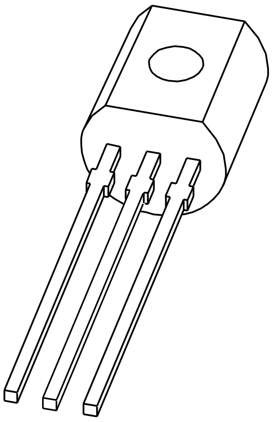
assembely

```
*  Label Definition
********************
        cblock  h'20'
s_count
;Send-out pulse count adr
s_adj
;Adjustment data address
s_adj_count                                ;Rotate
value save adr
s_digit                                    ;Digit
cont work address
g_time1                                    ;Guard
timer address 1
g_time2                                    ;Guard
timer address 2
p_countl
;Propagation L cnt adr
p_counth
;Propagation H cnt adr
digit_cnt                                  ;Digit
counter head adr
disp_ha                                    ;Digit
head address
disp_u                                     ;1st
digit address
disp_t                                     ;10th
digit address
disp_h                                     ;100th
digit address
seg7_ha                                    ;7
segLED table head adr
seg70                                      ;Pattern
0 set adr
```

# DATA SHEET



# 2PA1015
## PNP general purpose transistor

Product specification
Supersedes data of 1997 May 01

1999 Apr 08

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INTEGRATED CIRCUITS

# DATA SHEET

For a complete data sheet, please also download:

- The IC04 LOCMOS HE4000B Logic Family Specifications HEF, HEC
- The IC04 LOCMOS HE4000B Logic Package Outlines/Information HEF, HEC

# HEF4011B gates

Quadruple 2-input NAND gate

Product specification
File under Integrated Circuits, IC04

January 1995

Philips Semiconductors

PHILIPS

# Quadruple 2-input NAND gate

# HEF4011B gates

## DESCRIPTION

The HEF4011B provides the positive quadruple 2-input NAND function. The outputs are fully buffered for highest noise immunity and pattern insensitivity of output impedance.

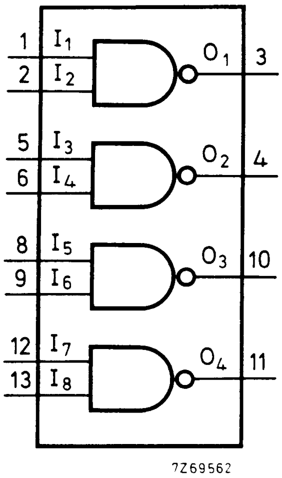



Fig.1 Functional diagram.

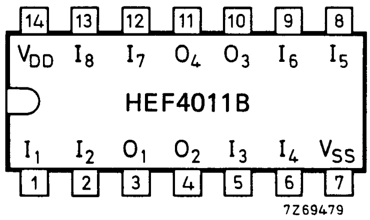



Fig.2 Pinning diagram.

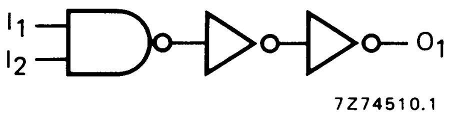



Fig.3 Logic diagram (one gate).

HEF4011BP(N): 14-lead DIL; plastic (SOT27-1)

HEF4011BD(F): 14-lead DIL; ceramic (cerdip) (SOT73)

HEF4011BT(D): 14-lead SO; plastic (SOT108-1)

( ): Package Designator North America

## FAMILY DATA, $I_{DD}$ LIMITS category GATES

See Family Specifications

**AC CHARACTERISTICS**

$V_{SS}$ = 0 V; $T_{amb}$ = 25 °C; $C_L$ = 50 pF; input transition times ≤ 20 ns

| | $V_{DD}$ V | SYMBOL | TYP | MAX | | TYPICAL EXTRAPOLATION FORMULA |
|---|---|---|---|---|---|---|
| Propagation delays | 5 | | 55 | 110 | ns | 28 ns + (0,55 ns/pF) $C_L$ |
| $I_n \rightarrow O_n$ | 10 | $t_{PHL}$; $t_{PLH}$ | 25 | 45 | ns | 14 ns + (0,23 ns/pF) $C_L$ |
| | 15 | | 20 | 35 | ns | 12 ns + (0,16 ns/pF) $C_L$ |
| Output transition times | 5 | | 60 | 120 | ns | 10 ns + (1,0 ns/pF) $C_L$ |
| HIGH to LOW | 10 | $t_{THL}$ | 30 | 60 | ns | 9 ns + (0,42 ns/pF) $C_L$ |
| | 15 | | 20 | 40 | ns | 6 ns + (0,28 ns/pF) $C_L$ |
| | 5 | | 60 | 120 | ns | 10 ns + (1,0 ns/pF) $C_L$ |
| LOW to HIGH | 10 | $t_{TLH}$ | 30 | 60 | ns | 9 ns + (0,42 ns/pF) $C_L$ |
| | 15 | | 20 | 40 | ns | 6 ns + (0,28 ns/pF) $C_L$ |

| | $V_{DD}$ V | TYPICAL FORMULA FOR P (μW) | |
|---|---|---|---|
| Dynamic power | 5 | $1300\ f_i + \sum (f_oC_L) \times V_{DD}^2$ | where |
| dissipation per | 10 | $6000\ f_i + \sum (f_oC_L) \times V_{DD}^2$ | $f_i$ = input freq. (MHz) |
| package (P) | 15 | $20\ 100\ f_i + \sum (f_oC_L) \times V_{DD}^2$ | $f_o$ = output freq. (MHz) |
| | | | $C_L$ = load capacitance (pF) |
| | | | $\sum (f_oC_L)$ = sum of outputs |
| | | | $V_{DD}$ = supply voltage (V) |

# PNP general purpose transistor 2PA1015

## FEATURES

- Low current (max. 150 mA)
- Low voltage (max. 50 V).

## APPLICATIONS

- General purpose switching and amplification.

## DESCRIPTION

PNP transistor in a plastic TO-92; SOT54 package.
NPN complement: 2PC1815.

## PINNING

| PIN | DESCRIPTION |
|---|---|
| 1 | base |
| 2 | collector |
| 3 | emitter |

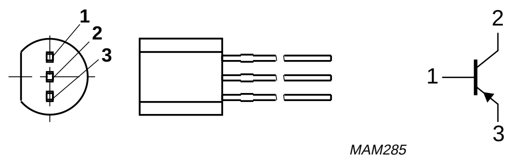



Fig.1 Simplified outline (TO-92; SOT54) and symbol.

## LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 134).

| SYMBOL | PARAMETER | CONDITIONS | MIN. | MAX. | UNIT |
|---|---|---|---|---|---|
| $V_{CBO}$ | collector-base voltage | open emitter | – | –50 | V |
| $V_{CEO}$ | collector-emitter voltage | open base | – | –50 | V |
| $V_{EBO}$ | emitter-base voltage | open collector | – | –5 | V |
| $I_C$ | collector current (DC) | | – | –150 | mA |
| $I_{CM}$ | peak collector current | | – | –200 | mA |
| $I_{BM}$ | peak base current | | – | –200 | mA |
| $P_{tot}$ | total power dissipation | $T_{amb} \leq 25$ °C; note 1 | – | 500 | mW |
| $T_{stg}$ | storage temperature | | –65 | +150 | °C |
| $T_j$ | junction temperature | | – | 150 | °C |
| $T_{amb}$ | operating ambient temperature | | –65 | +150 | °C |

**Note**

1. Transistor mounted on an FR4 printed-circuit board.

## THERMAL CHARACTERISTICS

| SYMBOL | PARAMETER | CONDITIONS | VALUE | UNIT |
|---|---|---|---|---|
| $R_{th\ j\text{-}a}$ | thermal resistance from junction to ambient | note 1 | 250 | K/W |

