Figure 6. Quiescent Current

Typical Applications

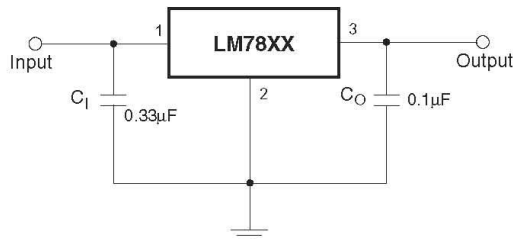


Figure 7. DC Parameters

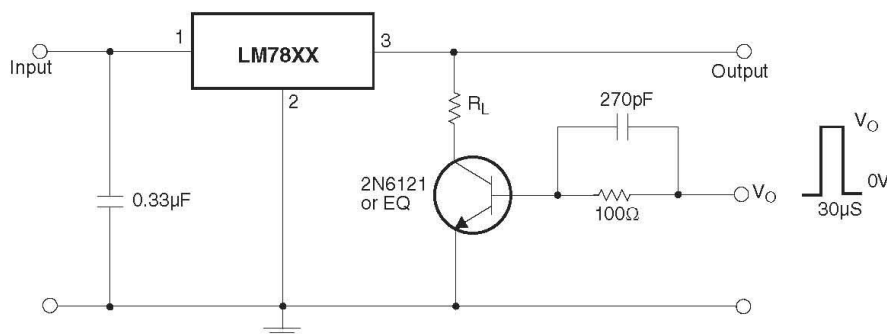


Figure 8. Load Regulation

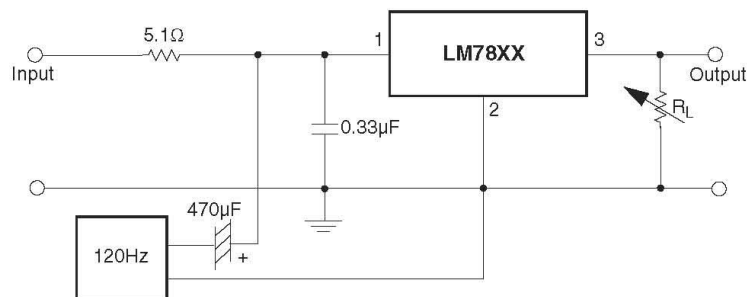


Figure 9. Ripple Rejection

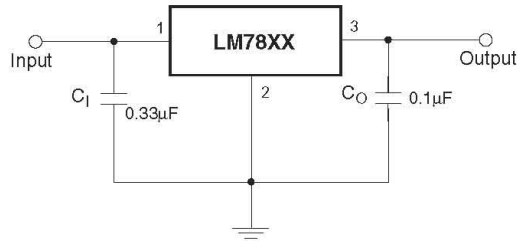
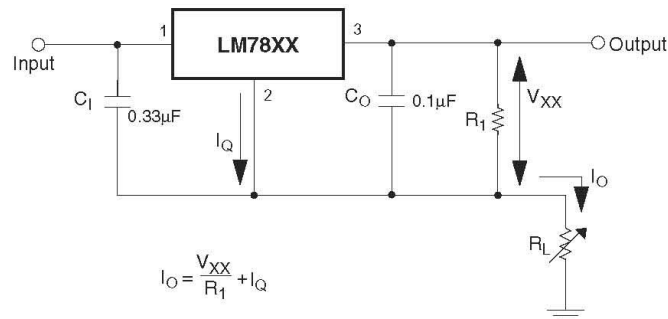


Figure 10. Fixed Output Regulator



Notes:

1. To specify an output voltage, substitute voltage value for "XX." A common ground is required between the input and the output voltage. The input voltage must remain typically 2.0V above the output voltage even during the low point on the input ripple voltage.
2. C_1 is required if regulator is located an appreciable distance from power supply filter.
3. C_0 improves stability and transient response.

Figure 11.

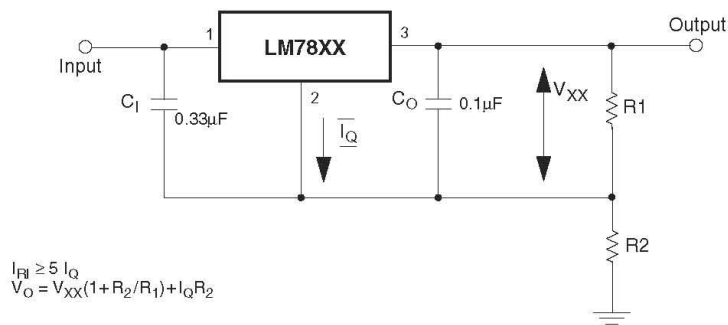


Figure 12. Circuit for Increasing Output Voltage

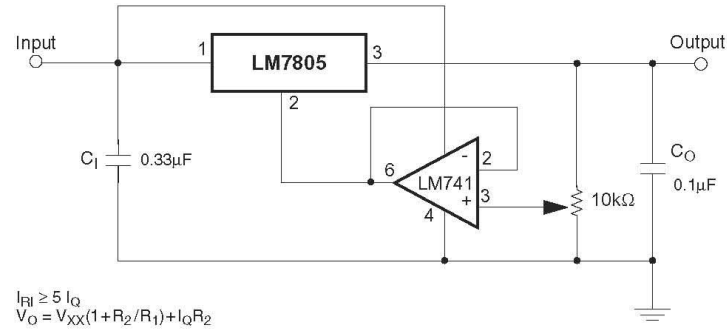


Figure 13. Adjustable Output Regulator (7V to 30V)

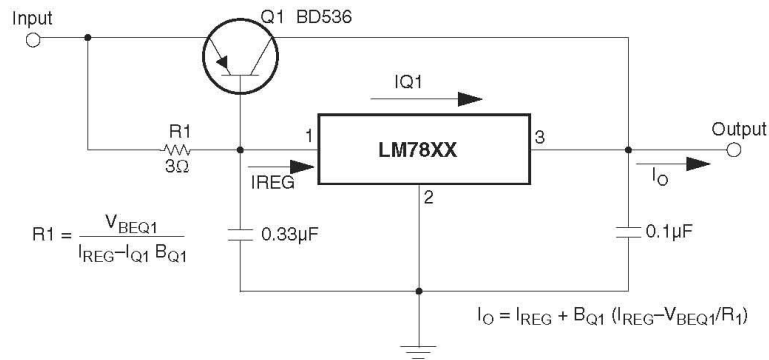


Figure 14. High Current Voltage Regulator

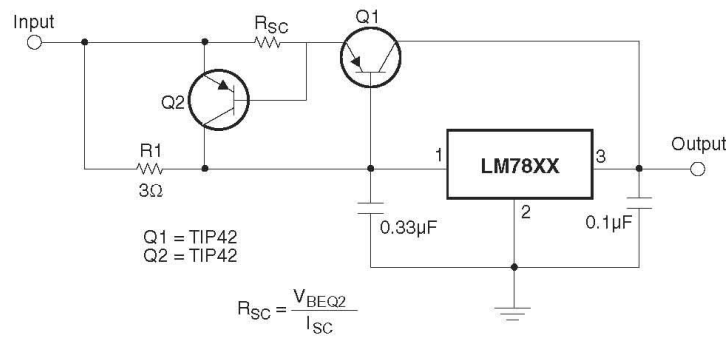


Figure 15. High Output Current with Short Circuit Protection

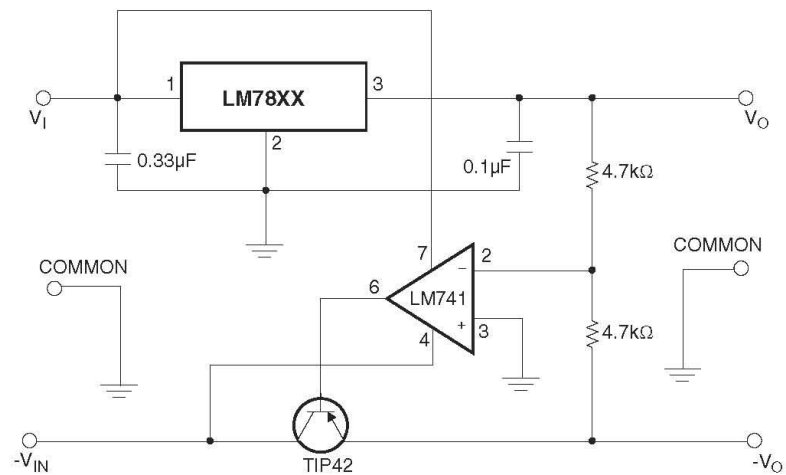


Figure 16. Tracking Voltage Regulator

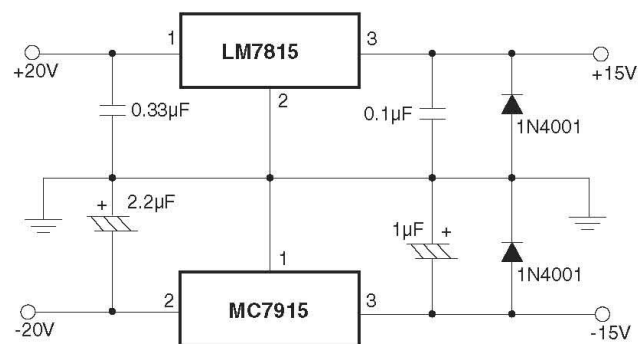


Figure 17. Split Power Supply ($\pm 15V - 1A$)

