LAMPIRAN A

Listing Program

Program pada Mikrokontroler ATmega32  A-1
Program pada Mikrokontroler ATmega16  A-15
LISTING PROGRAM PADA MIKROKONTROLER ATMega32
(PENAMPIL SIGNAL)

*PROGRAM UTAMA*

```c
#include <avr/io.h>
#include <avr/interrupt.h>
#include "glcd.c"

void USART_Init(unsigned int baudrate);
void timePause(unsigned long count);
void ADC_init (void);
void initTimer (void);

#ifndef F_CPU
#define F_CPU 16000000UL
#endif

#define msUp    1
#define msDwn    4
#define YposUp   0
#define YposDwn   3
#define freeze    2
#define AC     0
#define DC     1
#define SQUARE   2
#define TRUE    0
#define FALSE    1

unsigned int counter = 0;
unsigned int dataCounter = 0;
unsigned int timeDiv = 52;
unsigned int analogInput = 0;
unsigned char trigger = 2;
unsigned char cnt = 0;
unsigned char empty = 0;
unsigned int out = 0;
unsigned char findZero = 0;
unsigned char pressedButton = 0;
unsigned char upLimit = 0;
unsigned char dnLimit = 255;
unsigned char limitBkup = 0;
unsigned char tipeTeg = AC;
unsigned char complete = TRUE;

signed char Ypos   = 0;
signed char Ypos2  = 0;
signed char position  = 0;
```
int main (void)
{
    DDRC = 0b00000000;
    PORTC = 0b11111111;
    DDRA = 0b00000000;
    unsigned char temp1;
    unsigned int temp2;
    unsigned char i;
    glcdInit();
    ADC_init();
    createWelcomeScreen();
    showTheWave();
    timePause(10000000);
    for(;;)
    {
        //---------
        if (pressedButton == 0)
        {
            if (~PINC & (1<<msUp) && (timeDiv <= 1000))
            {
                if(timeDiv == 0)
                    timeDiv = 52;
                else
                    timeDiv += 145;
                pressedButton = 1;
            }
            if (~PINC & (1<<msDwn) && (timeDiv >= 52))
            {
                if(timeDiv <= 145)
                    timeDiv = 0;
                else
                    timeDiv -= 145;
                pressedButton = 1;
            }
            if (~PINC & (1<<YposUp) && (Ypos2 <= 60))
                Ypos2++;
            if (~PINC & (1<<YposDwn) && (Ypos2 >= -60))
                Ypos2--;
            if (~PINC & (1<<freeze))
            {
                //---------
            }
        }
    }
}
while (~PINC & (1<<freeze));

else {
    temp1 = PINC;
    if (temp1 == 255)
        pressedButton = 0;
}

//--------v

dataCounter = 0;
findFirst = 0;
upLimit = 0;
dnLimit = 255;

for (i=99; i>0; i--)
{
    ADCSRA |= (1 << ADSC);
    loop_until_bit_is_set(ADCSRA, ADIF);
    temp1 = ADCL;
    temp2 = ADCH;
    timePause(timeDiv);
    if (upLimit < temp2)
        upLimit = temp2;
    if (dnLimit > temp2)
        dnLimit = temp2;
    if (temp2 > 0)
    {
        temp2 += 5;
        temp2 /= 5;
        temp2 += 2;
    } else temp2 = 2;
    position = temp2 + Ypos2 +5;
    if (position <= 63 & & position >= 0
        fillDataLcdBuffer(i,position);
    else
        fillDataLcdBuffer(i,0);
}

if(upLimit != dnLimit)
    trigger = (((upLimit - dnLimit)/2)+ dnLimit);

//--------^
createRaster();
createWave();
showTheWave();

dataCounter = 0;
do
{
    limitBkup = temp2;

    ADCSRA |= (1 << ADSC);
    loop_until_bit_is_set(ADCSRA, ADIF);
    temp1 = ADCL;
    temp2 = ADCH;
    //timerPause(timeDiv);

    if(limitBkup == temp2)
    {
        dataCounter++;
        if(dataCounter >= 500)
            tipeTeg = DC;
        else
            tipeTeg = AC;
    }

    if((tipeTeg == AC) && ((temp2 == trigger) &&
        (limitBkup < temp2)))
        complete = TRUE;
    else
    if((tipeTeg == DC) && (limitBkup == temp2) &&
        (upLimit != dnLimit))
    {
        dataCounter = 0;
do
        {
            ADCSRA |= (1 << ADSC);
            loop_until_bit_is_set(ADCSRA, ADIF);
            temp1 = ADCL;
            temp2 = ADCH;
            complete = TRUE;
            dataCounter++;
        }while ((temp2 > trigger) && (dataCounter <1000));

    dataCounter = 0;
do
    {
        ADCSRA |= (1 << ADSC);
        loop_until_bit_is_set(ADCSRA, ADIF);
temp1 = ADCL;
temp2 = ADCH;
complete = TRUE;
dataCounter++;
}
while ((temp2 < trigger) && (dataCounter <1000));
else
    if((tipeTeg == DC) && (limitBkup == temp2))
        complete = TRUE;
    else
        complete = FALSE;