**Note**

1. Transistor mounted on an FR4 printed-circuit board.

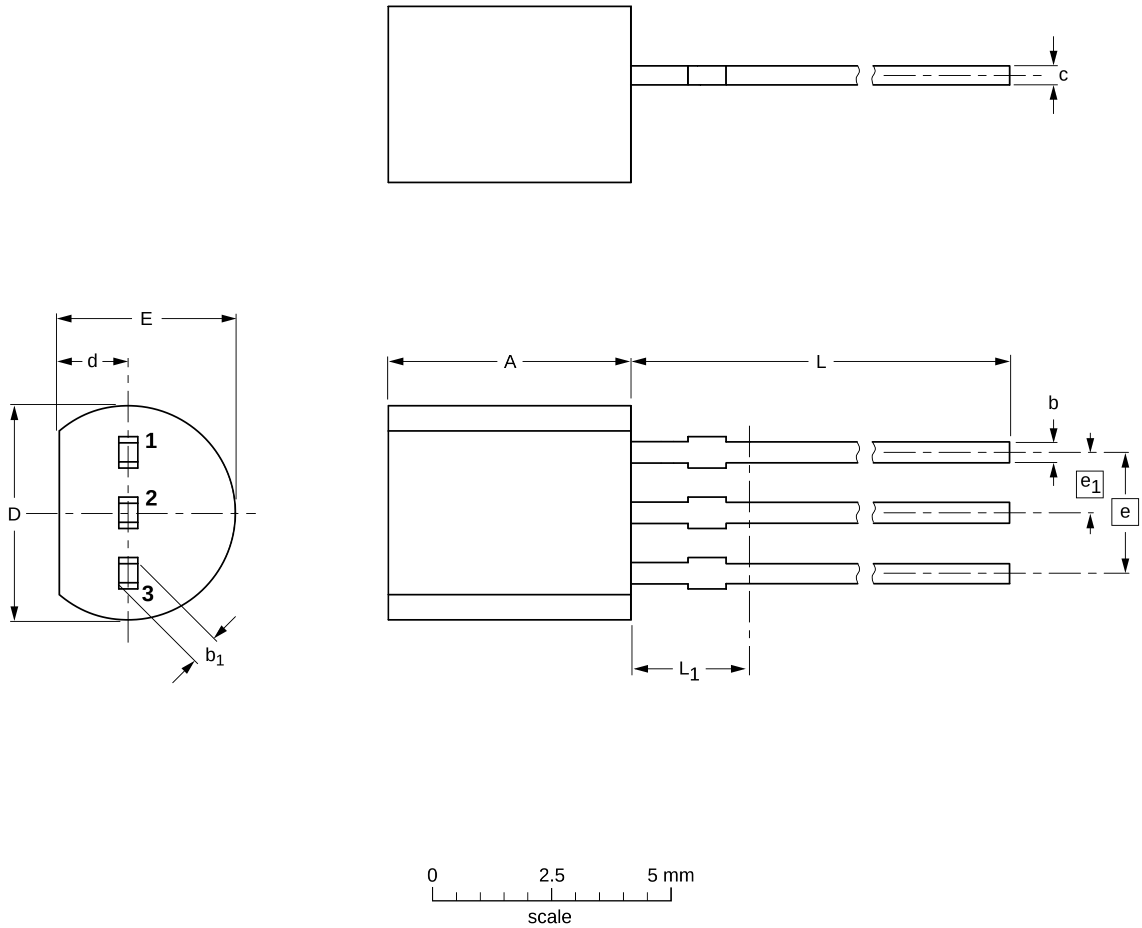
## CHARACTERISTICS

$T_j$ = 25 °C unless otherwise specified.

| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|---|---|---|---|---|---|---|
| $I_{CBO}$ | collector cut-off current | $I_E$ = 0; $V_{CB}$ = –50 V | – | – | –100 | nA |
| $I_{EBO}$ | emitter cut-off current | $I_C$ = 0; $V_{EB}$ = –5 V | – | – | –100 | nA |
| $h_{FE}$ | DC current gain | $I_C$ = –2 mA; $V_{CE}$ = –6 V | | | | |
| | 2PA1015Y | | 120 | – | 240 | |
| | 2PA1015GR | | 200 | – | 400 | |
| $h_{FE}$ | DC current gain | $I_C$ = –150 mA; $V_{CE}$ = –6 V | 25 | – | – | |
| $V_{CEsat}$ | collector-emitter saturation voltage | $I_C$ = –100 mA; $I_B$ = –10 mA | – | – | –300 | mV |
| $V_{BEsat}$ | base-emitter saturation voltage | $I_C$ = –100 mA; $I_B$ = –10 mA | – | – | –1.1 | V |
| $C_c$ | collector capacitance | $I_E$ = $i_e$ = 0; $V_{CB}$ = –10 V; f = 1 MHz | – | 4 | 7 | pF |
| $f_T$ | transition frequency | $I_C$ = –1 mA; $V_{CB}$ = –10 V; f = 100 MHz | 80 | – | – | MHz |
| F | noise figure | $I_C$ = –200 μA; $V_{CE}$ = –5 V; $R_S$ = 2 kΩ; f = 1 kHz; B = 200 Hz | – | – | 10 | dB |

## PACKAGE OUTLINE

**Plastic single-ended leaded (through hole) package; 3 leads** **SOT54**




**DIMENSIONS (mm are the original dimensions)**

| UNIT | A | b | $b_1$ | c | D | d | E | e | $e_1$ | L | $L_1^{(1)}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | 5.2<br>5.0 | 0.48<br>0.40 | 0.66<br>0.56 | 0.45<br>0.40 | 4.8<br>4.4 | 1.7<br>1.4 | 4.2<br>3.6 | 2.54 | 1.27 | 14.5<br>12.7 | 2.5 |

**Note**

1. Terminal dimensions within this zone are uncontrolled to allow for flow of plastic and terminal irregularities.

| OUTLINE VERSION | REFERENCES | | | | EUROPEAN PROJECTION | ISSUE DATE |
|---|---|---|---|---|---|---|
| | IEC | JEDEC | EIAJ | | | |
| SOT54 | | TO-92 | SC-43 | | | 97-02-28 |

## DEFINITIONS

| Data sheet status | |
|---|---|
| Objective specification | This data sheet contains target or goal specifications for product development. |
| Preliminary specification | This data sheet contains preliminary data; supplementary data may be published later. |
| Product specification | This data sheet contains final product specifications. |
| **Limiting values** | |
| Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability. | |
| **Application information** | |
| Where application information is given, it is advisory and does not form part of the specification. | |

## LIFE SUPPORT APPLICATIONS

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Philips customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Philips for any damages resulting from such improper use or sale.

## NOTES

## NOTES

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**Philips Semiconductors**

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National Semiconductor

August 2000

# LM833
# Dual Audio Operational Amplifier

## General Description

The LM833 is a dual general purpose operational amplifier designed with particular emphasis on performance in audio systems.

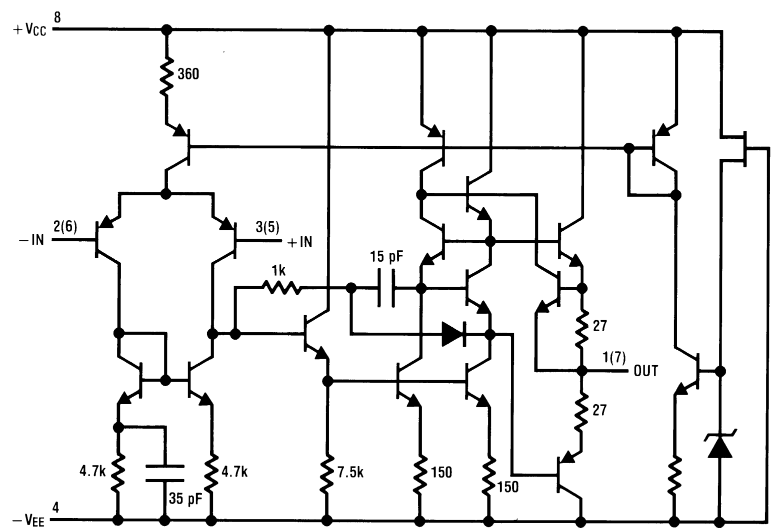
This dual amplifier IC utilizes new circuit and processing techniques to deliver low noise, high speed and wide bandwidth without increasing external components or decreasing stability. The LM833 is internally compensated for all closed loop gains and is therefore optimized for all preamp and high level stages in PCM and HiFi systems.

The LM833 is pin-for-pin compatible with industry standard dual operational amplifiers.

## Features

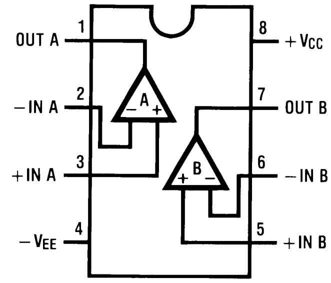
- Wide dynamic range: 140dB
- Low input noise voltage: 4.5nV/√Hz
- High slew rate: 7 V/µs (typ); 5V/µs (min)
- High gain bandwidth: 15MHz (typ); 10MHz (min)
- Wide power bandwidth: 120KHz
- Low distortion: 0.002%
- Low offset voltage: 0.3mV
- Large phase margin: 60˚
- Available in 8 pin MSOP package

## Schematic Diagram (1/2 LM833)




DS005218-1

## Connection Diagram




DS005218-2

**Order Number LM833M, LM833MX, LM833N, LM833MM or LM833MMX**
**See NS Package Number**
**M08A, N08E or MUA08A**

## Absolute Maximum Ratings (Note 1)

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

| | |
|---|---|
| Supply Voltage $V_{CC}–V_{EE}$ | 36V |
| Differential Input Voltage (Note 3) $V_I$ | ±30V |
| Input Voltage Range (Note 3) $V_{IC}$ | ±15V |
| Power Dissipation (Note 4) $P_D$ | 500 mW |
| Operating Temperature Range $T_{OPR}$ | −40 ~ 85˚C |
| Storage Temperature Range $T_{STG}$ | −60 ~ 150˚C |

Soldering Information
Dual-In-Line Package
Soldering (10 seconds) 260˚C
Small Outline Package
(SOIC and MSOP)
Vapor Phase (60 seconds) 215˚C
Infrared (15 seconds) 220˚C

See AN-450 “Surface Mounting Methods and Their Effect on Product Reliability” for other methods of soldering surface mount devices.