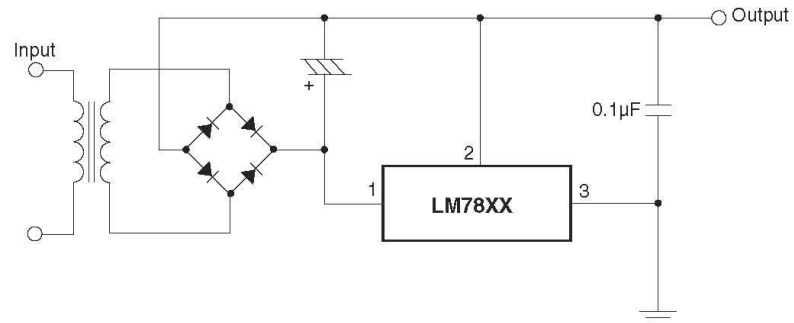


Figure 18. Negative Output Voltage Circuit

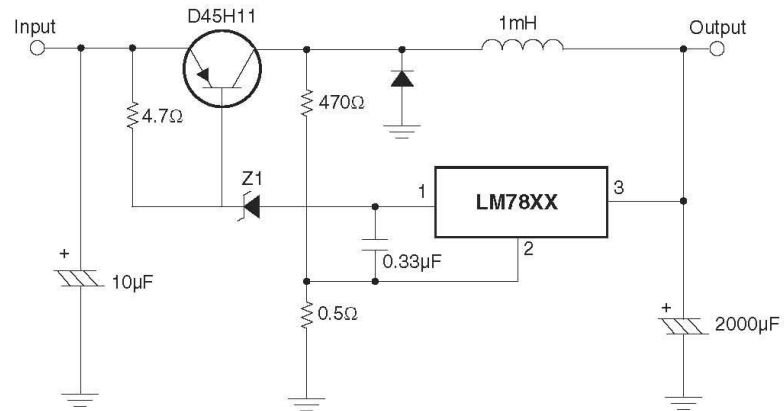
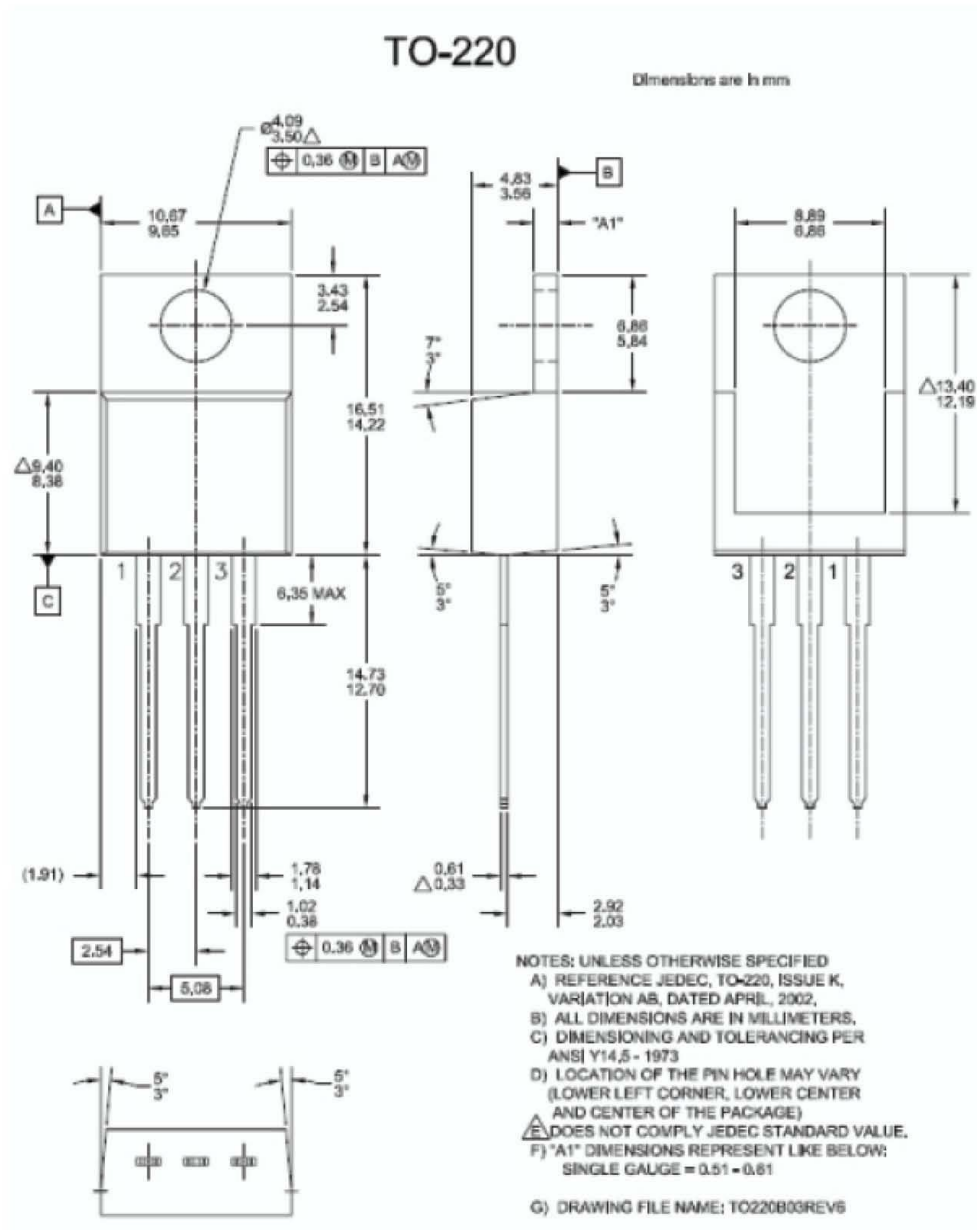


Figure 19. Switching Regulator

Mechanical Dimensions

Dimensions in millimeters



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Definition of Terms

Datasheet Identification	Product Status	Definition
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Preliminary	First Production	This datasheet contains preliminary data, and supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
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Rev. 119

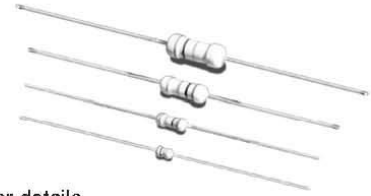


Carbon Film Fixed Resistors (RoHS Compliant)

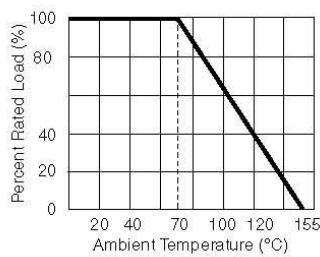
CF-RC Series

FEATURES

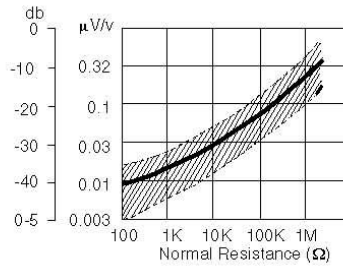
- Temperature Range -55°C ~ +155°C
- $\pm 5\%$ tolerance
- High quality performance at economical prices
- Compatible with automatic insertion equipment
- Flame retardant type available
- Tin coated annealed copper wire
- Values below 1 Ω or above 10M Ω are available by special request, please ask for details



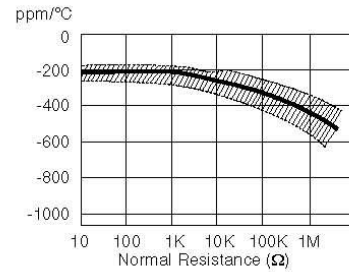
DERATING CURVE



CURRENT NOISE



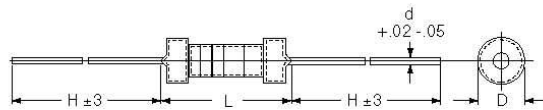
TEMPERATURE COEFFICIENT



PART NUMBERING SYSTEM

2	9	1	-	1	0	K	/	R	E	E	L	-	R	C
Series				Ohms				Package Code				Suffix (RoHS Compliant)		

SERIES, WATTAGE, SIZE, VOLTAGE, DIMENSIONS, AND AVAILABLE PACKAGING



Code:	Package:
	Bulk
/REEL	Tape and Reel
/AP	Ammo Pack

Series	Watts	Size	Voltage (max.)		Dimensions (mm)				Standard Quantities Available		
			W.V.	O.V.	L max.	D max.	H	d	Bulk	Tape and Reel	Ammo Pack
294	1W	Small	500	1,000	12	5.0	28	0.7	1,000	3,000	1,000
299	1/8W	Standard	200	400	3.5	1.85	28	0.45	1,000	5,000	2,000
291	1/4W	Standard	250	500	6.8	2.5	28	0.54	1,000	5,000	1,000
293	1/2W	Standard	350	700	10	3.5	28	0.54	1,000	3,000	1,000

STANDARD VALUES (Ω)

0.5	2.0	4.3	9.1	20	43	91	200	430	910	2K	3.9K	8.2K	18K	39K	82K	180K	390K	820K	1.8M	3.9M	8.2M
1.0	2.2	4.7	10	22	47	100	220	470	1K	2.2K	4.3K	9.1K	20K	43K	91K	200K	430K	910K	2M	4.3M	9.1M
1.1	2.4	5.1	11	24	51	110	240	510	1.1K	2.4K	4.7K	10K	22K	47K	100K	220K	470K	1M	2.2M	4.7M	10M
1.2	2.7	5.6	12	27	56	120	270	560	1.2K	2.7K	5.1K	11K	24 K	51K	110K	240K	510K	1.1M	2.4M	5.1M	15M
1.3	3.0	6.2	13	30	62	130	300	620	1.3K	3K	5.6K	12K	27K	56K	120K	270K	560K	1.2M	2.7M	5.6M	22M
1.5	3.3	6.8	15	33	68	150	330	680	1.5K	3.2K	6.2K	13K	30K	62K	130K	300K	620K	1.3M	3M	6.2M	
1.6	3.6	7.5	16	36	75	160	360	750	1.6K	3.3K	6.8K	15K	33K	68K	150K	330K	680K	1.5M	3.3M	6.8M	
1.8	3.9	8.2	18	39	82	180	390	820	1.8K	3.6K	7.5K	16K	36K	75K	160K	360K	750K	1.6M	3.6M	7.5M	



Carbon Film Fixed Resistors (RoHS Compliant) CF-RC Series

■ CHARACTERISTICS

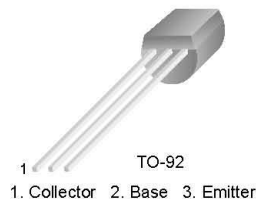
Characteristics	Limits		Test Methods (JIS C 5201-1)		
DC. Resistance	Must be within the specified tolerance.		5.1 The limit of error of measuring apparatus shall not exceed allowable range or 5% of resistance tolerance		
Temperature coefficient	Resist. Range	T.C.R. (PPM / °C)	5.2 Natural resistance change per temp. degree centigrade. R2-R1 ———— x106 (PPM/°C) R1(t2-t1) R1: Resistance value at room temperature (t1) R2: Resistance value at room temp.plus 100°C (t2)		
	< 10 Ω 11Ω ~ 99K 100K ~ 1M 1.1M ~ 10M	0 ~ ±350 0 ~ -450 0 ~ -700 0 ~ -1500			
Short time overload	Resistance change rate is ± (1 % + 0.05Ω) Max. with no evidence of mechanical damage		5.5 Permanent resistance change after the application of a potential of 2.5 times RCWV for 5 seconds.		
Insulation Resistance	Insulation resistance is 10,000 MΩ Min		5.6 Resistors shall be clamped in the trough of a 90° metallic V-block and shall be tested at DC potential respectively specified in the above list for 60 +10/- 0 seconds.		
Dielectric withstanding voltage	No evidence of flashover mechanical damage,arcing or insulation break down.		5.7 Resistors shall be clamped in the trough of a 90° metallic V-block and shall be tested at AC potential respectively specified in the table 1 for 60 + 10/-0 seconds.		
Terminal strength	No evidence of mechanical damage.		6.1 Direct load Resistance to a 2.5 kgs direct load for 10 secs. in the direction of the longitudinal axis of the terminal leads. Twist test : Terminal leads shall be bent through 90° at a point of about 6mm from the body of the resistor and shall be rotated through 360° about the original axis of the bent terminal in alternating direction for a total of 3 rotations.		
Resistance to soldering heat	Resistance change rate is ± (1% + 0.05Ω) Max. with no evidence of mechanical damage.		6.4 Permanent resistance change when leads immersed to 3.2 to 4.8 mm from the body in 350 °C ± 10°C solder for 3 ± 0.5 seconds		
Solderability	95 % coverage Min.		6.5 The area covered with a new , smooth clean , shiny and continuous surface free from concentrated pinholes. Test temp. of solder : 245°C ± 3°C Dwell time in solder : 2 ~ 3 seconds		
Temperature cycling	Resistance change rate is ± (1% + 0.05Ω) Max. with no evidence of mechanical damage.		7.4 Resistance change after continuous 5 cycles for duty shown below:		
			Step	Temperature	Time
			1	-55°C ±3°C	30 mins
			2	Room temp.	10~15 mins
			3	+155°C ±2°C	30 mins
4	Room temp.	10~15 mins			
Load life in humidity	Resistance value		ΔR/R	7.9 Resistance change after 1,000 hours operating at RCWV with duty cycle of (1.5 hours "on", 0.5 hour "off") in a humidity test chamber controlled at 40°C ± 2°C and 90 to 95 % relative humidity	
	Normal Type	< than 100KΩ >100KΩ			± 3 % ± 5 %
Load life	Resistance value		ΔR/R	7.10 Permanent resistance change after 1,000 hours operating at RCWV with duty cycle of (1.5 hours "on", 0.5 hour "off") at 70°C ± 2°C ambient	
	Normal Type	< than 56KΩ > 56KΩ			± 2 % ± 3 %