} while(complete == FALSE);

void ADC_init (void)
{
    ADMUX = 0b01100000;
    ADCSRA = 0b11000100;
}

void timePause(unsigned long count)
{
    while(count--);
}


**SUB PROGRAM GLCD.C**

```c
#include "glcd.h"
#include <util/delay.h>

void glcdInit (void)
{
    data_port_pins = 0;  //DATA Port Low
    data_port_ddr = 0xff; //Make DATA port output

    ctrl_port = 0;   //CONTROL Port Low
    ctrl_port_ddr = 0xff; //Make CONTROL port outputs

    ctrl_port |= (1<<lcdrst);  //Enable the CS1 of the display
    ctrl_port |= (1<<lcdcs1); //Enable the CS2 of the display
    ctrl_port &= ~(1<<lcdrs); //Clear RS
    ctrl_port &= ~(1<<lcdrw); //Clear RW/ Command mode

    //delayTimexx(10000);
    _delay_us(42);
    data_port = 0b11000000; //Display start line = 0 (0-63)
    eStrobe();

    //delayTimexx(10000);
    _delay_us(42);
    data_port = 0b01000000; //Set address = 0 (0-63)
    eStrobe();

    //delayTimexx(10000);
    _delay_us(42);
    data_port = 0b10111000; //Set page = 0 (0-7)
    eStrobe();

    //delayTimexx(10000);
    _delay_us(42);
    data_port = 0b00111111; //Display ON
    eStrobe();

    ctrl_port &= ~(1<<lcdcs1); //Disable the CS1 of display
    ctrl_port &= ~(1<<lcdcs2); //Disable the CS2 of display

    createRaster(); // raster...
    showTheWave(); // LCD.
}
```
void createWelcomeScreen (void) 
{
unsigned int size;

lcdAddress = 0; 
flashAddress =0; 
const char *data = welcomeScreen;

for (size = 0; size<1024; size++)
   lcdBuffer[lcdAddress++] = pgm_read_byte(data++);
} 

void createRaster (void) 
{
unsigned int size;

lcdAddress = 0; 
flashAddress =0; 
const char *data = LcdRaster;

for (size = 0; size<1024; size++)
    lcdBuffer[lcdAddress++] = pgm_read_byte(data++);
} 

void changeLine (unsigned char lineData) 
{
    ctrl_port |= (1<<lcdcs1); //Enable the CS1 of the display
    ctrl_port |= (1<<lcdcs2); //Enable the CS2 of the display
    ctrl_port &= ~(1<<lcdrs); //Clear RS. Command mode
    ctrl_port &= ~(1<<lcdrw); //Clear RW. Command mode

    lineData += 0b10111000;
    data_port = lineData; //Set page = 0 (0-7)
    eStrobe();

    data_port = 0b01000000; //Set address = 0 (0-63)
    eStrobe();

    ctrl_port |= (1<<lcdrs); //Set RS. Data mode
```c
void fillDataLcdBuffer (unsigned char address, unsigned char data)
{
    dataLcdBuffer[address] = data;
}

void showTheWave (void)
{
    for(lcdAddress = 0; lcdAddress < 1024 ;lcdAddress++)
    {
        if (line == 8)
            line = 0;

        if (column == 128)
        {
            column = 0;
            line++;
            if (line == 8)
                line = 0;
            changeLine(line);
        }

        if (column <= 63)
            enable_cs1();

        if (column == 64)
            enable_cs2();

        //delayTimexx(10);
        _delay_us(3);
        ctrl_port |= (1<<lcdrs); // "DATA SEND" mode
        ctrl_port &= ~1<<lcdrw;
        data_port = lcdBuffer[lcdAddress];
        eStrobe();

        column++;  // increase column (maximum 128).
    }
}
```
void createWave (void)
{
    unsigned char data;
    unsigned char byte;
    unsigned char i = 0;

    for (i=0; i<128; i++)
    {
        byte = 0b10000000;
        lcdAddress = 996;

        if(i<100)
        {
            data = dataLcdBuffer[i];
            for (; data>7; data-=8)
                lcdAddress -= 128;
            lcdAddress -= i;
            for(; data>0; data--)
                byte >>= 1;
            lcdBuffer[lcdAddress] |= byte;
        }
    }
}

void enable_cs1 (void)
{
    ctrl_port |= (1<<lcdcs1);   //Enable the CS1 of the display
    ctrl_port &= ~(1<<lcdcs2);   //Disable the CS2 of the display
}

void enable_cs2 (void)
{
    ctrl_port |= (1<<lcdcs2);   //Enable the CS2 of the display
    ctrl_port &= ~(1<<lcdcs1);   //Disable the CS1 of the display
}
// Wait for graphics LCD to be unbusy
void glcdWait (void)
{
    unsigned char dataIn;

    data_port_ddr = 0;   // Make portB all inputs
    ctrl_port |= (1<<lcdrw); // Set r/w pin to read
    ctrl_port &= ~(1<<lcdrs); // Set register select to command

    do
    {
        eStrobe();
        dataIn = data_port_pins; // Read busy flag

        while bit_is_set(dataIn, 7); // Loop until bit7 of 'dataIn' will be cleared.
    }
    data_port_ddr = 0xff;  // Make portB all outputs
    ctrl_port &= ~(1<<lcdrw); // Set r/w pin to write
    ctrl_port |= (1<<lcdrs); // Set register select to data

    }

//
//
void eStrobe (void)
{

    ctrl_port |= (1<<lcde);   // Lcd 'E' pin high
    // delayTimexx(10);
    _delay_us(3);
    ctrl_port &= ~(1<<lcde);  // Lcd 'E' pin low
    // delayTimexx(10);
    _delay_us(3);