ESD tolerance (Note 5) 1600V

## DC Electrical Characteristics (Notes 1, 2)

($T_A$ = 25˚C, $V_S$ = ±15V)

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $V_{OS}$ | Input Offset Voltage | $R_S$ = 10Ω | | 0.3 | 5 | mV |
| $I_{OS}$ | Input Offset Current | | | 10 | 200 | nA |
| $I_B$ | Input Bias Current | | | 500 | 1000 | nA |
| $A_V$ | Voltage Gain | $R_L$ = 2 kΩ, $V_O$ = ±10V | 90 | 110 | | dB |
| $V_{OM}$ | Output Voltage Swing | $R_L$ = 10 kΩ | ±12 | ±13.5 | | V |
| | | $R_L$ = 2 kΩ | ±10 | ±13.4 | | V |
| $V_{CM}$ | Input Common-Mode Range | | ±12 | ±14.0 | | V |
| CMRR | Common-Mode Rejection Ratio | $V_{IN}$ = ±12V | 80 | 100 | | dB |
| PSRR | Power Supply Rejection Ratio | $V_S$ = 15~5V, −15~−5V | 80 | 100 | | dB |
| $I_Q$ | Supply Current | $V_O$ = 0V, Both Amps | | 5 | 8 | mA |

## AC Electrical Characteristics

($T_A$ = 25˚C, $V_S$ = ±15V, $R_L$ = 2 kΩ)

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| SR | Slew Rate | $R_L$ = 2 kΩ | 5 | 7 | | V/µs |
| GBW | Gain Bandwidth Product | f = 100 kHz | 10 | 15 | | MHz |

## Design Electrical Characteristics

($T_A$ = 25˚C, $V_S$ = ±15V)
The following parameters are not tested or guaranteed.

| Symbol | Parameter | Conditions | Typ | Units |
|---|---|---|---|---|
| $\Delta V_{OS}/\Delta T$ | Average Temperature Coefficient of Input Offset Voltage | | 2 | µV/˚C |
| THD | Distortion | $R_L$ = 2 kΩ, f = 20~20 kHz<br>$V_{OUT}$ = 3 Vrms, $A_V$ = 1 | 0.002 | % |
| $e_n$ | Input Referred Noise Voltage | $R_S$ = 100Ω, f = 1 kHz | 4.5 | $nV/\sqrt{Hz}$ |
| $i_n$ | Input Referred Noise Current | f = 1 kHz | 0.7 | $pA/\sqrt{Hz}$ |
| PBW | Power Bandwidth | $V_O$ = 27 $V_{pp}$, $R_L$ = 2 kΩ, THD ≤ 1% | 120 | kHz |
| $f_U$ | Unity Gain Frequency | Open Loop | 9 | MHz |
| $\phi_M$ | Phase Margin | Open Loop | 60 | deg |
| | Input Referred Cross Talk | f = 20~20 kHz | −120 | dB |

## Design Electrical Characteristics (Continued)

**Note 1:** *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Operating Ratings* indicate conditions for which the device is functional, but do not guarantee specific performance limits. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

**Note 2:** All voltages are measured with respect to the ground pin, unless otherwise specified.

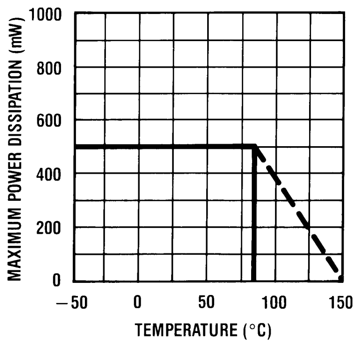
**Note 3:** If supply voltage is less than ±15V, it is equal to supply voltage.

**Note 4:** This is the permissible value at $T_A \leq 85^{\circ}C$.

**Note 5:** Human body model, 1.5 kΩ in series with 100 pF.

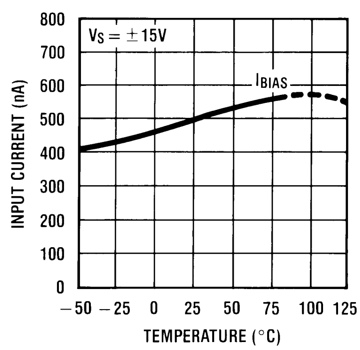
## Typical Performance Characteristics

**Maximum Power Dissipation vs Ambient Temperature**



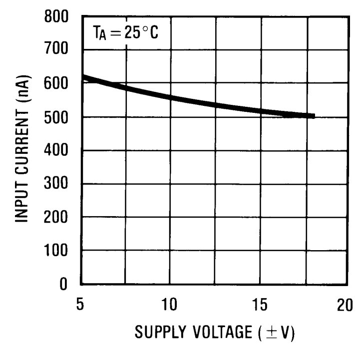

DS005218-4

**Input Bias Current vs Ambient Temperature**



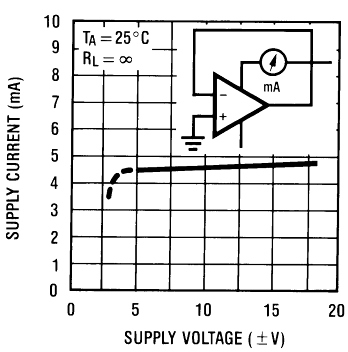

DS005218-5

**Input Bias Current vs Supply Voltage**



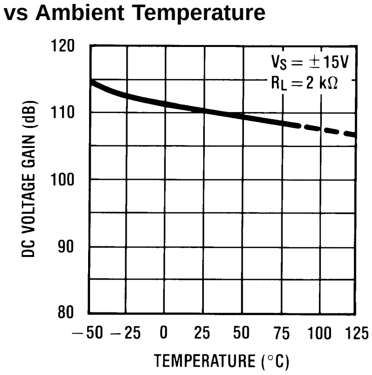

DS005218-6

**Supply Current vs Supply Voltage**



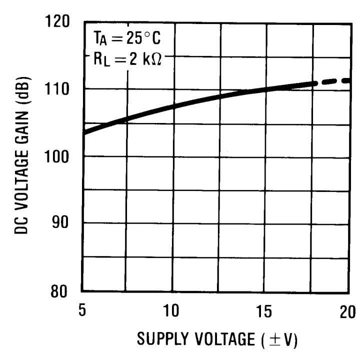

DS005218-7

**DC Voltage Gain vs Ambient Temperature**



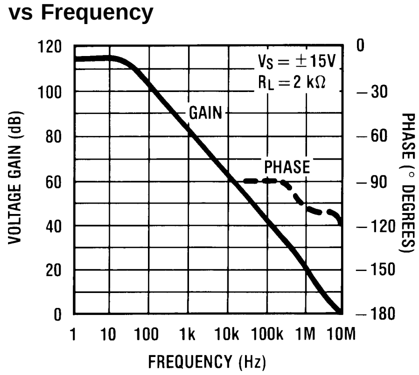

DS005218-8

**DC Voltage Gain vs Supply Voltage**



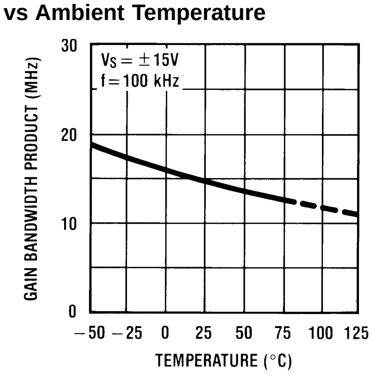

DS005218-9

**Voltage Gain & Phase vs Frequency**



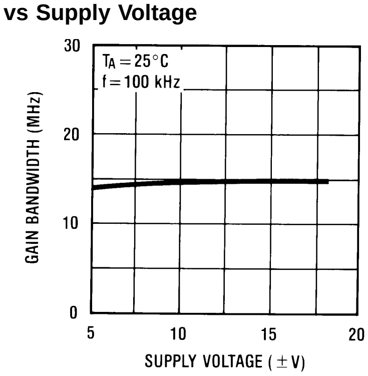

DS005218-10

**Gain Bandwidth Product vs Ambient Temperature**




DS005218-11

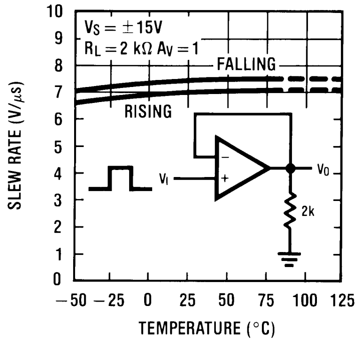
**Gain Bandwidth vs Supply Voltage**




DS005218-12

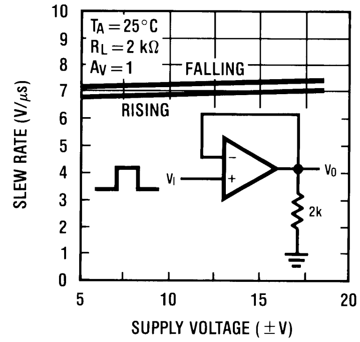
## Typical Performance Characteristics (Continued)