BC546/547/548/549/550

Switching and Applications

- High Voltage: BC546, $V_{CE0}=65V$
- Low Noise: BC549, BC550
- Complement to BC556 ... BC560



NPN Epitaxial Silicon Transistor

Absolute Maximum Ratings $T_a=25^{\circ}C$ unless otherwise noted

Symbol	Parameter	Value	Units
V_{CBO}	Collector-Base Voltage : BC546	80	V
	: BC547/550	50	V
	: BC548/549	30	V
V_{CEO}	Collector-Emitter Voltage : BC546	65	V
	: BC547/550	45	V
	: BC548/549	30	V
V_{EBO}	Emitter-Base Voltage : BC546/547	6	V
	: BC548/549/550	5	V
I_C	Collector Current (DC)	100	mA
P_C	Collector Power Dissipation	500	mW
T_J	Junction Temperature	150	$^{\circ}C$
T_{STG}	Storage Temperature	-65 ~ 150	$^{\circ}C$

Electrical Characteristics $T_a=25^{\circ}C$ unless otherwise noted

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
I_{CBO}	Collector Cut-off Current	$V_{CB}=30V, I_E=0$			15	nA
h_{FE}	DC Current Gain	$V_{CE}=5V, I_C=2mA$	110		800	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C=10mA, I_B=0.5mA$		90	250	mV
		$I_C=100mA, I_B=5mA$		200	600	mV
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	$I_C=10mA, I_B=0.5mA$		700		mV
		$I_C=100mA, I_B=5mA$		900		mV
$V_{BE(on)}$	Base-Emitter On Voltage	$V_{CE}=5V, I_C=2mA$	580	660	700	mV
		$V_{CE}=5V, I_C=10mA$			720	mV
f_T	Current Gain Bandwidth Product	$V_{CE}=5V, I_C=10mA, f=100MHz$		300		MHz
C_{ob}	Output Capacitance	$V_{CB}=10V, I_E=0, f=1MHz$		3.5	6	pF
C_{ib}	Input Capacitance	$V_{EB}=0.5V, I_C=0, f=1MHz$		9		pF
NF	Noise Figure : BC546/547/548 : BC549/550	$V_{CE}=5V, I_C=200\mu A$		2	10	dB
		$f=1KHz, R_G=2K\Omega$		1.2	4	dB
		$V_{CE}=5V, I_C=200\mu A$		1.4	4	dB
		$R_G=2K\Omega, f=30\sim 15000MHz$		1.4	3	dB

h_{FE} Classification

Classification	A	B	C
h_{FE}	110 ~ 220	200 ~ 450	420 ~ 800

Typical Characteristics

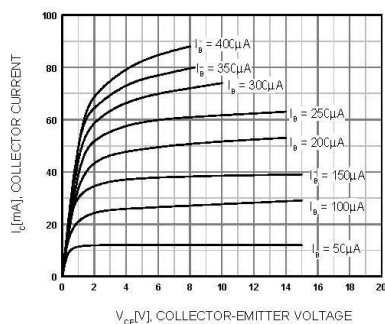


Figure 1. Static Characteristic

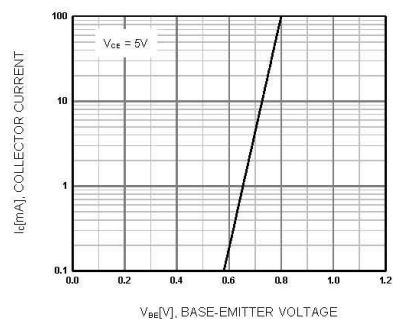


Figure 2. Transfer Characteristic

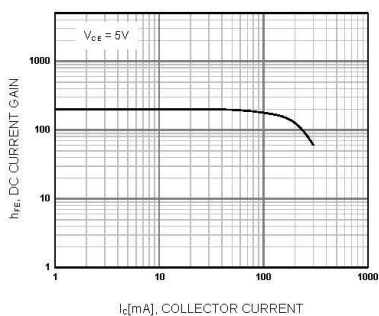


Figure 3. DC current Gain

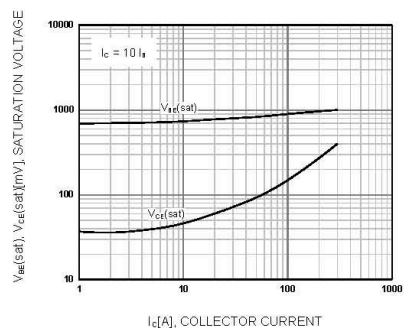
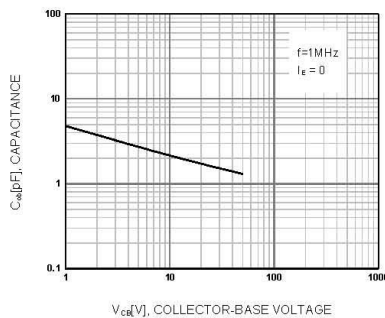
Figure 4. Base-Emitter Saturation Voltage
Collector-Emitter Saturation Voltage

Figure 5. Output Capacitance

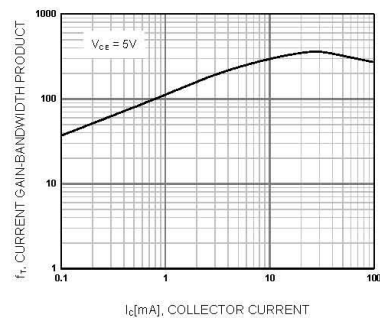
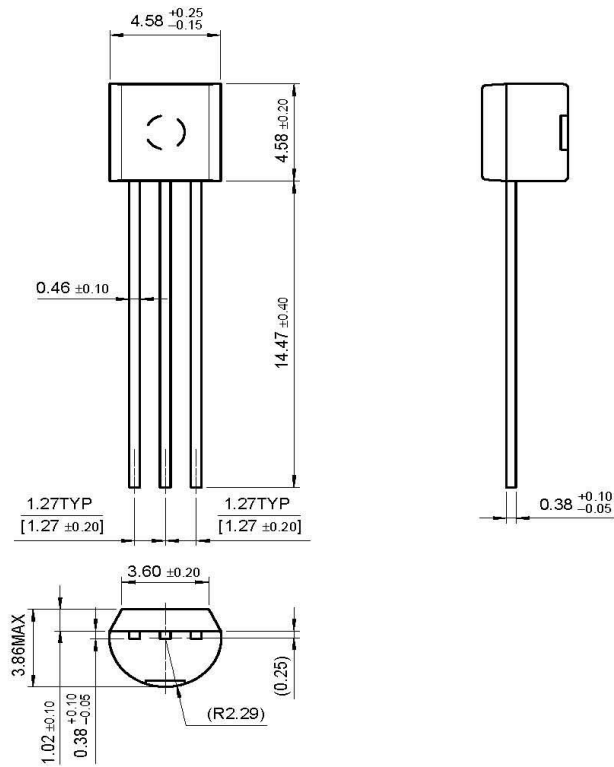


Figure 6. Current Gain Bandwidth Product

Package Dimensions

TO-92



Dimensions in Millimeters

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Bottomless [™]	FAST [®]	LittleFET [™]	Power247 [™]	SuperSOT [™] -3
CoolFET [™]	FAST [™]	MicroFET [™]	PowerTrench [®]	SuperSOT [™] -6
CROSSVOLT [™]	FRFET [™]	MicroPak [™]	QFET [™]	SuperSOT [™] -8
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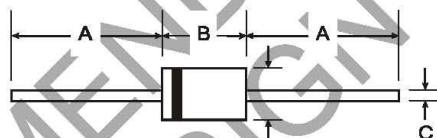
PRODUCT STATUS DEFINITIONS

Definition of Terms

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

Features

- Diffused Junction
- High Current Capability and Low Forward Voltage Drop
- Surge Overload Rating to 30A Peak
- Low Reverse Leakage Current
- Lead Free Finish, RoHS Compliant (Note 3)



Mechanical Data

- Case: DO-41
- Case Material: Molded Plastic. UL Flammability Classification Rating 94V-0
- Moisture Sensitivity: Level 1 per J-STD-020D
- Terminals: Finish - Bright Tin. Plated Leads Solderable per MIL-STD-202, Method 208
- Polarity: Cathode Band
- Ordering Information: See Page 2
- Marking: Type Number
- Weight: 0.30 grams (Approximate)

Dim	DO-41 Plastic	
	Min	Max
A	25.40	—
B	4.06	5.21
C	0.71	0.864
D	2.00	2.72
All Dimensions in mm		

Maximum Ratings and Electrical Characteristics (@T_A = +25°C unless otherwise specified.)

Single phase, half wave, 60Hz, resistive or inductive load.
For capacitive load, derate current by 20%.

Characteristic	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
Peak Repetitive Reverse Voltage	V _{RRM}	50	100	200	400	600	800	1000	V
Working Peak Reverse Voltage	V _{RWM}								
DC Blocking Voltage	V _R								
RMS Reverse Voltage	V _{R(RMS)}	35	70	140	280	420	560	700	V
Average Rectified Output Current (Note 1) @ T _A = +75°C	I _O	1.0							A
Non-Repetitive Peak Forward Surge Current 8.3ms	I _{FSM}	30							A
Single Half Sine-Wave Superimposed on Rated Load									
Forward Voltage @ I _F = 1.0A	V _{FM}	1.0							V
Peak Reverse Current @ T _A = +25°C	I _{RM}	5.0							μA
at Rated DC Blocking Voltage @ T _A = +100°C		50							
Typical Junction Capacitance (Note 2)	C _J	15					8		pF
Typical Thermal Resistance Junction to Ambient	R _{θJA}	100							K/W
Maximum DC Blocking Voltage Temperature	T _A	+150							°C
Operating and Storage Temperature Range	T _J T _{STG}	-65 to +150							°C

- Notes:
1. Leads maintained at ambient temperature at a distance of 8.5mm from the case.
 2. Measured at 1.0 MHz and applied reverse voltage of 4.0V DC.
 3. EU Directive 2002/95/EC (RoHS). All applicable RoHS exemptions applied, see EU Directive 2002/95/EC Annex Notes.