    }


*SUB PROGRAM GLCD.H*

```c
#define lcdrs 0   // LCD's RS pin is connected to Pin0 of AVR
#define lcdrw 1   // LCD's r/w pin is connected to Pin1 of AVR
#define ldce 2    // LCD's e pin is connected to Pin2 of AVR
#definelcdcs1 5   // LCD's CS1 pin is connected to Pin5 of AVR
#definelcdcs2 4   // LCD's CS2 pin is connected to Pin4 of AVR
#define lcrst 3   // LCD's RST pin is connected to Pin3 of AVR

#define ctrl_port   PORTB
#define ctrl_port_ddr DDRB
#define ctrl_port_pins PINB

#define data_port  PORTD
#define data_port_ddr DDRD
#define data_port_pins PINB
#define pgm_read_byte

void glcdInit (void);
void createWelcomeScreen (void);
void createRaster (void);
void delayTime (unsigned long counter);
void glcdWait (void);
void eStrobe (void);
void enable_cs1 (void);
void enable_cs2 (void);
void showTheWave (void);
void changeLine (unsigned char data);
void createWave (void);
void fillDataLcdBuffer (unsigned char address, unsigned char data);

unsigned char column = 0;
unsigned char line = 0;
unsigned char lcdBuffer[1024];
unsigned int lcdAddress = 0;
unsigned int flashAddress = 0;
static unsigned char dataLcdBuffer[128];
unsigned int backupLcdAddress = 0;
```
const char LcdRaster[] __attribute__((progmem)) = {
  255,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
  1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
  1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
  1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
  1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
  1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
  0,0,0,0,255,0,0,60,66,66,60,64,68,98,
  82,76,60,74,74,48,0,112,8,112,8,112,0,0,
  255,0,0,0,0,0,0,8,0,0,0,0,0,0,0,
  0,0,8,0,0,0,0,0,0,0,8,0,0,
  0,0,0,0,0,8,0,0,0,0,0,0,0,0,
  8,170,8,0,0,0,0,0,0,8,0,0,0,0,
  0,0,0,8,0,0,0,0,0,0,0,0,0,8,
  0,0,0,0,0,0,8,0,0,0,0,0,0,0,
  0,0,255,0,0,30,33,161,30,0,32,0,39,165,
  165,25,0,0,0,0,0,56,4,56,4,56,0,0,
  255,0,0,0,0,0,0,32,0,0,0,0,0,
  0,0,32,0,0,0,0,0,0,32,0,0,
  0,0,0,0,0,32,0,0,0,0,0,0,
  32,170,32,0,0,0,0,0,32,0,0,0,
  0,0,0,32,0,0,0,0,0,0,0,32,
  0,0,0,0,0,0,32,0,0,0,0,0,
  0,0,0,255,0,0,145,223,16,0,16,0,207,80,
  80,79,0,0,0,0,0,28,2,28,2,28,0,0,
  255,128,0,128,0,128,0,128,0,128,0,128,0,128,0,128,
  0,128,0,128,0,128,0,128,0,128,0,128,0,128,0,128,
  0,128,0,128,0,128,0,128,0,128,0,128,0,128,0,128,
  128,234,128,0,128,0,128,0,128,0,128,0,128,0,128,
  0,128,0,128,0,128,0,128,0,128,0,128,0,128,0,128,
  0,0,0,255,0,0,64,40,47,200,0,8,0,201,41,
  41,198,0,0,0,0,0,14,129,14,129,14,14,0,0,
  255,0,0,0,0,0,0,1,0,0,0,0,0,0,
  0,0,1,0,0,0,0,0,0,1,0,0,
  0,0,0,0,0,0,1,0,0,0,0,0,0,
  0,171,0,0,0,0,0,0,1,0,0,0,0,
  0,0,0,0,1,0,0,0,0,0,0,0,1,
  0,0,0,0,0,0,1,0,0,0,0,0,
  0,0,0,255,0,0,36,22,149,100,0,4,0,115,84,
  84,147,0,0,0,0,0,135,64,135,64,135,0,0,0,
  255,0,0,0,0,0,0,2,0,0,0,0,0,0,
  0,0,2,0,0,0,0,0,0,2,0,0,0,
  0,0,0,0,0,2,0,0,0,0,0,0,0,
  2,170,2,0,0,0,0,0,0,2,0,0,0,0,
  0,0,0,0,2,0,0,0,0,0,0,2,
  0,0,0,0,0,0,2,0,0,0,0,0,
  0,0,0,255,0,0,10,43,90,138,0,2,0,242,10,
  10,241,0,0,0,0,0,195,32,195,32,195,0,0,0,
  255,0,0,0,0,0,0,0,0,0,0,0,0,0,
const char welcomeScreen[] __attribute__((progmem)) = {
 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
 8,170,8,0,0,0,0,0,0,0,0,0,0,0,0,0,
 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,8,
 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
 0,0,0,0,255,0,0,133,149,173,68,0,129,0,156,149,
 149,100,0,0,0,0,0,225,16,225,0,0,0,0,0,0,0,
 0,0,0,0,0,0,0,225,16,225,0,0,0,0,0,0,0,
 0,0,0,0,0,225,16,225,100,0,0,0,0,0,0,0,
 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
 0,0,0,255,0,0,24,30,16,126,0,64,0,60,66,
 66,60,0,0,0,0,0,112,8,112,8,112,0,0,0};
LISTING PROGRAM PADA MIKROKONTROLER ATMEGA16
(PENAMPIL ANGKA)

Project :
Version :
Date    : 5/19/2009
Author  : F4CG
Company : F4CG
Comments:

Chip type : ATmega16
Program type : Application
Clock frequency : 16.000000 MHz
Memory model  : Small
External SRAM size : 0
Data Stack size : 256

#include <mega16.h>
#include <delay.h>
#include <stdio.h>

// Alphanumeric LCD Module functions
asm
    .equ __lcd_port=0x15 ;PORTC
#endasm

#include <lcd.h>
unsigned long int a,frek;
int text[33];

// External Interrupt 0 service routine
interrupt [EXT_INT0] void ext_int0_isr(void)
{a++;
// Place your code here
}