**Slew Rate vs Ambient Temperature**



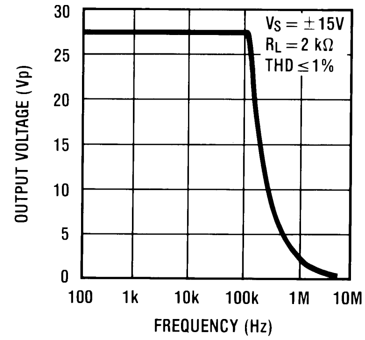

DS005218-13

**Slew Rate vs Supply Voltage**



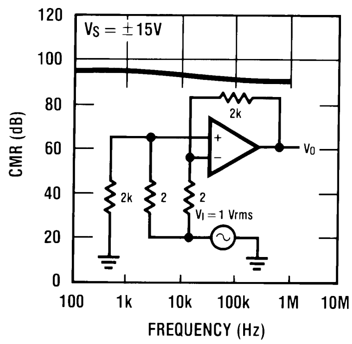

DS005218-14

**Power Bandwidth**



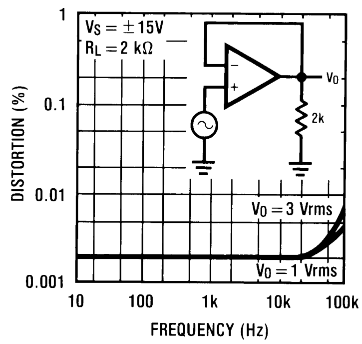

DS005218-15

**CMR vs Frequency**



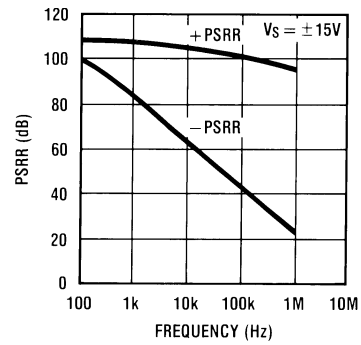

DS005218-19

**Distortion vs Frequency**



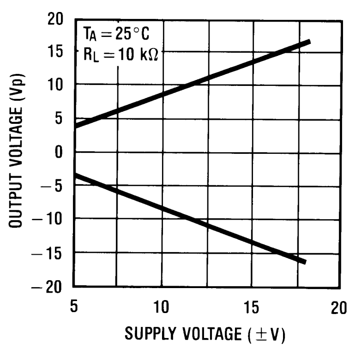

DS005218-20

**PSRR vs Frequency**



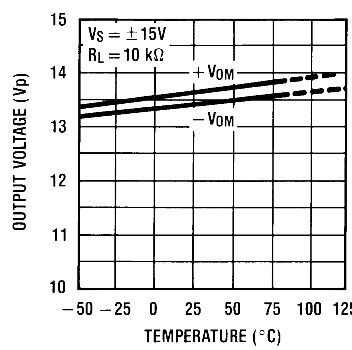

DS005218-18

**Maximum Output Voltage vs Supply Voltage**




DS005218-16

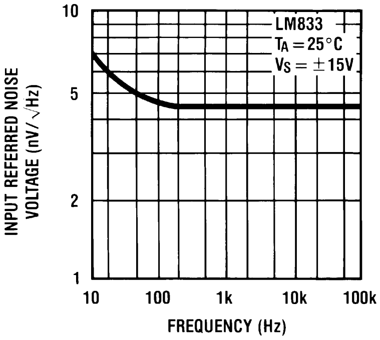
**Maximum Output Voltage vs Ambient Temperature**




DS005218-17

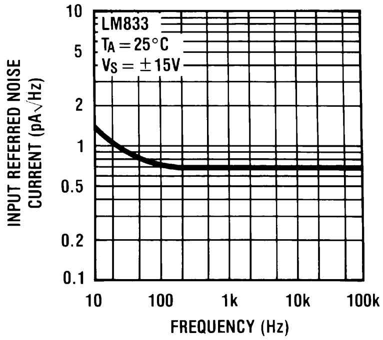
## Typical Performance Characteristics (Continued)

**Spot Noise Voltage vs Frequency**



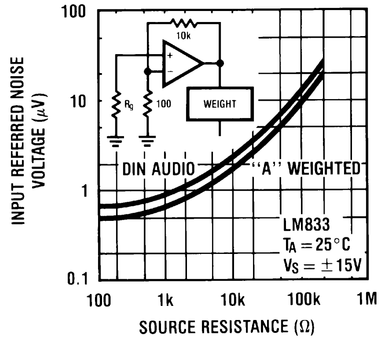

DS005218-21

**Spot Noise Current vs Frequency**



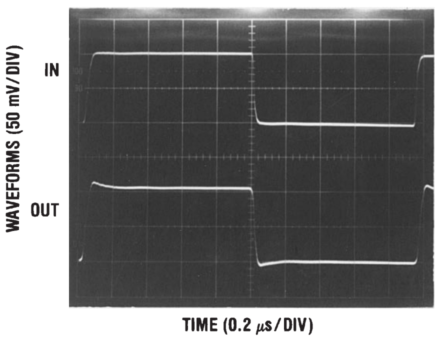

DS005218-22

**Input Referred Noise Voltage vs Source Resistance**



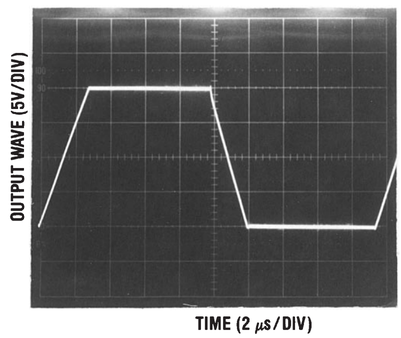

DS005218-23

**Noninverting Amp**



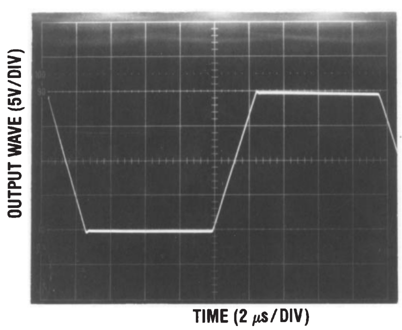

DS005218-24

**Noninverting Amp**




DS005218-25

**Inverting Amp**



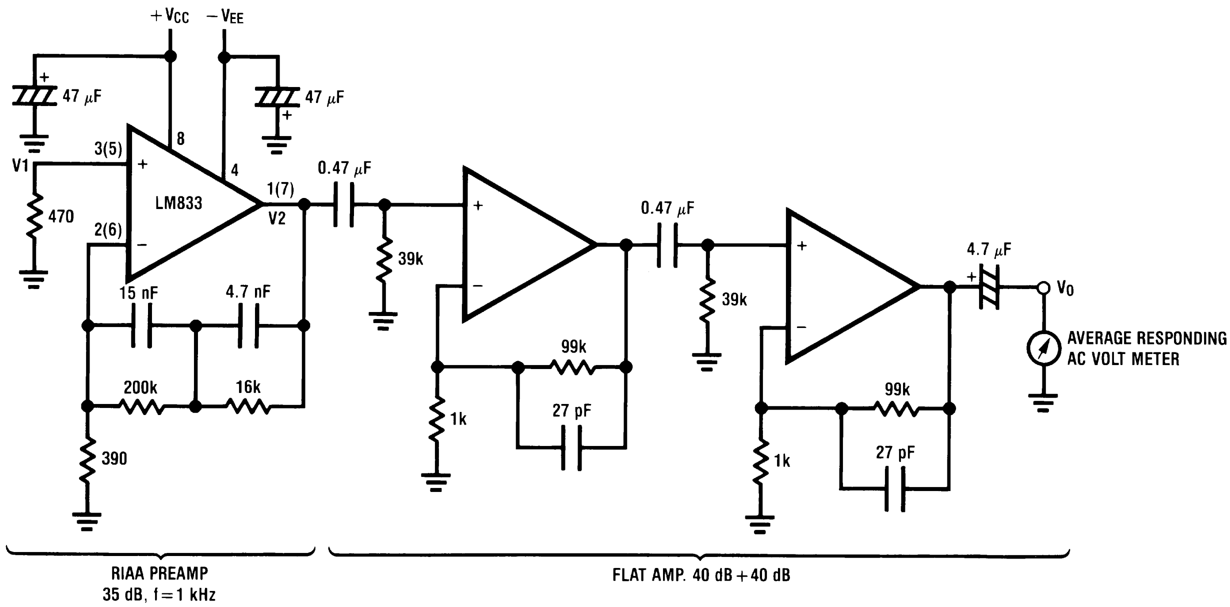

DS005218-26

## Application Hints

The LM833 is a high speed op amp with excellent phase margin and stability. Capacitive loads up to 50 pF will cause little change in the phase characteristics of the amplifiers and are therefore allowable.

Capacitive loads greater than 50 pF must be isolated from the output. The most straightforward way to do this is to put a resistor in series with the output. This resistor will also prevent excess power dissipation if the output is accidentally shorted.

## Noise Measurement Circuit

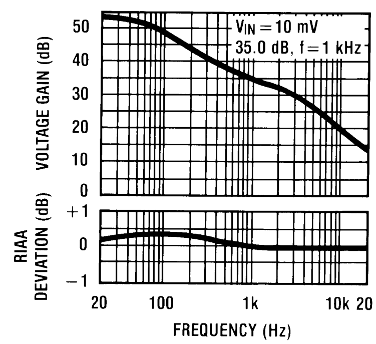



DS005218-27

Complete shielding is required to prevent induced pick up from external sources. Always check with oscilloscope for power line noise.

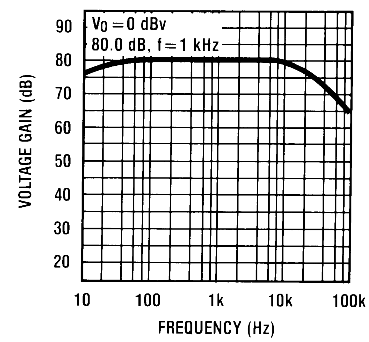
**Total Gain: 115 dB @f = 1 kHz**
**Input Referred Noise Voltage: $e_n$ = V0/560,000 (V)**

### RIAA Preamp Voltage Gain, RIAA Deviation vs Frequency




DS005218-28

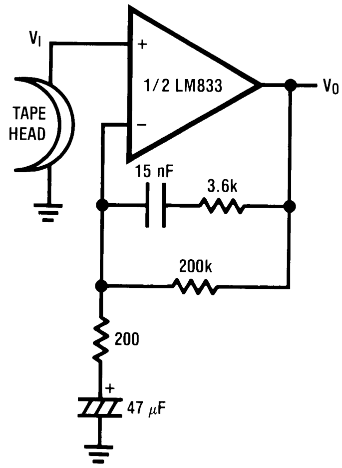
### Flat Amp Voltage Gain vs Frequency




DS005218-29

## Typical Applications

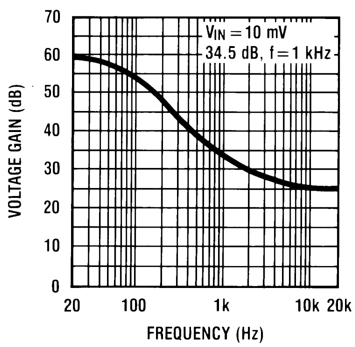
### NAB Preamp



DS005218-30

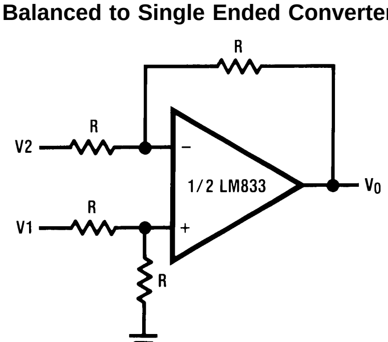
$A_V$ = 34.5
F = 1 kHz
$E_n$ = 0.38 μV
A Weighted