NOT RECOMMENDED FOR NEW DESIGN
USE S1A-S1M series

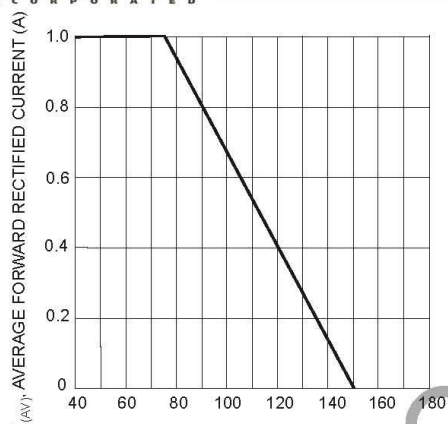


Fig. 1 Forward Current Derating Curve

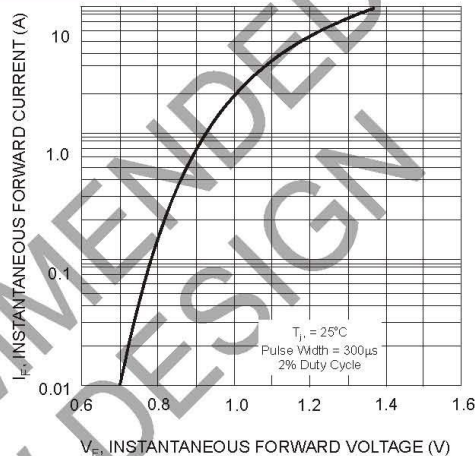


Fig. 2 Typical Forward Characteristics

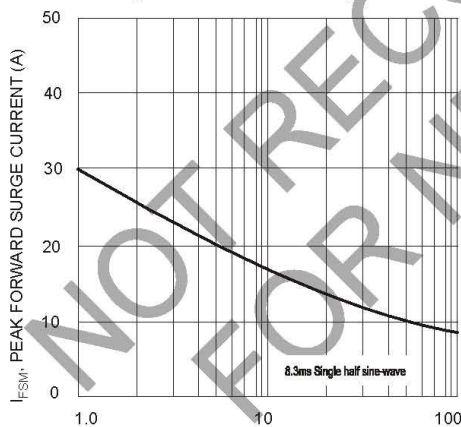


Fig. 3 Max Non-Repetitive Peak Fwd Surge Current

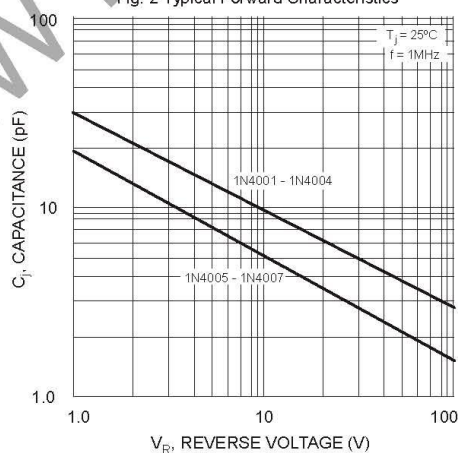


Fig. 4 Typical Junction Capacitance

Ordering Information (Note 4)

Device	Packaging	Shipping
1N4001-B	DO-41 Plastic	1K/Bulk
1N4001-T	DO-41 Plastic	5K/Tape & Reel, 13-inch
1N4002-B	DO-41 Plastic	1K/Bulk
1N4002-T	DO-41 Plastic	5K/Tape & Reel, 13-inch
1N4003-B	DO-41 Plastic	1K/Bulk
1N4003-T	DO-41 Plastic	5K/Tape & Reel, 13-inch
1N4004-B	DO-41 Plastic	1K/Bulk
1N4004-T	DO-41 Plastic	5K/Tape & Reel, 13-inch
1N4005-B	DO-41 Plastic	1K/Bulk
1N4005-T	DO-41 Plastic	5K/Tape & Reel, 13-inch
1N4006-B	DO-41 Plastic	1K/Bulk
1N4006-T	DO-41 Plastic	5K/Tape & Reel, 13-inch
1N4007-B	DO-41 Plastic	1K/Bulk
1N4007-T	DO-41 Plastic	5K/Tape & Reel, 13-inch

Note: 4. For packaging details, visit our website at <http://www.diodes.com/datasheets/ap02008.pdf>.



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SERVO

Compact DC Motors

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LONG LIFE, HIGH QUALITY DC BRUSH MOTORS

NEW

DMN Series

Long life

High quality

High output

Low noise

RoHS-compliant

Features

- *Long-life:*
Intermittent operation
over 1 million cycles with
optimized brush design^{*1}
- *Continuous operating life of*
3000 hours^{*1}
- *High output: High heat dissipation*
and heat resistance achieves higher
output
- *High strength: High radial load capacity due*
to robust construction, large diameter output
shaft and ball bearings
- *Low noise and increased insulation due to new resin*
brush holders
- *Large selection of gear heads and reduction ratios are*
available to meet all needs
- *Also available with magnetic revolution sensor and noise filter*^{*2}

^{*1} Differs depending on environment and application. Contact us for details. ^{*2} Scheduled for release

April 2006.

Long Life

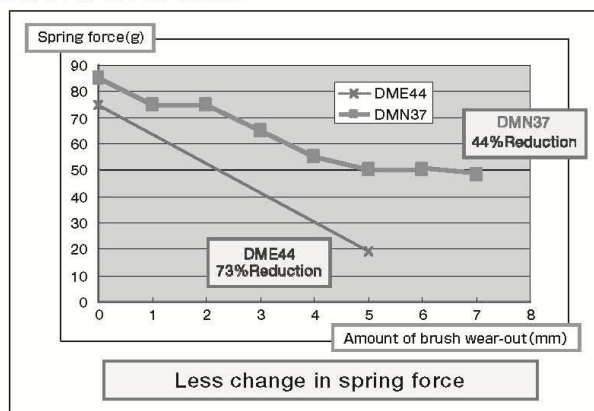
Life time

DME Series	DME25	DME33	DME34	DME37	DME44
	1000Hours			2000Hours	
DMN Series	DMN29			DMN37	
	3000Hours			3000Hours	

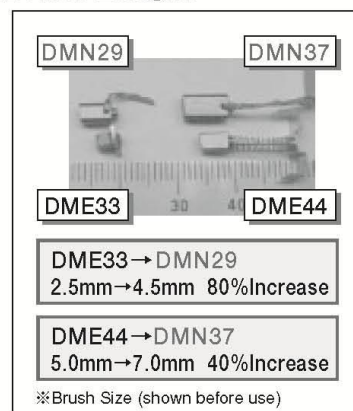
Continuous Operation :

※The motor life-time is dependent upon actual application conditions. Please consult us for more information.

Brush Wear Rate

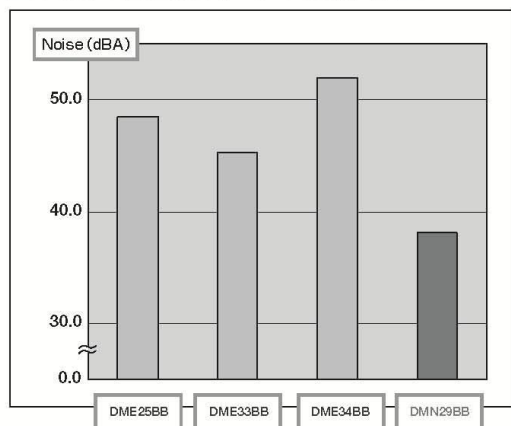


Brush Length



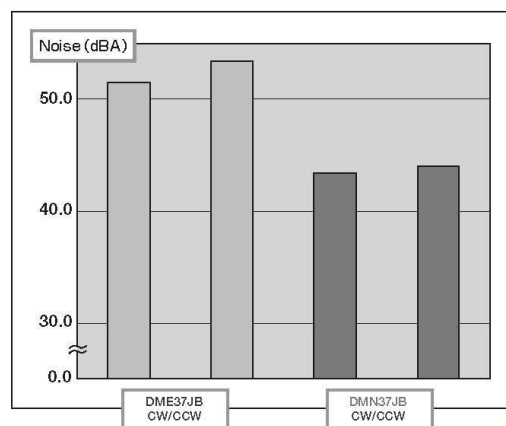
Comparison of Noise

DME25/33/34 ⇔ DMN29



By adoption of Resin Brush Holder, Noise reduced by 8dB compared to DME25, 33, 34

DME37 ⇔ DMN37

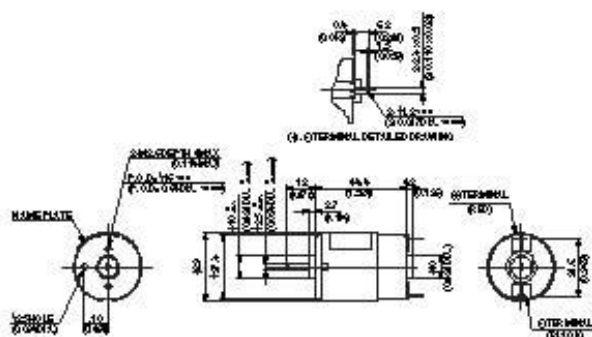


By adoption of Resin Brush Holder, Noise reduced by 8dB compared to DME37

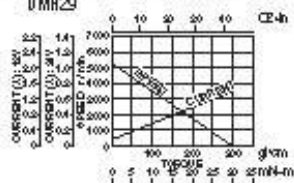
DMN29



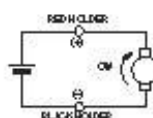
●DIMENSIONS Unit mm(inch)



●CURRENT, SPEED-TORQUE CURVE
DMH29



● CONNECTION



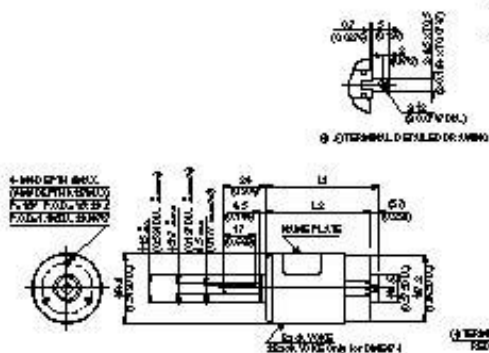
●STANDARD SPECIFICATIONS

Model	Rated					No load		Stall torque		Weight		
	Output	Voltage	Torque		Current	Speed	Current	Speed	mNm	ozin	Weight	
			W	V							mN-m	ozin
DM H298A	3.0	12	7.8	1.11	0.42	3700	0.07	5000	30	4.17	90	0.20
DM H298B	3.0	24	7.8	1.11	0.21	3700	0.05	5000	30	4.17	90	0.20

DMN37



● DIMENSIONS Unit mm(inch)

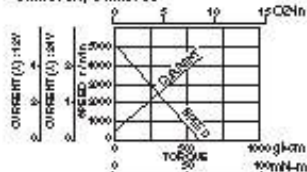


MODEL CODE	VOLTAGE	OUTPUT	CURRENT
SA	12V	4.6W	0.78A
SB	24V	4.6W	0.37A
BA	12V	7.2W	1.01A
BB	24V	7.2W	0.53A
KA	12V	9.2W	1.20A
KB	24V	9.2W	0.60A
JB	24V	14.7W	0.94A

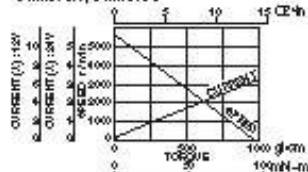
Model	L1		L2	
	(mm)	(inch)	(mm)	(inch)
DMH37S	45.2	1.780	39.5	1.555
DMH37B	53.2	2.094	47.5	1.870
DMH37K	59.2	2.291	52.5	2.067
DMH37J	63.2	2.489	57.5	2.264

● CURRENT, SPEED-TORQUE CURVE

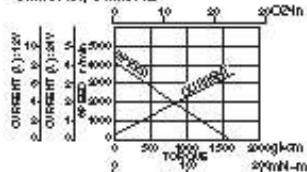
DMH37SA, DMH37SB



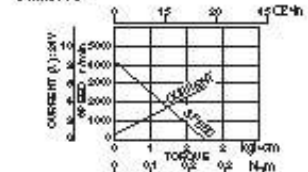
DMH37BA, DMH37BB



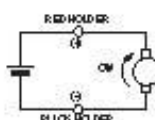
DMH37KA, DMH37KB



DMH37JB



● CONNECTION



● STANDARD SPECIFICATIONS

Model	Output W	Voltage V	Rated Torque		Current A	Speed r/min	No load		Stall torque		Weight	
			mN·m	oz·in			Current A	Speed r/min	mN·m	oz·in		
DMH37SA	4.6	12	9.8	1.39	0.78	4500	0.26	5500	54	7.64	130	0.29
DMH37SB	4.6	24	9.8	1.39	0.37	4500	0.12	5500	54	7.64	130	0.29
DMH37BA	7.2	12	14.7	2.08	1.01	4700	0.26	5500	99	13.89	180	0.40
DMH37BB	7.2	24	14.7	2.08	0.53	4700	0.13	5500	99	13.89	180	0.40
DMH37KA	9.2	12	24.5	3.47	1.20	3600	0.27	4300	160	23.61	210	0.46
DMH37KB	9.2	24	24.5	3.47	0.60	3600	0.14	4300	160	23.61	210	0.46
DMH37JB	14.7	24	39.2	5.55	0.94	3600	0.16	4300	240	34.72	240	0.53

Standard ratings are given for DMH37JB (Duty 50%)

Structure

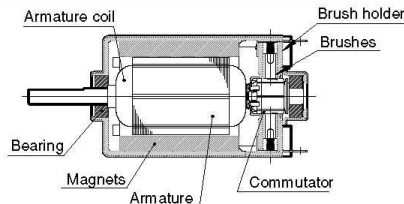


Fig. 1

• Brushes

The brush is an important part that serves as a commutating mechanism. The brush's service life (in accordance with wear) will be the service life of the direct-current motor.