// Timer 1 output compare A interrupt service routine
interrupt [TIM1_COMPA] void timer1_compa_isr(void)
{
  frek=a;
a=0;
// Place your code here
}

#define ADC_VREF_TYPE 0xC0

// Read the AD conversion result
unsigned int read_adc(unsigned char adc_input)
{
  ADMUX=adc_input | (ADC_VREF_TYPE & 0xff);
  // Start the AD conversion
  ADCSRA|=0x40;
  // Wait for the AD conversion to complete
  while ((ADCSRA & 0x10)==0);
  ADCSRA|=0x10;
  return ADCW;
}

// Declare your global variables here
float v2;
float v;
int adc;
int adc2;
void main(void)
{
    // Declare your local variables here
    // Input/Output Ports initialization
    // Port A initialization
    // Func7=In Func6=In Func5=In Func4=In Func3=In Func2=In Func1=In Func0=In
    // State7=T State6=T State5=T State4=T State3=T State2=T State1=T State0=T
    PORTA=0x00;
    DDRA=0x00;

    // Port B initialization
    // Func7=In Func6=In Func5=In Func4=In Func3=In Func2=In Func1=In Func0=In
    // State7=T State6=T State5=T State4=T State3=T State2=T State1=T State0=T
    PORTB=0x00;
    DDRB=0x00;

    // Port C initialization
    // Func7=In Func6=In Func5=In Func4=In Func3=In Func2=In Func1=In Func0=In
    // State7=T State6=T State5=T State4=T State3=T State2=T State1=T State0=T
    PORTC=0x00;
    DDRC=0x00;

    // Port D initialization
    // Func7=In Func6=In Func5=In Func4=In Func3=In Func2=In Func1=In Func0=In
    // State7=T State6=T State5=T State4=T State3=T State2=T State1=T State0=T
    PORTD=0x00;
    DDRD=0x00;

    // Timer/Counter 0 initialization
    // Clock source: System Clock
    // Clock value: Timer 0 Stopped
    // Mode: Normal top=FFh
    // OC0 output: Disconnected
    TCCR0=0x00;
TCNT0=0x00;
OCR0=0x00;

// Timer/Counter 1 initialization
// Clock source: System Clock
// Clock value: 15.625 kHz
// Mode: CTC top=OCR1A
// OC1A output: Discon.
// OC1B output: Discon.
// Noise Canceler: Off
// Input Capture on Falling Edge
// Timer 1 Overflow Interrupt: Off
// Input Capture Interrupt: Off
// Compare A Match Interrupt: On
// Compare B Match Interrupt: Off
TCCR1A=0x00;
TCCR1B=0x0D;
TCNT1H=0x00;
TCNT1L=0x00;
ICR1H=0x00;
ICR1L=0x00;
OCR1AH=0x3D;
OCR1AL=0x09;
OCR1BH=0x00;
OCR1BL=0x00;

// Timer/Counter 2 initialization
// Clock source: System Clock
// Clock value: Timer 2 Stopped
// Mode: Normal top=FFh
// OC2 output: Disconnected
ASSR=0x00;
TCCR2=0x00;
TCNT2=0x00;
OCR2=0x00;

// External Interrupt(s) initialization
// INT0: On
// INT0 Mode: Falling Edge
// INT1: Off
// INT2: Off
GICR|=0x40;
MCUCR=0x02;
MCUCSR=0x00;
GIFR=0x40;

// Timer(s)/Counter(s) Interrupt(s) initialization
TIMSK=0x10;

// Analog Comparator initialization
// Analog Comparator: Off
// Analog Comparator Input Capture by Timer/Counter 1: Off
ACSR=0x80;
SFIOR=0x00;

// ADC initialization
// ADC Clock frequency: 1000.000 kHz
// ADC Voltage Reference: Int., cap. on AREF
// ADC Auto Trigger Source: None
ADMUX=ADC_VREF_TYPE & 0xff;
ADCSRA=0x84;

// LCD module initialization
lcd_init(16);

// Global enable interrupts
#asm("sei")
while (1)
{

    adc=read_adc(1);
    if(frek>=5) v=((float)adc*(5/1.075)/1024);
    else   v=((float)adc*5/1024);

    frek=(frek/1.45);
    sprintf(text,"frek = %li \n V = %0.3f V ",frek,v);
    lcd_puts(text);
    delay_ms(1000);
    lcd_clear();
}
}
Lampiran
LAMPIRAN B

Penampil Sinyal B-1
Penampil Angka B-2
Pembagi Frekuensi B-3
Penyearah B-4
• Penampil Sinyal Tampak Atas

• Penampil Sinyal Tampak Samping
- Penampil Angka Tampak Atas

- Penampil Angka Tampak Samping
- Pemabagi Frekuensi Tampak Atas

- Pembagi Frekuensi Tampak Samping
• Penyearah Tampak Atas

• Penyearah Tampak Samping
LAMPIRAN C

Datasheet IC 74390 C-1
Datasheet IC LM 358 C-7
• Datasheet IC 74390

DM74LS390 Dual 4-Bit Decade Counter

General Description
Each of these monolithic circuits contains eight master-slave flip-flops and additional gating to implement two individual four-bit counters in a single package. The DM74LS390 incorporates dual divide-by-two and divide-by-five counters, which can be used to implement cycle lengths equal to any whole and/or cumulative multiples of 2 and/or 5 up to divide-by-100. When connected as a bi-Quinary counter, the separate divide-by-two circuit can be used to provide symmetry (a square wave) at the final output stage. The DM74LS390 has parallel outputs from each counter stage so that any submultiple of the input count frequency is available for system-timing signals.