### NAB Preamp Voltage Gain vs Frequency



DS005218-31

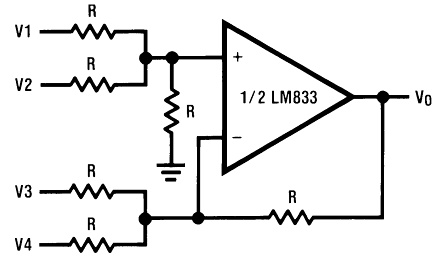
### Balanced to Single Ended Converter



DS005218-32

$V_O$ = V1–V2

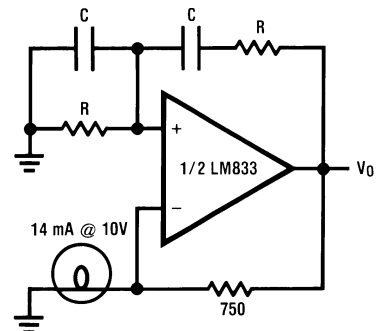
### Adder/Subtracter



DS005218-33

$V_O$ = V1 + V2 − V3 − V4

### Sine Wave Oscillator

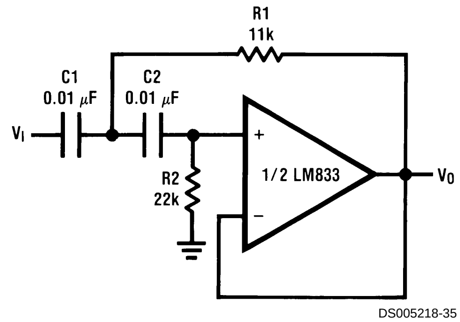


DS005218-34

$$f_o = \frac{1}{2\pi RC}$$

## Typical Applications (Continued)

**Second Order High Pass Filter (Butterworth)**



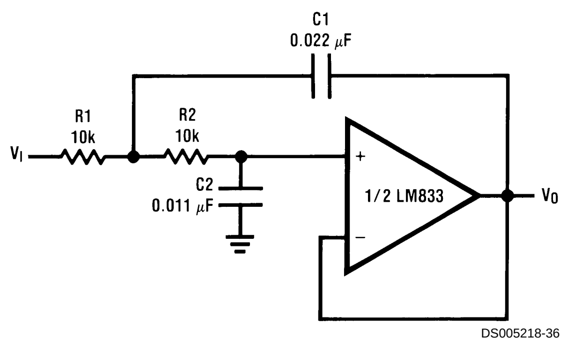

if C1 = C2 = C

$$R1 = \frac{\sqrt{2}}{2\omega_o C}$$

$$R2 = 2 \bullet R1$$

Illustration is $f_0$ = 1 kHz

**Second Order Low Pass Filter (Butterworth)**




if R1 = R2 = R

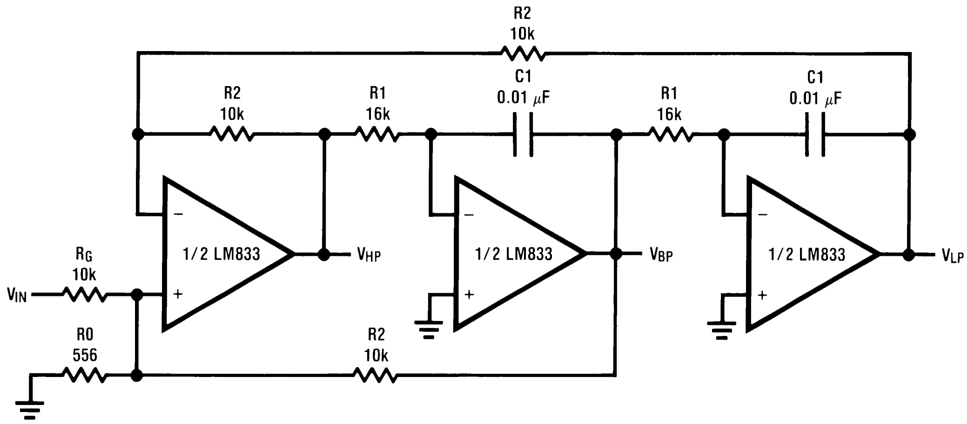
$$C1 = \frac{\sqrt{2}}{\omega_o R}$$

$$C2 = \frac{C1}{2}$$

Illustration is $f_0$ = 1 kHz

## Typical Applications (Continued)

### State Variable Filter

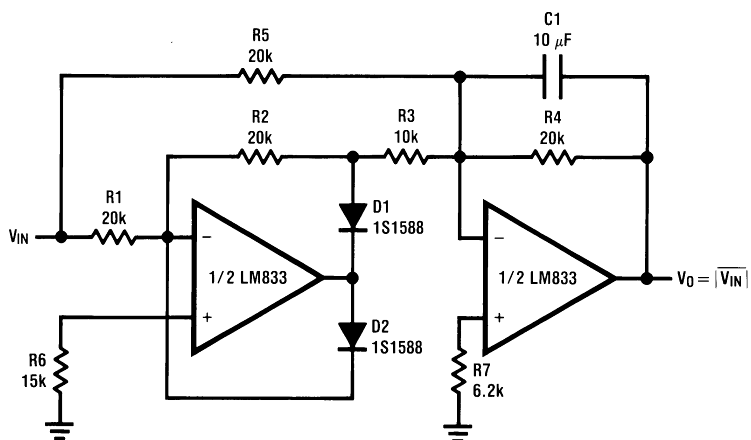



DS005218-37

$$f_0 = \frac{1}{2\pi C1R1},\ Q = \frac{1}{2}\left(1 + \frac{R2}{R0} + \frac{R2}{RG}\right),\ A_{BP} = QA_{LP} = QA_{LH} = \frac{R2}{RG}$$

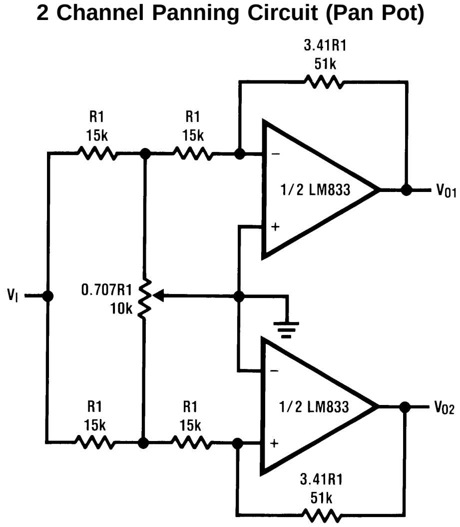
Illustration is $f_0$ = 1 kHz, Q = 10, $A_{BP}$ = 1

### AC/DC Converter



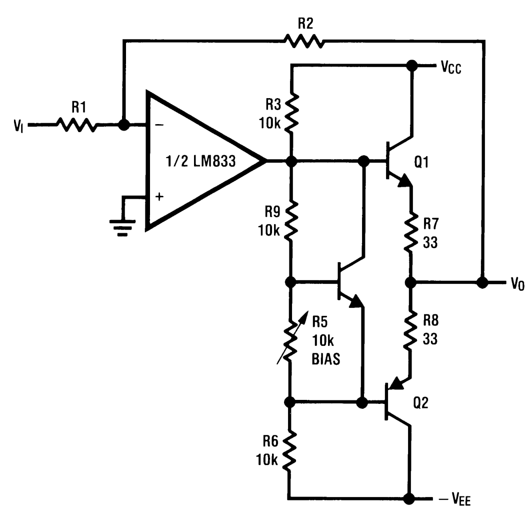

DS005218-38

### 2 Channel Panning Circuit (Pan Pot)




DS005218-39

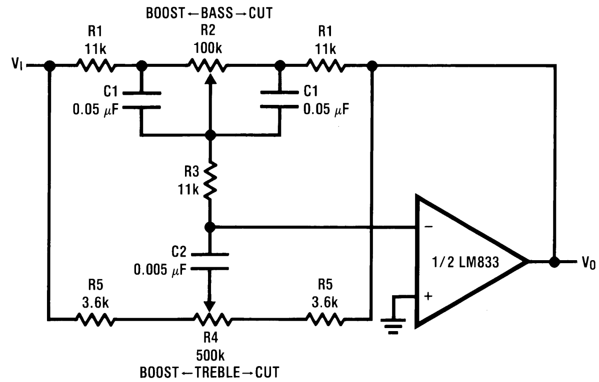
### Line Driver




DS005218-40

## Typical Applications (Continued)

### Tone Control




DS005218-41

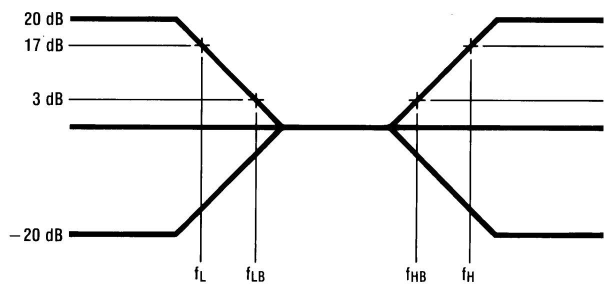
$$f_L = \frac{1}{2\pi R2C1}, f_{LB} = \frac{1}{2\pi R1C1}$$

$$f_H = \frac{1}{2\pi R5C2}, f_{HB} = \frac{1}{2\pi (R1 + R5 + 2R3)C2}$$

Illustration is:

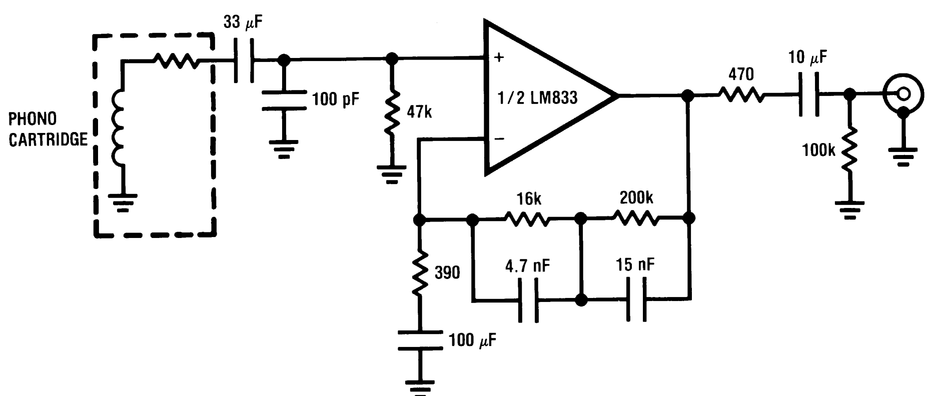
$f_L$ = 32 Hz, $f_{LB}$ = 320 Hz

$f_H$ =11 kHz, $f_{HB}$ = 1.1 kHz




DS005218-42

### RIAA Preamp




DS005218-3

$A_v$ = 35 dB

$E_n$ = 0.33 µV

S/N = 90 dB

f = 1 kHz

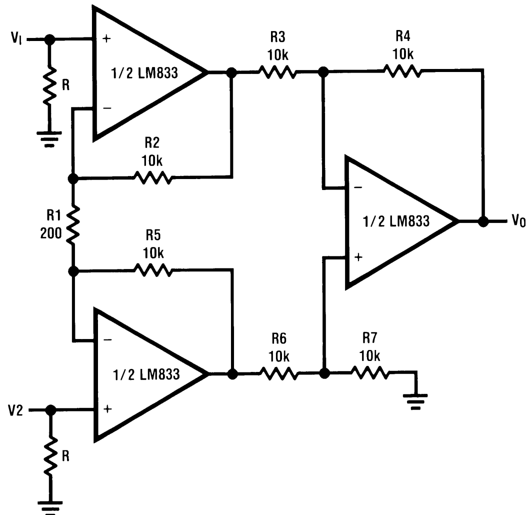
A Weighted

A Weighted, $V_{IN}$ = 10 mV

@f = 1 kHz

## Typical Applications (Continued)

**Balanced Input Mic Amp**




DS005218-43

If R2 = R5, R3 = R6, R4 = R7

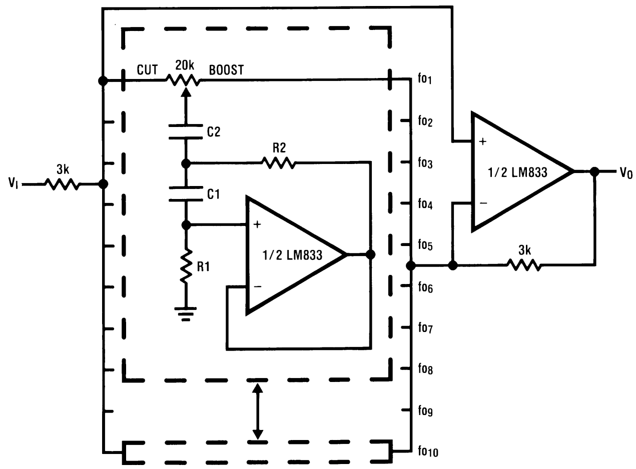
$$V0 = \left(1 + \frac{2R2}{R1}\right)\frac{R4}{R3}(V2 - V1)$$

Illustration is:

V0 = 101(V2 − V1)

## Typical Applications (Continued)

**10 Band Graphic Equalizer**




DS005218-44

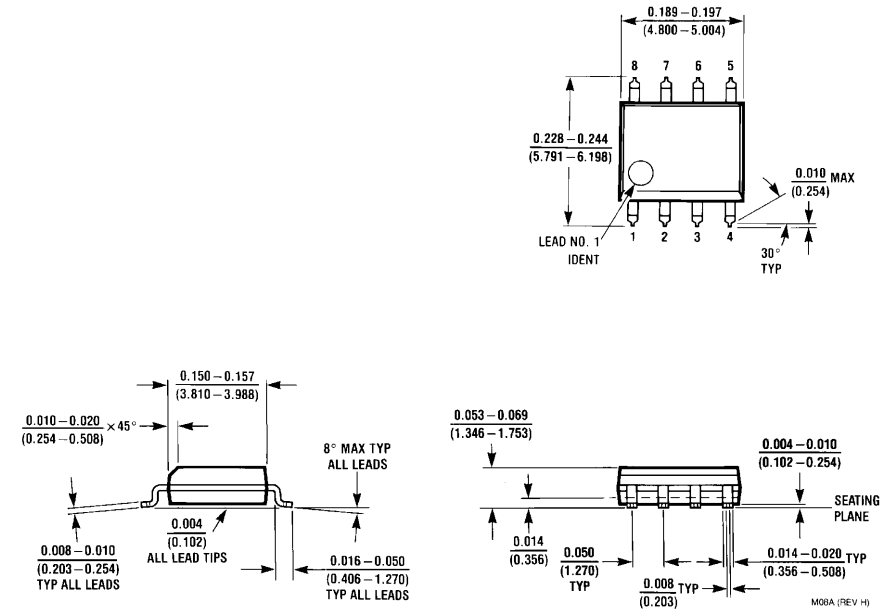
| fo(Hz) | $C_1$ | $C_2$ | $R_1$ | $R_2$ |
|---|---|---|---|---|
| 32 | 0.12µF | 4.7µF | 75kΩ | 500Ω |
| 64 | 0.056µF | 3.3µF | 68kΩ | 510Ω |
| 125 | 0.033µF | 1.5µF | 62kΩ | 510Ω |
| 250 | 0.015µF | 0.82µF | 68kΩ | 470Ω |
| 500 | 8200pF | 0.39µF | 62kΩ | 470Ω |
| 1k | 3900pF | 0.22µF | 68kΩ | 470Ω |
| 2k | 2000pF | 0.1µF | 68kΩ | 470Ω |
| 4k | 1100pF | 0.056µF | 62kΩ | 470Ω |
| 8k | 510pF | 0.022µF | 68kΩ | 510Ω |
| 16k | 330pF | 0.012µF | 51kΩ | 510Ω |