• Commutator

In general, copper is the material used, but to counteract how it softens at high temperatures, a small amount of silver is mixed with it.

• Armature coil

In general, electric wire known as magnet wire is used. Wire diameter is selected in accordance with the motor's specifications, and the wire is connected to the commutator bar by means of welding, soldering or other such methods.

• Armature

For the armature, magnetic steel sheet is used to increase magnetic flux density.

• Magnets

Broadly speaking, the magnets used in the motor can be classified in terms of whether they are ferrite, alnico, rare earth, etc. Magnets are selected in accordance with usage purpose, based on their features.

• Bearing

There are ball bearings and sleeve bearings, and they are used in accordance with purpose. The ball bearing is the type that is appropriate for uses involving large bending loads.

Current and rotating torque characteristics

The magnet DC motor has dropping characteristics (rotation speed) and rising characteristics, as shown in Figure 2. When applied voltage V is changed, as shown in Figure 2, torque rotating speed characteristics will be proportional to the value for V , but current torque characteristics will only change very slightly. (For details, please refer to the relational expression for current and torque rotating speed.)

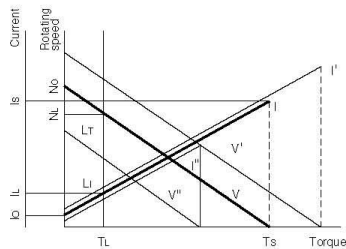


Fig. 2

How to view characteristics

As shown in Figure 2, at applied voltage V , when load torque T_L is added to the motor, rotating speed and current will be N_L and I_L , respectively. When V has been changed to $V'V''$, the result can be similarly sought. No-load rotating speed, N_0 , and stalling (starting) torque, T_s , will be proportional to the applied voltage; thus, the values for when a 24V motor, for example, is used at 20V

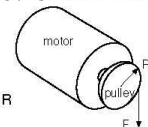
or 18V will be on the order of those shown in Table 1. (No-load current I_0 will be sufficiently small compared with the stalling current and can thus be disregarded.) When changing the rated voltage substantially (from 24V to 6V, for example), it will be necessary to depend on actual measurement.

However, use at something other than the rated voltage could cause abnormal brush wear and startup malfunctions. Thus, we ask that you confirm the usage conditions.

Voltage	No-load rotating speed N_0	Stalling torque T_s	Stalling current I_s
24V	5000r/min	40mN·m	1.0A
20V	$\frac{20}{24} \times 5000$ 4166	$\frac{20}{24} \times 40$ 33	$\frac{20}{24} \times 1$ 0.83
18V	$\frac{18}{24} \times 5000$ 3750	$\frac{18}{24} \times 40$ 30	$\frac{18}{24} \times 1$ 0.75

Table 1

Explanation of Terminology

Term/Symbol	Content
No-load rotating speed N_0	Rotating speed with no load
No-load current I_0	Input current with no load
Stalling torque T_s	Max. value for motor-generated torque. In general, a DC motor's stalling torque is equal to its starting torque.
Load torque T_L	As shown in Figure 3, when a pulley with radius R is attached to the motor and force of F is applied to the pulley's circumference, the torque generated, T_L , can be derived by multiplying F and R ($F \times R = T_L$).  Note : Using the lock with voltage applied could cause burnout.

Relational expressions for torque, rotating speed and current

Relational expressions are as follows.

If the no-load rotating speed from formula 1 is taken to be N_0 , when load torque T_L is zero, there will be no load; thus, if $T_L = 0$, the following will be the case.

No-load rotating speed N_0 will be determined from the size of the motor's friction torque, T_0 . If T_0 is low, the no-load rotating speed from formula 3 will be roughly proportional to the applied voltage. In addition, stalling (starting) torque will equal the load torque when rotating speed N from formula 1 is zero, resulting in the following:

Starting torque will be roughly proportional to the applied voltage. Current will be as follows.

From this formula, when load torque T_L and friction torque are constant, the current will be constant with no relation to applied voltage. The no-load current will be the value that makes the load torque zero in formula 5, but friction torque T_0 will change slightly, in accordance with rotating speed; thus, there will be some change caused by the applied voltage.

If motor output is designated as P (W), torque as T (N·m) and rotating speed as N (r/min), motor output P (W) will be as follows.

$$P = 0.105 \times T \times N \dots \dots \dots \text{Formula 6}$$

N : Rotating speed T_0 : Motor's friction torque

V : Applied voltage T_L : Load torque

r : Armature-circuit resistance K_1 and K_2 : Motor-specific constant

Technical Description:

Operating Precautions

DC motors are compact and display high output, and their speed is easy to control. They may be driven by battery or any other power supply and are therefore also easy to use. However, inappropriate power supply may lead to burnout or abnormal brush wear.

Problems with power supply, installation, and general precautions and problems with a motor installed in-circuit will be described.

• Overload and lock-up

An excessive amount of load torque is applied during overloaded driving or when locked up, causing an excessive current flow with heat damage being incurred by the motor. Therefore, overloaded or locked-up use is to be avoided. (Locking up for 5 or more seconds results in damage to a motor. Do not lock up a motor for 5 or more seconds.)

• Applied voltage

Be sure to use a motor at its rated voltage ($+10V$), and avoid any surge voltage. We can specially manufacture motors designed with an electrical path protecting the motor from surges and reversed polarity. Please contact us for details.

• Applying non-rated supply voltages

Applying a voltage higher than the motor's rating results in a temperature increase, leading to heat damage or lowered service life. Scoring of the commutator surface by sparks and mechanical brush wear arising from vibration may also occur.

Applying a voltage lower than the motor's rating may eventually result in the motor failing to start. This is due to the build up of carbon powder on the commutator.

Motors are manufactured for use within $+10V$ of their rated specifications.

Please contact us if you need to use motors outside their ratings.

• Brush wear promoted by power supply ripples

Brush wear may be mechanical wear due to brush and commutator abrasion or electrical wear due to sparking between the brush and commutator, the latter being the most common. Brush wear is therefore greatly affected by ripples in the power supply voltage, and use of general regulated DC is recommended. However, when rectifying AC for use by a motor, be sure to use full-wave rectification with a capacitor or similar element in a smoothing circuit.

• Ambient conditions

The service life of a DC motor is dependant upon its rectifying action. Care must be taken to ensure good commutation, as dust, oil, gas, water, etc. Water, etc, on the commutator surface results in poor rectification and increases brush wear.

• Changing the brush position

The brushes are generally fixed in position such that rotational speed and current characteristics are maintained equivalent in both clockwise and counter-clockwise directions. These are basically determined based on the position of the magnetic poles. Rotating the motor after not carefully relocating parts such as the brush holder (for fixing the brushes) or rear cover results in misalignment of the brushes and magnets. This will produce change in the above characteristics in the rotational direction or cause poor rectification, leading to abnormal brush wear. Therefore, changing of the brush positioning is to be avoided.

• Installed orientation

Motors are generally designed for use with a horizontal output shaft. Special consideration must be given to components including bearings and grease washers when intended for an upward- or downward-facing output shaft. Please contact us for details.

Further, avoid installing a motor in a manner in which grease from the gear head would tend to enter the motor (e.g., with an upward-facing output shaft).

• Noise generation

Electrical noise is generated as a result of sparks from commutation between the brushes and commutator. Please contact us for assistance with lowering noise.

• Gear heads for intermittent drive

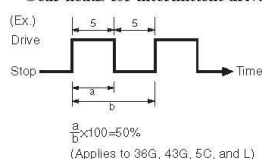


Fig. 5

The gearhead is assembled with a fixed shaft about which a gear revolves and transmits power. It is not suited to continuous drive. You should maintain the duty ratio between ON and OFF states at no more than 50%, with the maximum ON state not exceeding 5 seconds.

• Motor and gear head combination

When combining a gear head with a pinion shaft, gently fit the gear head on turning it right and left, being careful that the pinion and the gear in the gear head do not strongly clash with each other.

Using force will cause noise-producing scratches in the pinion and the gear. Scratches are Failures by a decreased service life and are the cause of unforeseen accidents.

• Load variation

Even with torque below the rated load, a motor will incur more damage than might be imagined if there is frequent load variation. Exercise caution with operating conditions and load restrictions.

• Insulation resistance

The insulation resistance of a brush motor will naturally continue to decrease as its running time increases. The figures for resistance given in the catalog are for a new motor.

• Service life

Service life depends greatly on operating conditions and environment. Please contact us for details.

• Other aspects

Oil may seep out of the grease in the gear head depending on operating conditions, storage environment, etc.

This does not present any problems in the use of the gear head. However, contamination of the machine or equipment to which the geared motor is fitted may occur.

DME

Motors with pulse generators:

There are two types of pulse generators that are featured in DME series motors : the magnetic and optical revolution sensor. (Note, the optical revolution sensor is available only in the DME34 model.) Both are incremental revolution sensor. And all the above generators can output Single Phase pulse signal only. When TWO Phase signal is required, contact our sales agent near you or directly to us. We may quote on case by case basis.



Magnetic Type

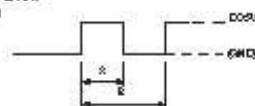
Magnetic Revolution Sensor :

Compared to the optical revolution sensor, the magnetic revolution sensor is more resistant to high temperatures, dust contaminations, vibrations and impact shocks. The design of the magnetic revolution sensor type motor is also more simple. In incremental type revolution sensor, pulse output signals are sent to a counter wherein the incremented value is displayed. Signal noise, here, lead to performance errors. Magnetic type revolution sensors are especially vulnerable to signal noise since the signal levels are usually very low (20mA to 30mA). Thus, make sure magnetic revolution sensor type motors are provided proper magnetic shielding, and signal lines are as short as possible (ideally within 5m).

●STANDARD SPECIFICATION OF REVOLUTION SENSOR

REVOLUTION SENSOR TYPE	MAGNETIC	OPTICAL
PULSE PER REVOLUTION	12P/rev.	24P/rev.
INPUT VOLTAGE	DC5V $\pm$ 0%	DC5V $\pm$ 0%
CURRENT CONSUMPTION	5mA nominal	25mA nominal
DUTY (B/A)	50 $\pm$ 20%	50 $\pm$ 0%

OUTPUT WAVEFORM (COMMON)

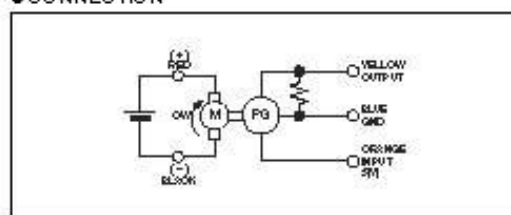


Optical Type

Optical Revolution Sensor:

Long-life LED is used as the light emitter, and a photo-transistor is used as the light detector. When using optical revolution sensor type motors, special considerations are needed to protect against dust and extreme temperatures. The most frequent causes of trouble in optical revolution sensors are : dust build-ups impairing proper optical properties ; and extreme leading to deterioration in light emission performance. Japan Servo can thus ensure full rated performance only in ambient temperatures between 0 to 40 degrees centigrade, and in dust-free conditions.