Features
- Dual version of the popular DM74LS90
- DM74LS390...individual clocks for A and B flip-flops provide dual + 2 and + 5 counters
- Direct clear for each 4-bit counter
- Dual 4-bit version can significantly improve system densities by reducing counter package count by 50%
- Typical maximum count frequency...35 MHz
- Buffered outputs reduce possibility of collector commutation

Ordering Code:

<table>
<thead>
<tr>
<th>Order Number</th>
<th>Package Number</th>
<th>Package Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM74LS390M</td>
<td>M16A</td>
<td>16-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150 Narrow</td>
</tr>
<tr>
<td>DM74LS390N</td>
<td>N16E</td>
<td>16-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide</td>
</tr>
</tbody>
</table>

Devices also available in Tape and Reel. Specify by appending the suffix letter "R" to the ordering code.

Connection Diagram

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Function Tables

BCD Count Sequence
(Each Counter) (Note 1)

<table>
<thead>
<tr>
<th>Count</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>L</td>
</tr>
<tr>
<td>1</td>
<td>L</td>
</tr>
<tr>
<td>2</td>
<td>L</td>
</tr>
<tr>
<td>3</td>
<td>L</td>
</tr>
<tr>
<td>4</td>
<td>H</td>
</tr>
<tr>
<td>5</td>
<td>H</td>
</tr>
<tr>
<td>6</td>
<td>H</td>
</tr>
<tr>
<td>7</td>
<td>H</td>
</tr>
<tr>
<td>8</td>
<td>L</td>
</tr>
<tr>
<td>9</td>
<td>L</td>
</tr>
</tbody>
</table>

Output Q_A is connected to input B for BCD count.

Bi-Quinary (5-2)
(Each Counter) (Note 2)

<table>
<thead>
<tr>
<th>Count</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>L</td>
</tr>
<tr>
<td>1</td>
<td>L</td>
</tr>
<tr>
<td>2</td>
<td>L</td>
</tr>
<tr>
<td>3</td>
<td>L</td>
</tr>
<tr>
<td>4</td>
<td>H</td>
</tr>
<tr>
<td>5</td>
<td>H</td>
</tr>
<tr>
<td>6</td>
<td>H</td>
</tr>
<tr>
<td>7</td>
<td>H</td>
</tr>
<tr>
<td>8</td>
<td>L</td>
</tr>
<tr>
<td>9</td>
<td>L</td>
</tr>
</tbody>
</table>

Output Q_A is connected to input A for Bi-Quinary count.

Logic Diagram

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### Absolute Maximum Ratings (Note 3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Nom</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>7V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Voltage</td>
<td></td>
<td></td>
<td>7V</td>
<td></td>
</tr>
<tr>
<td>Clear</td>
<td></td>
<td>5.5V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A or B</td>
<td></td>
<td></td>
<td>5.5V</td>
<td></td>
</tr>
<tr>
<td>Operating Free Air Temperature</td>
<td>0°C</td>
<td></td>
<td>+70°C</td>
<td></td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>−65°C</td>
<td></td>
<td>+150°C</td>
<td></td>
</tr>
</tbody>
</table>

Note 3: The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the Electrical Characteristics tables are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.

### Recommended Operating Conditions

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min</th>
<th>Nom</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CC}$</td>
<td>Supply Voltage</td>
<td>4.75</td>
<td>5</td>
<td>5.25</td>
<td>V</td>
</tr>
<tr>
<td>$V_{IH}$</td>
<td>HIGH Level Input Voltage</td>
<td>2</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_{IL}$</td>
<td>LOW Level Input Voltage</td>
<td>0.3</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$I_{OH}$</td>
<td>HIGH Level Output Current</td>
<td>−0.4</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$I_{OL}$</td>
<td>LOW Level Output Current</td>
<td>8</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$f_{CLK}$</td>
<td>Clock Frequency (Note 4)</td>
<td></td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td>A to QA</td>
<td>0</td>
<td>25</td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td>B to QB</td>
<td>0</td>
<td>20</td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>$f_{CLK}$</td>
<td>Clock Frequency (Note 5)</td>
<td></td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td>A to QA</td>
<td>0</td>
<td>20</td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td>B to QB</td>
<td>0</td>
<td>15</td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>$t_{W}$</td>
<td>Pulse Width (Note 4)</td>
<td></td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>20</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>25</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>Clear HIGH</td>
<td>20</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$t_{RCL}$</td>
<td>Clear Release Time (Note 6) (Note 7)</td>
<td>254</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$T_A$</td>
<td>Free Air Operating Temperature</td>
<td>0</td>
<td>70</td>
<td></td>
<td>°C</td>
</tr>
</tbody>
</table>

Note 4: $C_L = 100 \, \mu F, R_L = 2 \, \Omega, T_A = 25°C$ and $V_{CC} = 6\, \text{V}$.  
Note 5: $C_L = 15 \, \mu F, R_L = 2 \, \Omega, T_A = 25°C$ and $V_{CC} = 6\, \text{V}$.  
Note 6: The symbol (4) indicates the falling edge of the clear pulse is used for reference.  
Note 7: $T_A = 25°C$ and $V_{CC} = 6\, \text{V}$.