**Note 6:** At volume of change = ±12 dB

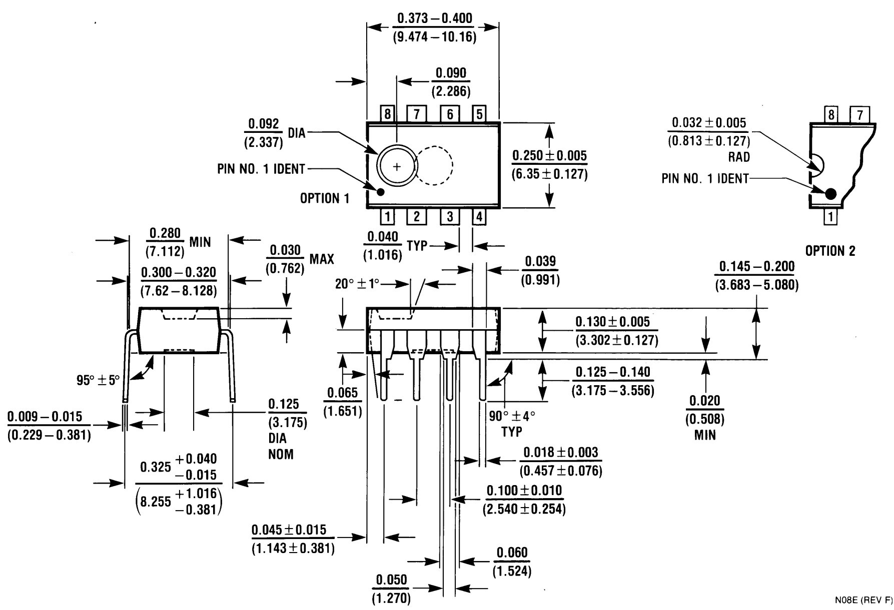
Q = 1.7

Reference: “AUDIO/RADIO HANDBOOK”, National Semiconductor, 1980, Page 2–61

## Physical Dimensions inches (millimeters) unless otherwise noted

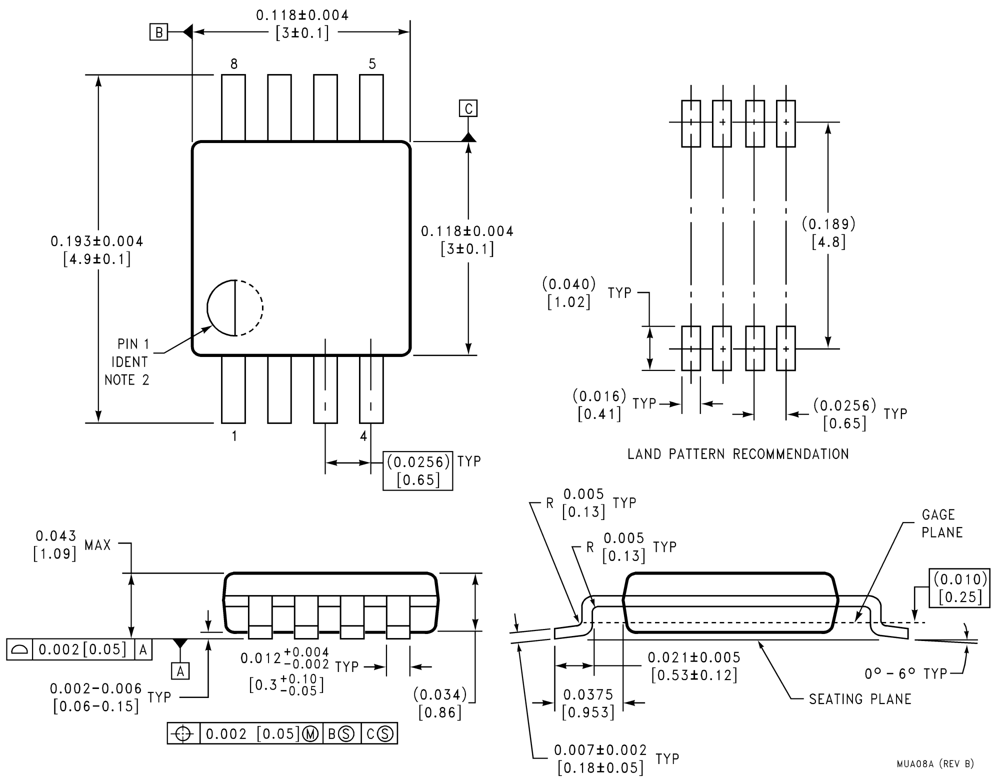



**Molded Small Outline Package (M)**
**Order Number LM833M or LM833MX**
**NS Package Number M08A**




**Molded Dual-In-Line Package (N)**
**Order Number LM833N**
**NS Package Number N08E**

## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)




**8-Lead (0.118" Wide) Molded Mini Small Outline Package**
**Order Number LM833MM or LM833MMX**
**NS Package Number MUA08A**

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```
seg71                                   ;Pattern
1 set adr
seg72                                   ;Pattern
2 set adr
seg73                                   ;Pattern
3 set adr
seg74                                   ;Pattern
4 set adr
seg75                                   ;Pattern
5 set adr
seg76                                   ;Pattern
6 set adr
seg77                                   ;Pattern
7 set adr
seg78                                   ;Pattern
8 set adr
seg79                                   ;Pattern
9 set adr
seg7a                                   ;Pattern
A set adr
seg7b                                   ;Pattern
B set adr
        endc

ra1     equ     h'01'                   ;RA1
port designation
ra2     equ     h'02'                   ;RA2
port designation
ra3     equ     h'03'                   ;RA3
port designation
ra5     equ     h'05'                   ;RA5
port designation
```

assembely

```
ccp1    equ     h'02'
;CCP1(RC2) designation

seg7_0  equ     b'01000000'
;-gfedcba Pattern 0
seg7_1  equ     b'01111001'     ;
 Pattern 1
seg7_2  equ     b'00100100'     ;
 Pattern 2
seg7_3  equ     b'00110000'     ;
 Pattern 3
seg7_4  equ     b'00011001'     ;
 Pattern 4
seg7_5  equ     b'00010010'     ;
 Pattern 5
seg7_6  equ     b'00000010'     ;
 Pattern 6
seg7_7  equ     b'01111000'     ;
 Pattern 7
seg7_8  equ     b'00000000'     ;
 Pattern 8
seg7_9  equ     b'00010000'     ;
 Pattern 9
seg7_a  equ     b'01111111'     ;
 Detect error
seg7_b  equ     b'00100011'     ;
 Illegal int

;****************  Program Start
**********************
        org     0               ;Reset
Vector
        goto    init
```

assembely

```
        org     4
;Interrupt Vector
        goto    int

;*****************  Initial Process
*********************
init

;*** Port initialization
        bsf     status,rp0          ;Change
to Bank1
        movlw   b'00000001'         ;AN0 to
input mode
        movwf   trisa               ;Set
TRISA register
        clrf    trisb               ;RB port
to output mode
        movlw   b'00000100'
;RC2/CCP1 to input mode
        movwf   trisc               ;Set
TRISC register

;*** Ultrasonic sending period
initialization (Timer0)
        movlw   b'11010111'
;TOCS=0,PSA=0,PS=1:256
        movwf   option_reg          ;Set
OPTION_REG register
        bcf     status,rp0          ;Change
to Bank0
        clrf    tmr0                ;Clear
TMR0 register
```

```
;*** Capture mode initialization
(Timer1)
        movlw   b'00000001'     ;Pre=1:1
TMR1=Int TMR1=ON
        movwf   t1con           ;Set
T1CON register
        clrf    ccp1con         ;CCP1
off

;*** A/D converter initialization
        movlw   b'01000001'     ;ADCS=01
CHS=AN0 ADON=ON
        movwf   adcon0          ;Set
ADCON0 register
        bsf     status,rp0      ;Change
to Bank1
        movlw   b'00001110'     ;ADFM=0
PCFG=1110
        movwf   adcon1          ;Set
ADCON1 register
        bcf     status,rp0      ;Change
to Bank0

;*** Display initialization (Timer2)
        movlw   disp_u          ;Set
digit head address
        movwf   disp_ha         ;Save
digit head sddress
        movlw   h'0a'           ;"Detect
error" data
        movwf   disp_u          ;Set 1st
digit
        movwf   disp_t          ;Set
```

```
10th digit
        movwf   disp_h              ;Set
100th digit
        movlw   d'3'                ;Digit
counter
        movwf   digit_cnt           ;Set
digit counter
        movlw   seg70               ;Set
7seg head address
        movwf   seg7_ha             ;Save
7seg head address
        movlw   seg7_0              ;Set
7segment pattern 0
        movwf   seg70               ;Save
pattern 0
        movlw   seg7_1              ;Set
7segment pattern 1
        movwf   seg71               ;Save
pattern 1
        movlw   seg7_2              ;Set
7segment pattern 2
        movwf   seg72               ;Save
pattern 2
        movlw   seg7_3              ;Set
7segment pattern 3
        movwf   seg73               ;Save
pattern 3
        movlw   seg7_4              ;Set
7segment pattern 4
        movwf   seg74               ;Save
pattern 4
        movlw   seg7_5              ;Set
7segment pattern 5
```

```
        movwf   seg75               ;Save
pattern 5
        movlw   seg7_6              ;Set
7segment pattern 6
        movwf   seg76               ;Save
pattern 6
        movlw   seg7_7              ;Set
7segment pattern 7
        movwf   seg77               ;Save
pattern 7
        movlw   seg7_8              ;Set
7segment pattern 8
        movwf   seg78               ;Save
pattern 8
        movlw   seg7_9              ;Set
7segment pattern 9
        movwf   seg79               ;Save
pattern 9
        movlw   seg7_a              ;Set
7segment pattern A
        movwf   seg7a               ;Save
pattern A
        movlw   seg7_b              ;Set
7segment pattern B
        movwf   seg7b               ;Save
pattern B
        movlw   b'00011110'
;OPS=1:4,T2=ON,EPS=1:16
        movwf   t2con               ;Set
T2CON register
        bsf     status,rp0          ;Change
to Bank1
        movlw   d'157'
```

```
;157x64=10048usec
        movwf   pr2                 ;Set PR2
register
        bsf     pie1,tmr2ie
;TMR2IE=ON
        bcf     status,rp0          ;Change
to Bank0


;*** Interruption control
        movlw   b'11100000'
;GIE=ON,PEIE=ON,T0IE=ON
        movwf   intcon              ;Set
INTCON register

wait
        goto    $
;Interruption wait

;****************  Interruption Process
*****************
int
        movfw   pir1                ;Read
PIR1 register
        btfsc   pir1,ccp1if         ;Capture
occurred ?
        goto    capture             ;Yes.
"Capture"
        btfsc   pir1,tmr2if         ;TMR2
time out ?
        goto    led_cont            ;Yes.
"LED display"
        movfw   intcon              ;Read
```

```
INTCON register
        btfsc   intcon,t0if     ;TMR0
time out ?
        goto    send            ;Yes.
"Pulse send"

;****************  Illegal interruption
*****************
illegal
        movlw   h'0b'           ;Set
Illegal disp digit
        addwf   seg7_ha,w       ;Seg7
H.Adr + digit
        movwf   fsr             ;Set FSR
register
        movfw   indf            ;Read
seg7 data
        movwf   portb           ;Write
LED data
        bcf     porta,ra1       ;RA1=ON
        bcf     porta,ra2       ;RA2=ON
        bcf     porta,ra3       ;RA3=ON
        goto    $               ;Stop

;*************  END of Interruption
Process **************
int_end
        retfie

;****************  Pulse send-out Process
****************
send
        bcf     intcon,t0if     ;Clear
```

```
TMR0 int flag
        clrf    tmr0                ;Timer0
clear

;*** Received Pulse detection check
        movfw   portc               ;Read
PORTC register
        btfsc   portc,ccp1
;Detected ?
        goto    detect_off          ;Yes.
Detected
        movlw   h'0a'               ;"Detect
error" data
        movwf   disp_u              ;Set 1st
digit
        movwf   disp_t              ;Set
10th digit
        movwf   disp_h              ;Set
100th digit

;*** Receive pulse detector off
detect_off
        bcf     porta,ra5           ;Set
detector OFF

;*** Capture start
        clrf    tmr1h               ;Clear
TMR1H register
        clrf    tmr1l               ;Clear
TMR1L register
        clrf    ccpr1h              ;Clear
CCPR1H register
        clrf    ccpr1l              ;Clear
```