●CONNECTION



DC SMALL MOTORS **DME** Series

The DME Series motor is a feasible and practical DC motor that is used popularly in many applications.

According to user demands, Japan Servo combines the DME motor with a wide variation of high-performance gearboxes to further increase the application possibilities for the DME Series.

Also, in response to demands for a simple, low-cost motor that has a certain amount of controllability, Japan Servo provides DME models that feature pulse generators (magnetic or optical PG).

For certain models of the DME Series, the motor and gearboxes can be ordered separately, allowing for much greater versatility by combining various type motors with a wide range of reduction gears. Please refer to the product line-up chart to select the DME Series motor that is just right for your specific needs.

●DME SERIES MOTOR'S CONSTRUCTION AND CHARACTERISTICS.

MODEL	BRUSH HOLDING	CORE SLOTS	BEARING	MAGNET	LIFE* (hrs)	OUTPUT POWER (W)							PAGE
						S	B	K	J	5	10	15	
DME 25	Holder	3 slots	Sintered sleeve bearing	Anisotropic	1000		○			◎ 3			12
DME 33	Spring plate	3 slots	Sintered sleeve bearing	Isotropic Anisotropic	1000	○				◎ 0.7			15
							○			◎ 3			
DME 34	Spring plate	3 slots	Sintered sleeve bearing	Isotropic Anisotropic	1000 (500)	○				◎ 1.3			21
							○			◎ 4.5			
								○		◎ 7			
DME 37	Holder	7 slots	Sintered sleeve bearing	Anisotropic	2000	○				◎ 4.6			29
							○			◎ 7.2			
								○		◎ 9.2			
									○			◎ 17.2	
DME 44	Holder	10 slots	Ball bearing	Anisotropic	2000	○				◎ 9.2			34
							○				◎ 14.8		
DME 60	Holder	12 slots	Sint. sleeve/Ball bearing	Isotropic Anisotropic	2000	○					◎ 13		38
							○					26◎	

FEATURE	BRUSH HOLDER	BEARING	MAGNET
	Holder:Long-life 2000hours (1000 hours only for DME25, due to its high-speed operation) Spring plate:Standard 1000hours	Ball bearing :Long-life Sintered sleeve bearing :Standard	Anisotropic :High output Isotropic :Standard

*Operated in motor alone, and single direction.

●SELECTION CHART

		MOTOR SPECIFICATION					MOTOR ONLY	MOTORS WITH SENSOR		GEARED MOTORS		
		OUTPUT POWER	RATED VOLTAGE		RATED CURRENT	MAGNETIC REVOLUTION SENSOR		OPTICAL REVOLUTION SENSOR	 36G	 43G		
			W	CODE								V
DME25		3	B	12 24	A B	0.47 0.23	DME25BA DME25BB			DME25B36G ☐ A DME25B36G ☐ B	DME25B43G ☐ A DME25B43G ☐ B	
DME33		0.7	S	12 24	A B	0.12 0.06	DME33SA DME33SB	DME33SMA DME33SMB		DME33S36G ☐ A DME33S36G ☐ B	DME33S43G ☐ A DME33S43G ☐ B	
		3	B	12 24	A B	0.42 0.22	DME33BA DME33BB	DME33BMA DME33BMB		DME33B36G ☐ A DME33B36G ☐ B	DME33B43G ☐ A DME33B43G ☐ B	
DME34		1.3	S	12 24	A B	0.20 0.10	DME34SA DME34SB	DME34SMA DME34SMB	DME34SEA DME34SEB	DME34S36G ☐ A DME34S36G ☐ B	DME34S43G ☐ A DME34S43G ☐ B	
		4.5	B	12 24	A B	0.65 0.31	DME34BA DME34BB	DME34BMA DME34BMB	DME34BEA DME34BEB	DME34B36G ☐ A DME34B36G ☐ B	DME34B43G ☐ A DME34B43G ☐ B	
		7	K	24	B	0.41	DME34KB	DME34KMB	DME34KEB			
DME37		4.6	S	12 24	A B	0.78 0.37	DME37SA DME37SB	DME37SMA DME37SMB				
		7.2	B	12 24	A B	1.01 0.53	DME37BA DME37BB	DME37BMA DME37BMB				
		9.2	K	12 24	A B	1.20 0.60	DME37KA DME37KB	DME37KMA DME37KMB				
		17.2	J	24	B	1.07	DME37JB	DME37JMB				
DME44		9.2	S	12 24	A B	1.31 0.65	DME44SA DME44SB	DME44SMA DME44SMB				
		14.8	B	24	B	0.94	DME44BB	DME44BMB				
DME60		13	S	12 24	A B	2.07 1.00	DME60SA DME60SB					
		26	B	24	B	2.2	DME60BB					
							12	24				
							PULSES PER REVOLUTION					

●MOTOR DESIGNATIONS

[1] MOTORS ONLY

DME **34** **B** **A**

— SERIES NAME
— OUTPUT POWER
S: STANDARD TYPE
B: HIGH POWER TYPE1
K: HIGH POWER TYPE2
J: HIGH POWER TYPE3
— RATED VOLTAGE
A: DC12V
B: DC24V
— MOTOR DIAMETER in (mm)
25, 33, 34, 37, 44, 60

[2] MOTORS WITH SENSOR

DME **34** **B** **M** **A**

— TYPE OF SENSOR
M: MAGNETIC REVOLUTION SENSOR
E: OPTICAL REVOLUTION SENSOR

[3] GEARED MOTORS

DME **34** **B** **36G** **10** **A**

— GEAR RATIO
— GEARBOX MODEL
36G, 43G, 50G, 5C, L

[4] MOTOR AND GEARBOX SUPPLIED SEPARATELY

DME **37** **B** **6H** **FP** **A**

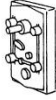
— TYPE OF PINION SHAFT

PINION SHAFT	MATCHING GEARBOX
6HP	6DG
6HFP	6DGF
8HP	8DG
8HFP	8DGF

6DG **15** **F**

— GEARBOX TYPE
6DG, 6DGF, 8DG, 8DGF
— GEAR RATIO

• Motors combined with gear heads are manufactured to order. The model code to be like: DME37B6DGF15B

				MOTOR AND GEARBOX SUPPLIED SEPERATELY				PAGE
	 50G	 5C	 L	 6DG	 6DGF	 8DG	 8DGF	
			DME25BL ☐ A DME25BL ☐ B	DME25B6HPA DME25B6HPB				12~14
		DME33S5C ☐ A DME33S5C ☐ B	DME33SL ☐ A DME33SL ☐ B	DME33S6HPA DME33S6HPB				15~20
	DME33B50G ☐ A DME33B50G ☐ B	DME33B5C ☐ A DME33B5C ☐ B	DME33BL ☐ A DME33BL ☐ B	DME33B6HPA DME33B6HPB				
		DME34S5C ☐ A DME34S5C ☐ B	DME34SL ☐ A DME34SL ☐ B	DME34S6HPA DME34S6HPB				21~28
	DME34B50G ☐ A DME34B50G ☐ B	DME34B5C ☐ A DME34B5C ☐ B	DME34BL ☐ A DME34BL ☐ B	DME34B6HPA DME34B6HPB		DME34B8HPA DME34B8HPB DME34K8HPB		
		DME34K5C ☐ B	DME34KL ☐ B					
	DME37S50G ☐ A DME37S50G ☐ B			DME37S6HPA DME37S6HPB				29~33
	DME37B50G ☐ A DME37B50G ☐ B			DME37B6HPA DME37B6HPB	DME37B6HFPA DME37B6HFPA	DME37B8HPA DME37B8HPB		
	DME37K50G ☐ A DME37K50G ☐ B			DME37K6HPA DME37K6HPB	DME37K6HFPA DME37K6HFPA	DME37K8HPA DME37K8HPB		
					DME37J6HFPA DME37J6HFPA	DME37J8HPA DME37J8HPB	DME37J8HFPA DME37J8HFPA	
	DME44S50G ☐ A DME44S50G ☐ B			DME44S6HPA DME44S6HPB	DME44S6HFPA DME44S6HFPA	DME44S8HPA DME44S8HPB		34~37
					DME44B6HFPA DME44B6HFPA	DME44B8HPA DME44B8HPB	DME44B8HFPA DME44B8HFPA	38~40
				DME60S6HPA DME60S6HPB	DME60S6HFPA DME60S6HFPA	DME60S8HPA DME60S8HPB	DME60S8HFPA DME60S8HFPA	
					DME60B6HFPA DME60B6HFPA	DME60B8HPA DME60B8HPB	DME60B8HFPA DME60B8HFPA	
NOTE: ☐ DENOMINATOR OF REDUCTION RATIO				6DG ☐	6DG ☐ F	8DG ☐	8DG ☐ F	
				MODEL NAMES OF MATCHING GEARBOX.				

● GEAR-HEAD DESIGN

GEAR RATIO (Denominator)	36G	43G	50G	5C	L	6DG	6DGF	8DG	8DGF
5						○	○	○	○
9									
10	○	○	○						
12.5						○	●	○	○
15						○	●	○	○
18	●	●	○			○	●	○	○
20	●	●		●		○	●	○	○
25						●	●	●	●
27			●						
30	●	●		●	○	●	●	●	●
36			●	●		●	●	●	●
40				●					
50	○	○		●	○	●	○	●	○
54			●			●		●	
60	○	○	●	●		●	○	●	○
72	○	○				●	○	●	
75	○	○		●		●	○	●	○
80				●					
96			○						
100	○	○		●		●	○	●	○
120	●	●			○	●	○	●	○
144			○						
150	●	●		●	○	○	○	●	○
180	●	●				○	○	●	○
192			○						
200	●	●		○	○			○	
250	●	●		○		○			
255					○				
256			○						
300	●	●		○		○		○	
400	○	○		○					
450						○		○	
500				○		●		●	
600	○	○				●		●	
750						●		●	
900						●		●	
1800						●		●	

○: Output shaft rotates in the same direction with motor shaft.
 ●: Output shaft rotates reversed direction to motor shaft.