### Electrical Characteristics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min</th>
<th>Typ (Note 6)</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_I$</td>
<td>Input Clamp Voltage $V_{CC} = \text{Min}, I_{in} &lt; 18 , \text{mA}$</td>
<td></td>
<td>−1.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_{OH}$</td>
<td>HIGH Level output voltage $V_{CC} = \text{Min}, I_{OH} = \text{Max}$</td>
<td></td>
<td>2.7</td>
<td>3.4</td>
<td>V</td>
</tr>
<tr>
<td>$V_{OL}$</td>
<td>LOW Level output voltage $V_{CC} = \text{Min}, I_{OL} = \text{Max}$</td>
<td></td>
<td>0.35</td>
<td>0.5</td>
<td>V</td>
</tr>
<tr>
<td>$I_{OH}$</td>
<td>HIGH Level Input Current $V_{CC} = \text{Max}, I_{OH} = \text{Max}$</td>
<td></td>
<td>0.25</td>
<td>0.4</td>
<td>mA</td>
</tr>
<tr>
<td>$I_{OL}$</td>
<td>LOW Level Input Current $V_{CC} = \text{Max}, I_{OL} = \text{Max}$</td>
<td></td>
<td>0.25</td>
<td>0.4</td>
<td>mA</td>
</tr>
<tr>
<td>$I_{OH}$</td>
<td>HIGH Level Input Current $V_{CC} = \text{Max}, I_{OH} = 2.7 , \text{mA}$</td>
<td></td>
<td>0.16</td>
<td>0.4</td>
<td>mA</td>
</tr>
<tr>
<td>$I_{OL}$</td>
<td>LOW Level Input Current $V_{CC} = \text{Max}, I_{OL} = 0.4 , \text{mA}$</td>
<td></td>
<td>0.16</td>
<td>0.4</td>
<td>mA</td>
</tr>
<tr>
<td>$I_{CC}$</td>
<td>Short Circuit Output Current $V_{CC} = \text{Max}$ (Note 9)</td>
<td></td>
<td>−0.4</td>
<td>−0.4</td>
<td>mA</td>
</tr>
<tr>
<td>$I_{CC}$</td>
<td>Supply Current $V_{CC} = \text{Max}$ (Note 10)</td>
<td></td>
<td>−100</td>
<td>−100</td>
<td>mA</td>
</tr>
</tbody>
</table>

Note 6: All typicals are at $V_{CC} = 6\, \text{V}, T_A = 25°C$.  
Note 8: Not more than one output should be shorted at a time, and the duration should not exceed one second.  
Note 9: $I_{OH}$ is measured with all outputs OPEN, both CLEAR inputs grounded following momentary connection to 4.5 and all other inputs grounded.
### Switching Characteristics

at $V_{CC} = 5\,V$ and $T_A = 25^\circ C$

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>From (Input) To (Output)</th>
<th>$R_L = 2,k\Omega$</th>
<th>$C_L = 15,\mu F$</th>
<th>$C_L = 10,\mu F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{MAX}$</td>
<td>Maximum Clock Frequency</td>
<td>A to Q_A B to Q_B</td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>$t_{PLH}$</td>
<td>Propagation Delay Time LOW-to-HIGH Level Output</td>
<td>A to Q_A</td>
<td>20</td>
<td>24</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{PHL}$</td>
<td>Propagation Delay Time HIGH-to-LOW Level Output</td>
<td>A to Q_A</td>
<td>20</td>
<td>30</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{PLH}$</td>
<td>Propagation Delay Time LOW-to-HIGH Level Output</td>
<td>A to Q_C</td>
<td>60</td>
<td>61</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{PHL}$</td>
<td>Propagation Delay Time HIGH-to-LOW Level Output</td>
<td>A to Q_C</td>
<td>60</td>
<td>81</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{PLH}$</td>
<td>Propagation Delay Time LOW-to-HIGH Level Output</td>
<td>B to Q_A</td>
<td>21</td>
<td>27</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{PHL}$</td>
<td>Propagation Delay Time HIGH-to-LOW Level Output</td>
<td>B to Q_A</td>
<td>21</td>
<td>33</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{PLH}$</td>
<td>Propagation Delay Time LOW-to-HIGH Level Output</td>
<td>B to Q_C</td>
<td>39</td>
<td>51</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{PHL}$</td>
<td>Propagation Delay Time HIGH-to-LOW Level Output</td>
<td>B to Q_C</td>
<td>39</td>
<td>54</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{PLH}$</td>
<td>Propagation Delay Time LOW-to-HIGH Level Output</td>
<td>B to Q_D</td>
<td>21</td>
<td>27</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{PHL}$</td>
<td>Propagation Delay Time HIGH-to-LOW Level Output</td>
<td>B to Q_D</td>
<td>21</td>
<td>33</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{PLH}$</td>
<td>Propagation Delay Time HIGH-to-LOW Level Output</td>
<td>Clear to Any</td>
<td>39</td>
<td>45</td>
<td>ns</td>
</tr>
</tbody>
</table>
Physical Dimensions inches (millimeters) unless otherwise noted

16-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150 Narrow
Package Number M16A
16-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide
Package Number N16E

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Datasheet IC LM 358

**LM158/LM258/LM358/LM2904**

**Low Power Dual Operational Amplifiers**

**General Description**

The LM158 series consists of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Applications include transducer amplifiers, dc gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM158 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V power supplies.

The LM158 and LM2904 are available in a chip sized package (8-Bump micro SMD) using National’s micro SMD package technology.

**Unique Characteristics**

- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage.
- The unity gain crossover frequency is temperature compensated.
- The input bias current is also temperature compensated.

**Advantages**

- Two internally compensated op amps
- Eliminates need for dual supplies
- Allows direct sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

**Features**

- Available in 8-Bump micro SMD chip sized package, (See AN-1112)
- Internally frequency compensated for unity gain
- Large dc voltage gain: 100 dB
- Wide bandwidth (unity gain): 1 MHz (temperature compensated)
- Wide power supply range:
  - Single supply: ±3V to ±32V
  - Dual supplies: ±1.5V to ±16V
- Very low supply current drain (500 µA) — essentially independent of supply voltage
- Low input offset voltage: ±2 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing

**Voltage Controlled Oscillator (VCO)**

![Diagram of Voltage Controlled Oscillator (VCO)](image_url)
Absolute Maximum Ratings (Note 9)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office.