```
CCPR1L register
        movlw   b'00000101'
;CCP1M=0101(Capture)
        movwf   ccp1con          ;Set
CCP1CON register
        bsf     status,rp0       ;Change
to Bank1
        bsf     pie1,ccp1ie      ;CCP1
interruptin enable
        bcf     status,rp0       ;Change
to Bank0
        bcf     pir1,ccp1if      ;Clear
CCP1 int flag

;*** 40KHz pulse send ( 0.5 msec )
        movlw   d'20'
;Send-out pulse count
        movwf   s_count          ;Set
count
s_loop
        call    pulse            ;Call
pulse send sub
        decfsz  s_count,f        ;End ?
        goto    s_loop           ;No.
Continue

;*** Get adjustment data
        bsf     adcon0,go        ;Start
A/D convert
ad_check
        btfsc   adcon0,go        ;A/D
convert end ?
        goto    ad_check         ;No.
```

```
Again
        movfw   adresh          ;Read
ADRESH register
        movwf   s_adj           ;Save
converted data

        movlw   d'5'            ;Set
rotate value
        movwf   s_adj_count     ;Save
rotate value
ad_rotate
        rrf     s_adj,f         ;Rotate
right 1 bit
        decfsz  s_adj_count,f   ;End ?
        goto    ad_rotate       ;No.
Continue
        movfw   s_adj           ;Read
rotated value
        andlw   b'00000111'     ;Pick-up
3 bits
        addlw   d'54'           ;(0 to
7) + 54 = 54 to 61
        movwf   s_adj           ;Save
adjustment data

;*** Capture guard timer ( 1 milisecound
)
        movlw   d'2'            ;Set
loop counter1
        movwf   g_time1         ;Save
loop counter1
g_loop1 movlw   d'124'          ;Set
loop counter2
```

```
                assembely
        movwf   g_time2           ;Save
loop counter2
g_loop2 nop                       ;Time
adjust
        decfsz  g_time2,f         ;g_time2
- 1 = 0 ?
        goto    g_loop2           ;No.
Continue
        decfsz  g_time1,f         ;g_time1
- 1 = 0 ?
        goto    g_loop1           ;No.
Continue

;*** Receive pulse detector on
        bsf     porta,ra5         ;Set
detector ON

        goto    int_end

;****************  Pulse send-out Process
****************
pulse
        movlw   b'00010000'       ;RC4=ON
        movwf   portc             ;Set
PORTC register
        call    t12us             ;Call
12usec timer
        clrf    portc             ;RC4=OFF
        goto    $+1
        goto    $+1
        nop
        return
```

```
;****************  12 microseconds timer
*****************
t12us
        goto   $+1
        goto   $+1
        goto   $+1
        goto   $+1
        nop
        return

;******************  Capture Process
********************
capture
        bcf     pir1,ccp1if      ;Clear
CCP1 int flag

        clrf    p_countl         ;Clear L
count
        clrf    p_counth         ;Clear H
count
        clrf    ccp1con          ;CCP1
off

division
        movfw   s_adj            ;Read
adjustment data
        subwf   ccpr1l,f         ;Capture
- adjust
        btfsc   status,z         ;Result
= 0 ?
        goto    division2        ;Yes. "R
= 0"
        btfsc   status,c         ;Result
```

```
< 0 ?
        goto    division1          ;No. "R
> 0"
        goto    division3          ;Yes."R
< 0"

division1                          ;( R > 0
)
        movlw   d'1'               ;Set
increment value
        addwf   p_countl,f
;Increment L count
        btfss   status,c
;Overflow ?
        goto    division           ;No.
Continue
        incf    p_counth,f
;Increment H count
        goto    division           ;Jump
next

division2                          ;( R = 0
)
        movfw   ccpr1h             ;Read
CCPR1H
        btfss   status,z           ;CCPR1H
= 0 ?
        goto    division1          ;No.
Next
        movlw   d'1'               ;Set
increment value
        addwf   p_countl,f
;Increment L count
```

```
        btfss   status,c
;Overflow ?
        goto    digit_set        ;Jump to
digit set
        incf    p_counth,f
;Increment H count
        goto    digit_set        ;Jump to
digit set

division3                        ;( R < 0
)
        movfw   ccpr1h           ;Read
CCPR1H
        btfss   status,z         ;CCPR1H
= 0 ?
        goto    division4        ;No.
Borrow process
        goto    digit_set        ;Jump to
digit set

division4
        decf    ccpr1h,f         ;CCPR1H
- 1
        movlw   d'255'           ;Borrow
value
        addwf   ccpr1l,f         ;CCPR1L
+ 255
        incf    ccpr1l,f         ;CCPR1L
+ 1
        goto    division1        ;Next

;****************  Digit Set Process
*******************
```

```
digit_set
        clrf    disp_u              ;Clear
1st digit
        clrf    disp_t              ;Clear
10th digit
        clrf    disp_h              ;Clear
100th digit

;*** 100th digit
digit_h
        movlw   d'100'              ;Divide
value
        subwf   p_countl,f          ;Digit -
divide
        btfsc   status,z            ;Result
= 0 ?
        goto    digit_h2            ;Yes. "R
= 0"
        btfsc   status,c            ;Result
< 0 ?
        goto    digit_h1            ;No. "R
> 0"
        goto    digit_h3            ;Yes."R
< 0"

digit_h1                            ;( R > 0
)
        incf    disp_h,f
;Increment 100th count
        goto    digit_h             ;Jump
next

digit_h2                            ;( R = 0
```

```
)
         movfw   p_counth          ;Read H
counter
         btfss   status,z          ;H
counter = 0 ?
         goto    digit_h1          ;No.
Next
         incf    disp_h,f
;Increment 100th count
         goto    digit_t           ;Jump to
10th digit pro

digit_h3                           ;( R < 0
)
         movfw   p_counth          ;Read H
counter
         btfss   status,z          ;H
counter = 0 ?
         goto    digit_h4          ;No.
Borrow process
         movlw   d'100'            ;Divide
value
         addwf   p_countl,f        ;Return
over sub value
         goto    digit_t           ;Jump to
10th digit pro

digit_h4
         decf    p_counth,f        ;H
counter - 1
         movlw   d'255'            ;Borrow
value
         addwf   p_countl,f        ;L
```

```
counter + 255
        incf    p_countl,f        ;L
counter + 1
        goto    digit_h1          ;Next

;*** 10th digit
digit_t

;*** Range over check
        movfw   disp_h            ;Read
100th digit
        sublw   d'9'              ;9 -
(100th digit)
        btfsc   status,z          ;Result
= 0 ?
        goto    digit_t0          ;Yes. "R
= 0"
        btfsc   status,c          ;Result
< 0 ?
        goto    digit_t0          ;No. "R
> 0"
        movlw   h'0a'             ;"Detect
error" data
        movwf   disp_u            ;Set 1st
digit
        movwf   disp_t            ;Set
10th digit
        movwf   disp_h            ;Set
100th digit
        goto    int_end

digit_t0
        movlw   d'10'             ;Divide
```

```
value
        subwf   p_countl,f          ;Digit -
divide
        btfsc   status,z            ;Result
= 0 ?
        goto    digit_t1            ;Yes. "R
= 0"
        btfsc   status,c            ;Result
< 0 ?
        goto    digit_t1            ;No. "R
> 0"
        goto    digit_t2            ;Yes."R
< 0"

digit_t1                            ;( R >=
0 )
        incf    disp_t,f
;Increment 10th count
        goto    digit_t             ;Jump
next

digit_t2                            ;( R < 0
)
        movlw   d'10'               ;Divide
value
        addwf   p_countl,f          ;Return
over sub value
        goto    digit_u             ;Jump to
1st digit pro

;*** 1st digit
digit_u
        movfw   p_countl            ;Read
```

```
propagetion counter
        movwf   disp_u            ;Save
1st count

        goto    int_end

;*****************  LED display control
*****************
led_cont
        bcf     pir1,tmr2if       ;Clear
TMR2 int flag

        movfw   digit_cnt         ;Read
digit counter
        movwf   s_digit           ;Save
digit counter
        decfsz  s_digit,f         ;1st
digit ?
        goto    d_check1          ;No.
Next
        bsf     porta,ra1         ;RA1=OFF
        bsf     porta,ra2         ;RA2=OFF
        bcf     porta,ra3         ;RA3=ON
        goto    c_digit           ;Jump to
digit cont
d_check1
        decfsz  s_digit,f         ;10th
digit ?
        goto    d_check2          ;No.
100th digit
        bsf     porta,ra1         ;RA1=OFF
        bcf     porta,ra2         ;RA2=ON
        bsf     porta,ra3         ;RA3=OFF
```

```
                assembely
        goto    c_digit            ;Jump to
digit cont
d_check2
        bcf     porta,ra1          ;RA1=ON
        bsf     porta,ra2          ;RA2=OFF
        bsf     porta,ra3          ;RA3=OFF

c_digit
        decf    digit_cnt,w        ;Digit
count - 1
        addwf   disp_ha,w          ;Digit
H.Adr + count
        movwf   fsr                ;Set FSR
register
        movfw   indf               ;Read
digit
        addwf   seg7_ha,w          ;Seg7
H.Adr + digit
        movwf   fsr                ;Set FSR
register
        movfw   indf               ;Read
seg7 data
        movwf   portb              ;Write
LED data

        decfsz  digit_cnt,f        ;Digit
count - 1
        goto    int_end            ;Jump to
interrupt end
        movlw   d'3'               ;Initial
value
        movwf   digit_cnt          ;Set
initial value
```

```
                assembely
        goto    int_end             ;Jump to
interrupt end
```