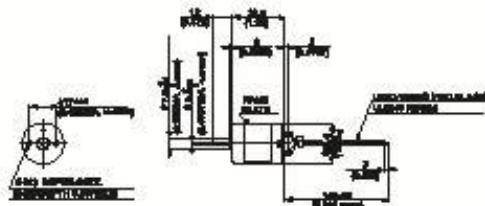
11

DME25

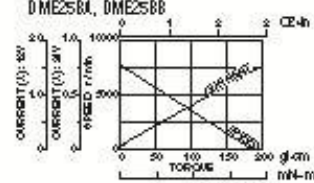


MODEL CODE	VOLTAGE	OUTPUT	CURRENT
BA	12V	3W	0.47A
BB	24V	3W	0.23A

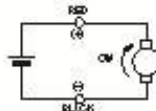
● DIMENSIONS Unit mm(inch) DME25BA, DME25BB



● CURRENT, SPEED-TORQUE CURVE DME25BA, DME25BB



● CONNECTION



● STANDARD SPECIFICATIONS

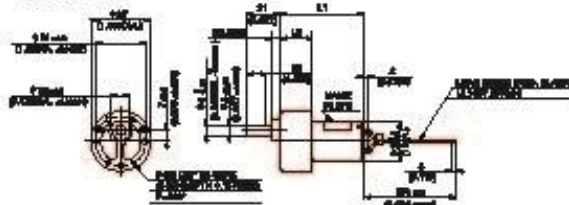
Model	Rated					No load		Stall torque		Weight		
	Output voltage		Torque		Current	Speed	Current	Speed	mNm	ozin	g	lb
	W	V	mN-m	ozin	A	r/min	A	r/min				
DME25BA	3	12	4.9	0.69	0.47	5900	0.07	9000	17.7	2.50	55	0.12
DME25BB	3	24	4.9	0.69	0.23	5900	0.04	9000	17.7	2.50	55	0.12

WITH GEARBOX

36G

Gear heads for
intermittent drive

● DIMENSIONS Unit mm(inch) DME2536G



GEAR RATIO	L1		L2		WEIGHT	
	(mm)	(inch)	(mm)	(inch)	a	b
10	52.3	2.059	12.8	0.78	160	0.35
18-30	54.8	2.157	22.3	0.878		
50-100	57.3	2.255	24.8	0.976		
120-300	59.8	2.354	27.3	1.075		
400-600	62.3	2.453	29.8	1.173	180	0.40

● with 36G TYPE GEARBOX

Model	Gear ratio		10	*18	*20	*30	50	60	75	100	*120	*150	*180	
	Rated speed		r/min	590	322	290	193	116	96.6	77.3	59	49.3	40.1	35.2
DME2536G□□□□	Rated torque		N·m	0.04	0.068	0.071	0.1	0.15	0.19	0.23	0.32	0.34	0.39	0.39
			oz·in	5.55	9.03	10.14	15.28	22.22	26.29	33.23	45.83	49.61	55.55	55.55
Model	Gear ratio		*200	*250	*300	400	500	600						
	Rated speed		r/min	32.5	27.2	23.3	17.9	14.6	12.4					
DME2536G□□□□	Rated torque		N·m	0.39	0.39	0.39	0.39	0.39	0.39					
			oz·in	55.55	55.55	55.55	55.55	55.55	55.55					

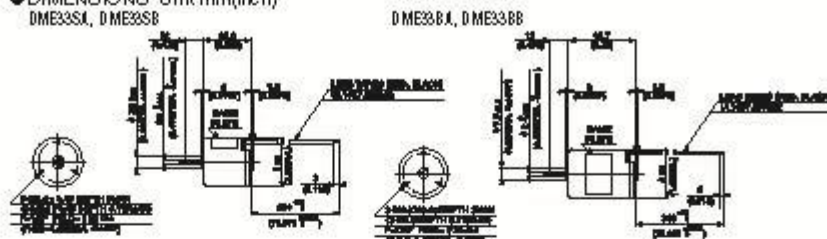
NOTE 1: Enter the required reduction ratio in the □
2: Rotation of gearbox shall be in reverse of rotation of motor
3: Enter the required voltage A or B in the □.

DME33

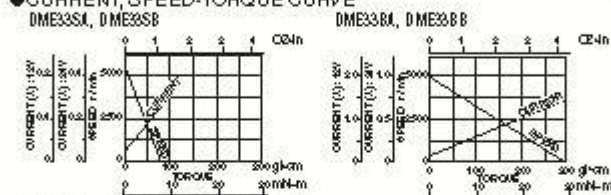


MODEL CODE	VOLTAGE	OUTPUT	CURRENT
SA	12V	0.7W	0.12A
SB	24V	0.7W	0.06A
BA	12V	3.0W	0.42A
BB	24V	3.0W	0.22A

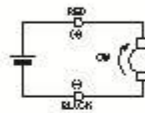
● DIMENSIONS Unit mm(inch)



● CURRENT, SPEED-TORQUE CURVE



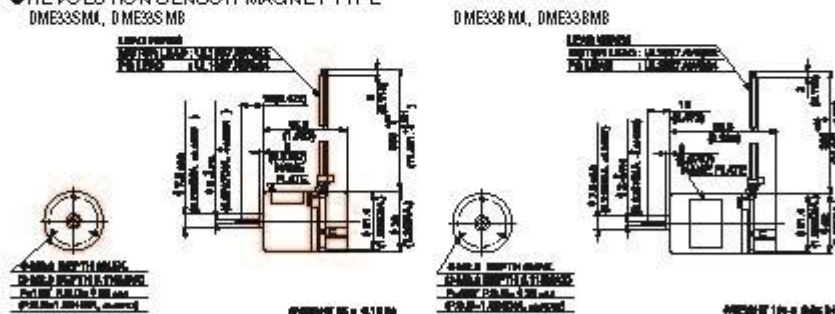
● CONNECTION



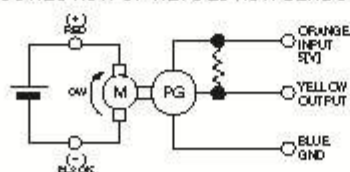
● STANDARD SPECIFICATIONS

Model	Output	voltage	Rated			No load		Start torque		Weight		
			Torque		Current	Speed	Current	Speed	mN-m	oz-in	g	lb
			mN-m	oz-in								
DME33SA	0.7	12	1.5	0.21	0.12	4500	0.05	5500	7.8	1.11	70	0.15
DME33SB	0.7	24	1.5	0.21	0.06	4500	0.02	5500	7.8	1.11	70	0.15
DME33BA	3	12	7.8	1.11	0.42	3700	0.06	5000	29	4.17	100	0.22
DME33BB	3	24	7.8	1.11	0.22	3700	0.04	5000	29	4.17	100	0.22

● REVOLUTION SENSOR MAGNET TYPE



● CONNECTION OF REVOLUTION SENSOR



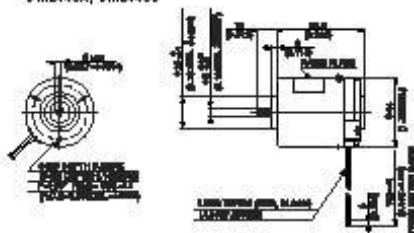
● SPECIFICATION OF REVOLUTION SENSOR SHOWN ON PAGE 9.

DME44

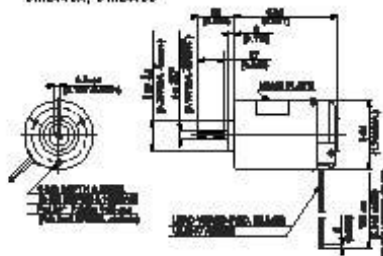


MODEL CODE	VOLTAGE	OUTPUT	CURRENT
SA	12V	9.2W	1.31A
SB	24V	9.2W	0.65A
BB	24V	14.8W	0.94A

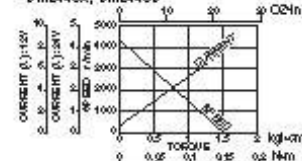
● DIMENSIONS Unit mm(inch) DME44SA, DME44SB



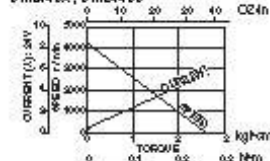
DME44BA, DME44BB



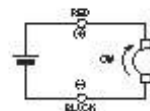
● CURRENT, SPEED-TORQUE CURVE DME44SA, DME44SB



DME44BA, DME44BB



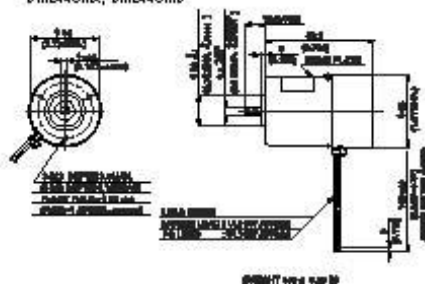
● CONNECTION



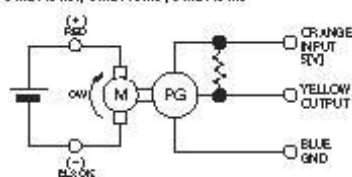
● STANDARD SPECIFICATIONS

Model	Rated						No load		Still torque		Weight	
	Output W	Voltage V	Torque		Current A	Speed r/min	Current A	Speed r/min	mN-m	oz-in	g	lb
DME44SA	9.2	12	2.4	3.47	1.31	3600	0.31	4300	150	22.22	300	0.66
DME44SB	9.2	24	2.4	3.47	0.65	3600	0.15	4300	150	22.22	300	0.66
DME44BB	14.8	24	3.9	5.55	0.94	3600	0.16	4300	250	36.11	400	0.88

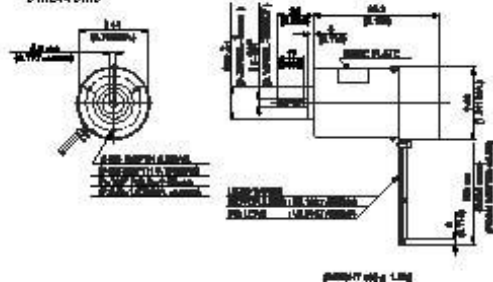
● REVOLUTION SENSOR MAGNET TYPE DME44SM, DME44SB



● CONNECTION OF REVOLUTION SENSOR DME44SM, DME44SB, DME44BB



DME44BMB



● SPECIFICATION OF REVOLUTION SENSOR ARE SHOWN ON PAGE 8.



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WARNING

- Please do not exceed the specifications noted in this catalogue, otherwise there is a chance of electric shock, injury, or other damage.
- Any modifications made to this motor are beyond the limits of our guarantee. NIDEC SERVO cannot take responsibility for any customer modifications.
- Please ensure that a thorough evaluation has been done before using this motor in medical equipment or other devices related to human lives.
- Please ensure that a thorough evaluation has been done before using this motor in applications that have a serious effect on the public.

NOTE

- Figures in this catalogue are average measured values. Please request the product delivery specification when preparing a purchase specification.
- The dimensions, specifications, and components contained in this catalogue are subject to change without prior notice due to further product improvements.

06SZ1K1

Apéndice D

PROGRAMA

```
/*Programa para el control del prototipo de molienda y tamizado */

#include <TouchScreenMenu.h>

#include <TouchScreen.h>

#include <TFT.h>

#include <cstdint.h>

const int PIN_LED1 = 1;    //Asignación de led 1 al PIN 12  MOLINO

const int PIN_LED2 = 0; //Asignación del led 2 al PIN 4   TAMICES

int val = 0;

int state = 0;

int old_val = 0;

// Elementos del menu procesar

TouchScreenMenuItem subMenuItems[] = {

    TouchScreenMenuItem("<- Menu"),

    TouchScreenMenuItem("Avena"), //padding

    TouchScreenMenuItem("Lenteja"), //right

    TouchScreenMenuItem("Frijol"), //left

    TouchScreenMenuItem("Garbanzo"), //spacing

    TouchScreenMenuItem("Haba"), //small

    TouchScreenMenuItem("Moler"),

    TouchScreenMenuItem("Tamizar"),
```



```

    TouchScreenMenuItem("ENDOFMENU")

};

// Elementos del menu principal

TouchScreenMenuItem mainMenuItems[] = {

    TouchScreenMenuItem("-> Procesar"),

    TouchScreenMenuItem("Info"),

    TouchScreenMenuItem("ENDOFMENU")

};

// Menu por grano

//Avena

TouchScreenMenuItem paddingSubMenuItems[] = {

    TouchScreenMenuItem("<- Volver"),

    TouchScreenMenuItem("INICIAR"),

    TouchScreenMenuItem("ENDOFMENU")

};

//Lenteja

TouchScreenMenuItem rightSubMenuItems[] = {

    TouchScreenMenuItem("<- Volver"),

    TouchScreenMenuItem("INICIAR"),

    TouchScreenMenuItem("ENDOFMENU")

};

//Frijol