Distributors for availability and specifications.

<table>
<thead>
<tr>
<th>LM158A/LM258A/LM358</th>
<th>LM2904</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage, V−</td>
<td>32V</td>
</tr>
<tr>
<td>Differential Input Voltage</td>
<td>32V</td>
</tr>
<tr>
<td>Input Voltage</td>
<td>−0.3V to +32V</td>
</tr>
<tr>
<td>Power Dissipation (Note 1)</td>
<td>650 mW</td>
</tr>
<tr>
<td>Molded DIP</td>
<td>550 mW</td>
</tr>
<tr>
<td>Metal Can</td>
<td>550 mW</td>
</tr>
<tr>
<td>Small Outline Package (M)</td>
<td>435 mW</td>
</tr>
<tr>
<td>micro SMD</td>
<td></td>
</tr>
<tr>
<td>Output Short-Circuit to GND</td>
<td></td>
</tr>
<tr>
<td>(One Amplifier) (Note 2)</td>
<td></td>
</tr>
<tr>
<td>V+ ≤ 15V and T.A = 25°C</td>
<td>Continuous</td>
</tr>
<tr>
<td>Input Current (</td>
<td>V</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td></td>
</tr>
<tr>
<td>LM158A</td>
<td>0°C to +70°C</td>
</tr>
<tr>
<td>LM258A</td>
<td>−25°C to +85°C</td>
</tr>
<tr>
<td>LM158B</td>
<td>−55°C to +125°C</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>−65°C to +150°C</td>
</tr>
<tr>
<td>Lead Temperature, DIP (Soldering, 10 seconds)</td>
<td>260°C</td>
</tr>
<tr>
<td>Lead Temperature, Metal Can (Soldering, 10 seconds)</td>
<td>300°C</td>
</tr>
<tr>
<td>Soldering Information</td>
<td></td>
</tr>
<tr>
<td>Dual-In-Line Package</td>
<td></td>
</tr>
<tr>
<td>Soldering (10 seconds)</td>
<td>260°C</td>
</tr>
<tr>
<td>Small Outline Package</td>
<td></td>
</tr>
<tr>
<td>Vapor Phase (60 seconds)</td>
<td>215°C</td>
</tr>
<tr>
<td>Infrared (15 seconds)</td>
<td>220°C</td>
</tr>
<tr>
<td>See AN-450 “Surface Mounting Methods and Their Effect on Product Reliability” for other methods of soldering surface mount devices.</td>
<td></td>
</tr>
<tr>
<td>ESD Tolerance (Note 10)</td>
<td>250V</td>
</tr>
</tbody>
</table>

Electrical Characteristics

V+ = +5.0V, unless otherwise stated

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM158A</th>
<th>LM258A</th>
<th>LM158B/LM258B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
</tr>
<tr>
<td>Input Offset Voltage</td>
<td>(Note 9), T.A = 25°C</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>I&lt;sub&gt;IN&lt;/sub&gt; (or</td>
<td>I&lt;sub&gt;N&lt;/sub&gt;−)</td>
<td>T.A = 25°C,</td>
<td>V&lt;sub&gt;CM&lt;/sub&gt; = 0V, (Note 6)</td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>I&lt;sub&gt;N&lt;/sub&gt;−</td>
<td>I&lt;sub&gt;N&lt;/sub&gt;−</td>
<td>V&lt;sub&gt;CM&lt;/sub&gt; = 0V, T.A = 25°C</td>
<td>2</td>
</tr>
<tr>
<td>Input Common-Mode Voltage Range</td>
<td>V+ = 30V, (Note 7)</td>
<td>(LM358A, V+ = 26V), T.A = 25°C</td>
<td>0</td>
<td>V−−1.5</td>
</tr>
<tr>
<td>Supply Current</td>
<td>Over Full Temperature Range</td>
<td>R&lt;sub&gt;L&lt;/sub&gt; = ∞ on All Op Amps</td>
<td>V+ = 30V (LM2904 V+ = 26V)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>V+ = 5V</td>
<td>0.5</td>
<td>1.2</td>
<td>0.5</td>
</tr>
</tbody>
</table>

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### Electrical Characteristics

**V**^\text{+} = \pm 5.0\,\text{V}, unless otherwise stated

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM358</th>
<th>LM2904</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input Offset Voltage</strong></td>
<td>(Note 5), ( T_\text{A} = 25^\circ\text{C} )</td>
<td>2</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td><strong>Input Bias Current</strong></td>
<td>( I_{\text{IN}+} ) or ( I_{\text{IN}-} ), ( T_\text{A} = 25^\circ\text{C} ), ( V_{\text{CM}} = 0\text{V} ), (Note 6)</td>
<td>45</td>
<td>250</td>
<td>45</td>
</tr>
<tr>
<td><strong>Input Offset Current</strong></td>
<td>( I_{\text{IN}+} - I_{\text{IN}-} ), ( V_{\text{CM}} = 0\text{V}, T_\text{A} = 25^\circ\text{C} )</td>
<td>5</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td><strong>Input Common-Mode Voltage Range</strong></td>
<td>( V^\text{+} = 30\text{V}, ) (Note 7) ( (\text{LM2904}, \ V^\text{+} = 26\text{V}), T_\text{A} = 25^\circ\text{C} )</td>
<td>0</td>
<td>( V^\text{+} - 1.5 )</td>
<td>0</td>
</tr>
<tr>
<td><strong>Supply Current</strong></td>
<td>Over Full Temperature Range ( R_L = \infty ) on All Op Amps ( V^\text{+} = 30\text{V} ) (LM2904 ( V^\text{+} = 26\text{V} )) ( V^\text{+} = 5\text{V} )</td>
<td>1</td>
<td>2</td>
<td>0.5</td>
</tr>
</tbody>
</table>