```

```

TouchScreenMenuItem leftSubMenuItems[] = {

    TouchScreenMenuItem("<- Volver"),

    TouchScreenMenuItem("INICIAR"),

    TouchScreenMenuItem("ENDOFMENU")

};

//Garbanzo

TouchScreenMenuItem spacingSubMenuItems[] = {

    TouchScreenMenuItem("<- Volver"),

    TouchScreenMenuItem("INICIAR"),

    TouchScreenMenuItem("ENDOFMENU")

};

//Haba

TouchScreenMenuItem smallSubMenuItems[] = {

    TouchScreenMenuItem("<- Volver"),

    TouchScreenMenuItem("INICIAR"),

    TouchScreenMenuItem("ENDOFMENU")

};

//Moler

TouchScreenMenuItem molerSubMenuItems[] = {

    TouchScreenMenuItem("<- Volver"),

    TouchScreenMenuItem("ON/OFF"),

    TouchScreenMenuItem("ENDOFMENU")

```



```

};

//Tamizar

TouchScreenMenuItem tamizSubMenuItems[] = {

    TouchScreenMenuItem("<- Volver"),

    TouchScreenMenuItem("ON/OFF"),

    TouchScreenMenuItem("ENDOFMENU")

};

// Titulo de menus

TouchScreenMenu paddingSubMenu = TouchScreenMenu(paddingSubMenuItems, 2, 5, 20,
CENTERJ, "Avena");

TouchScreenMenu rightSubMenu = TouchScreenMenu(rightSubMenuItems, 2, 5, 20,
CENTERJ, "Lenteja");

TouchScreenMenu leftSubMenu = TouchScreenMenu(leftSubMenuItems, 2, 5, 20, CENTERJ,
"Frijol");

TouchScreenMenu spacingSubMenu = TouchScreenMenu(spacingSubMenuItems, 2, 5, 20,
CENTERJ, "Garbanzo");

TouchScreenMenu smallSubMenu = TouchScreenMenu(smallSubMenuItems, 2, 5, 20,
CENTERJ, "Haba");

TouchScreenMenu subMenu = TouchScreenMenu(subMenuItems, 2, 10, 5, CENTERJ,
"Procesar");

TouchScreenMenu mainMenu = TouchScreenMenu(mainMenuItems, 2, 10, 10, CENTERJ,
"Menu");

TouchScreenMenu molerSubMenu = TouchScreenMenu(molerSubMenuItems, 2, 5, 20,
CENTERJ, "Moler");

```

```
TouchScreenMenu tamizSubMenu = TouchScreenMenu(tamizSubMenuItems, 2, 5, 20,
CENTERJ, "Tamizar");
```

```
// Botones de regreso
```

```
TouchScreenMenu *curMenu = &mainMenu;
```

```
TouchScreenArea backFromGfx = TouchScreenButton("<- Volver", TSC.createColor(255, 255,
255), TSC.createColor(0, 0, 0), 50, TSC.getScreenHeight() - 50, 2, 10);
```

```
TouchScreenArea backFromBtns = TouchScreenButton("<- Volver", TSC.createColor(255, 255,
255), TSC.createColor(0, 0, 0), 50, TSC.getScreenHeight() - 50, 2, 10);
```

```
TouchScreenArea backFromLbls = TouchScreenButton("<- Volver", TSC.createColor(255, 255,
255), TSC.createColor(0, 0, 0), 50, TSC.getScreenHeight() - 50, 2, 10);
```

```
void setup(void) {
```

```
    TSC.setBackColor(TSC.createColor(0, 0, 0)); // Color del fondo de pantalla
```

```
    TSC.init(); // Asegurar que todo se ha inicializado
```

```
    curMenu->draw();
```

```
}
```

```
void loop(void) {
```

```
    pinMode(PIN_LED1,OUTPUT); //Especificar que el PIN del led 1 es salida
```

```
    pinMode(PIN_LED2, OUTPUT); //Especificar que el PIN del led 2 es salida
```

```
    // confirmar menu actual
```

```
    if(curMenu!=NULL){
```

```
        // proceder menu actual
```

```
        TouchScreenMenuItem *item = curMenu->process(false);
```

```
        // verificar que menu es presionado
```

```

        checkMenuSelection(item);

    }else{

        // si no, verificar que boton se presiono

        checkButtons();

    }

}

// verificar botones

void checkButtons(){

    if(backFromGfx.process()){

        curMenu = &mainMenu;

        TSC.clearScreen();

        curMenu->draw();

    }

    else if(backFromBtns.process()){

        curMenu = &mainMenu;

        TSC.clearScreen();

        curMenu->draw();

    }

    else if(backFromLbls.process()){

        curMenu = &mainMenu;

        TSC.clearScreen();

        curMenu->draw();

    }

}

```

```
}
```

```
}
```

```
// verificar que boton se presiono y ejecutar alguna accion
```

```
void checkMenuSelection(TouchScreenMenuItem *item) {
```

```
    boolean handled = false;
```

```
    if(item != NULL){
```

```
        // Elementos menu principal
```

```
        if(curMenu == &mainMenu){
```

```
            if(!strcmp(item->getText(),"-> Procesar")){
```

```
                curMenu = &subMenu;
```

```
                TSC.clearScreen();
```

```
                curMenu->draw();
```

```
                handled = true;
```

```
            }
```

```
            else if (!strcmp(item->getText(),"Info")){
```

```
                curMenu = NULL;
```

```
                TSC.clearScreen();
```

```
                backFromLbIs.draw();
```

```
                Tft.drawString("Manual",5,20,3,WHITE);
```

```
                Tft.drawString("Ingresa al menu",5,80,2,WHITE);
```

```
                Tft.drawString("'Procesar'e",5,100,2,WHITE);
```

```
                Tft.drawString("indica el grano",5,120,2,WHITE);
```

```

Tft.drawString("deseado. Oprime",5,140,2,WHITE);

Tft.drawString("'iniciar' para",5,160,2,WHITE);

Tft.drawString("procesamiento",5,180,2,WHITE);

Tft.drawString("de material.",5,200,2,WHITE);

Tft.drawString("Laboratorio Ing. de Proceso",5,230,1,WHITE);

Tft.drawString("CCADET UNAM",5,240,1,WHITE);

handled = true;

}

}

// Elementos del submenu procesar

else if(curMenu == &subMenu){

if(!strcmp(item->getText(),"<- Menu")){

    curMenu = &mainMenu;

    TSC.clearScreen();

    curMenu->draw();

    handled = true;

}

else if(!strcmp(item->getText(),"Avena")){

    curMenu = &paddingSubMenu;

    TSC.clearScreen();

    curMenu->draw();

    handled = true;

```

```

}

else if(!strcmp(item->getText(),"Lenteja")){

    curMenu = &rightSubMenu;

    TSC.clearScreen();

    curMenu->draw();

    handled = true;

}

else if(!strcmp(item->getText(),"Frijol")){

    curMenu = &leftSubMenu;

    TSC.clearScreen();

    curMenu->draw();

    handled = true;

}

else if(!strcmp(item->getText(),"Garbanzo")){

    curMenu = &spacingSubMenu;

    TSC.clearScreen();

    curMenu->draw();

    handled = true;

}

else if(!strcmp(item->getText(),"Haba")){

    curMenu = &smallSubMenu;

    TSC.clearScreen();

```

```

    curMenu->draw();

    handled = true;
}

else if(!strcmp(item->getText(),"Moler")){

    curMenu = &molerSubMenu;

    TSC.clearScreen();

    curMenu->draw();

    handled = true;
}

else if(!strcmp(item->getText(),"Tamizar")){

    curMenu = &tamizSubMenu;

    TSC.clearScreen();

    curMenu->draw();

    handled = true;
}

}

// Operacion AVENA

else if(curMenu == &paddingSubMenu){

    if(!strcmp(item->getText(),"<- Volver")){

        curMenu = &subMenu;

        TSC.clearScreen();

        curMenu->draw();

```

```

        handled = true;
    }

    else if(!strcmp(item->getText(),"INICIAR")){

        digitalWrite(PIN_LED1,HIGH); //Encender led 1

        delay(275000);

        digitalWrite(PIN_LED1,LOW); //Apagar led 1

    }
}

// Operacion LENTEJA

else if(curMenu == &rightSubMenu){

    if(!strcmp(item->getText(),"<- Volver")){

        curMenu = &subMenu;

        TSC.clearScreen();

        curMenu->draw();

        handled = true;

    }

    else if(!strcmp(item->getText(),"INICIAR")){

        digitalWrite(PIN_LED1,HIGH); //Encender led 1

        digitalWrite(PIN_LED2,HIGH); //Encender led 2

        delay(120000);

        digitalWrite(PIN_LED1,LOW); //Apagar led 1

        delay(240000);

```



```

        digitalWrite(PIN_LED2,LOW); //Apagar led 2
    }
}

// Operacion FRIJOL

else if(curMenu == &leftSubMenu){

    if(!strcmp(item->getText(),"<- Volver")){

        curMenu = &subMenu;

        TSC.clearScreen();

        curMenu->draw();

        handled = true;

    }

    else if(!strcmp(item->getText(),"INICIAR")){

        digitalWrite(PIN_LED1,HIGH); //Encender led 1

        digitalWrite(PIN_LED2,HIGH); //Encender led 2

        delay(60000);

        digitalWrite(PIN_LED1,LOW); //Apagar led 1

        delay(180000);

        digitalWrite(PIN_LED2,LOW); //Apagar led 2

    }

}

// Operacion GARBANZO

else if(curMenu == &spacingSubMenu){

```

```

if(!strcmp(item->getText(),"<- Volver")){

    curMenu = &subMenu;

    TSC.clearScreen();

    curMenu->draw();

    handled = true;

}

else if(!strcmp(item->getText(),"INICIAR")){

    digitalWrite(PIN_LED1,HIGH); //Encender led 1

    digitalWrite(PIN_LED2,HIGH); //Encender led 2

    delay(50000);

    digitalWrite(PIN_LED1,LOW); //Apagar led 1

    delay(120000);

    digitalWrite(PIN_LED2,LOW); //Apagar led 2

}

}

// Operacion HABA

else if(curMenu == &smallSubMenu){

    if(!strcmp(item->getText(),"<- Volver")){

        curMenu = &subMenu;

        TSC.clearScreen();

        curMenu->draw();

        handled = true;

```

```

}

else if(!strcmp(item->getText(),"INICIAR")){

    digitalWrite(PIN_LED1,HIGH); //Encender led 1

    digitalWrite(PIN_LED2,HIGH); //Encender led 2

    delay(60000);

    digitalWrite(PIN_LED1,LOW); //Apagar led 1

    delay(120000);

    digitalWrite(PIN_LED2,LOW); //Apagar led 2

}

}

//Operacion moler

else if(curMenu == &molerSubMenu){

if(!strcmp(item->getText(),"<- Volver")){

    curMenu = &subMenu;

    TSC.clearScreen();

    curMenu->draw();

    handled = true;

}

else if(!strcmp(item->getText(),"ON/OFF")){

    val= !strcmp(item->getText(),"ON/OFF");

    if ((val == HIGH) && (old_val == HIGH)){

        state = 1-state;

```

```

        delay(10);

    }

    old_val = val;

    if (state==1){

        digitalWrite(PIN_LED1, HIGH);

    }

    else{

        digitalWrite(PIN_LED1, LOW);

    }

    }

}

//Operacion tamizar

    else if(curMenu == &tamizSubMenu){

if(!strcmp(item->getText(),"<- Volver")){

    curMenu = &subMenu;

    TSC.clearScreen();

    curMenu->draw();

    handled = true;

}

    else if(!strcmp(item->getText(),"ON/OFF")){

        val= !strcmp(item->getText(),"ON/OFF");

        if ((val == HIGH) && (old_val == HIGH)){

```

```

        state = 1-state;

        delay(10);
    }

    old_val = val;

    if (state==1){

        digitalWrite(PIN_LED2, HIGH);

    }

    else{

        digitalWrite(PIN_LED2, LOW);

    }

    }

    if(handled==false)

        curMenu->drawItem(item,false);

}

}

```

4. Bibliografía

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