### Electrical Characteristics

**V**^\text{+} = \pm 5.0\,\text{V}, (Note 4), unless otherwise stated

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM158A</th>
<th>LM358A</th>
<th>LM158A/LM258A</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Large Signal Voltage Gain</strong></td>
<td>( V^\text{+} = 15\text{V}, T_\text{A} = 25^\circ\text{C} ), ( R_L \geq 2 ,\text{k}\Omega ) (For ( V_\text{O} = 1\text{V} ) to ( 11\text{V} ))</td>
<td>50</td>
<td>100</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td><strong>Common-Mode Rejection Ratio</strong></td>
<td>( T_\text{A} = 25^\circ\text{C} ), ( V_{\text{CM}} = 0\text{V} ) to ( V^\text{+} - 1.5\text{V} )</td>
<td>70</td>
<td>85</td>
<td>70</td>
<td>85</td>
</tr>
<tr>
<td><strong>Power Supply Rejection Ratio</strong></td>
<td>( V^\text{+} = 5\text{V} ) to ( 30\text{V} ) ( (\text{LM2904}), V^\text{+} = 5\text{V} ) ( \text{to} 26\text{V}, T_\text{A} = 25^\circ\text{C} )</td>
<td>68</td>
<td>100</td>
<td>68</td>
<td>100</td>
</tr>
<tr>
<td><strong>Amplifier-to-Amplifier Coupling</strong></td>
<td>( f = 1\text{kHz} ) to ( 20\text{kHz}, T_\text{A} = 25^\circ\text{C} ) ( \text{(Input Referred)} ), (Note 8)</td>
<td>-120</td>
<td>-120</td>
<td>-120</td>
<td>-120</td>
</tr>
<tr>
<td><strong>Output Current</strong> Source</td>
<td>( V_{\text{IN}+} = 1\text{V}, V_{\text{IN}+} = 0\text{V}, V^\text{+} = 15\text{V}, V_\text{O} = 2\text{V}, T_\text{A} = 25^\circ\text{C} )</td>
<td>20</td>
<td>40</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td><strong>Sink</strong></td>
<td>( V_{\text{IN}+} = 1\text{V}, V_{\text{IN}+} = 0\text{V}, V^\text{+} = 15\text{V}, T_\text{A} = 25^\circ\text{C} ), ( V_\text{O} = 2\text{V} )</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td><strong>Short Circuit to Ground</strong></td>
<td>( T_\text{A} = 25^\circ\text{C}, ) (Note 2), ( V^\text{+} = 15\text{V} )</td>
<td>40</td>
<td>60</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td><strong>Input Offset Voltage</strong></td>
<td>(Note 5)</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>Input Offset Voltage Drift</strong></td>
<td>( R_\text{O} = 0\text{Q} )</td>
<td>7</td>
<td>15</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td><strong>Input Offset Current Drift</strong></td>
<td>( I_{\text{IN}+} - I_{\text{IN}-} )</td>
<td>30</td>
<td>75</td>
<td>100</td>
<td>nA</td>
</tr>
<tr>
<td><strong>Input Bias Current Drift</strong></td>
<td>( R_\text{O} = 0\text{Q} )</td>
<td>10</td>
<td>200</td>
<td>10</td>
<td>300</td>
</tr>
<tr>
<td><strong>Input Common-Mode Voltage Range</strong></td>
<td>( V^\text{+} = 30\text{V}, ) (Note 7) ( (\text{LM2904}), V^\text{+} = 26\text{V} )</td>
<td>0</td>
<td>( V^\text{+} - 2 )</td>
<td>0</td>
<td>( V^\text{+} - 2 )</td>
</tr>
</tbody>
</table>
### Electrical Characteristics (Continued)

V^+ = ±5.0 V, (Note 4), unless otherwise stated.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM158A</th>
<th>LM358A</th>
<th>LM158/LM258A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larga Signal Voltage Gain</td>
<td>V^+ = ±15V, ( V_O = 1V ) to ( 11V ), ( R_L \geq 2 , \Omega )</td>
<td>26</td>
<td>16</td>
<td>26</td>
</tr>
<tr>
<td>Output Voltage Swing</td>
<td>V_{CM}^+ = ±30V \quad (LM2904, V^+ = 28V) \quad R_L = 10 , \Omega</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Output Current Source</td>
<td>V_{IN}^+ = ±1V, ( V_{IN}^- = 0V ), ( V^+ = ±15V, V_O = -2V )</td>
<td>10</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>V_{IN}^+ = ±1V, ( V_{IN}^- = 0V ), ( V^+ = ±15V, V_O = +2V )</td>
<td>10</td>
<td>15</td>
<td>5</td>
</tr>
</tbody>
</table>

### Electrical Characteristics

V^+ = ±5.0 V, (Note 4), unless otherwise stated.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM358A</th>
<th>LM2904A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larga Signal Voltage Gain</td>
<td>V^+ = ±15V, ( T_A = 25^\circ C ), ( R_L \geq 2 , \Omega ), (\text{For } V_O = 1V \text{ to } 11V)</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Common-Mode Rejection Ratio</td>
<td>( V_{CM}^+ = 25V ), ( V_{CM}^- = 0V \text{ to } V^+ = 15V )</td>
<td>65</td>
<td>85</td>
</tr>
<tr>
<td>Power Supply Rejection Ratio</td>
<td>( V^+ = ±5V \text{ to } ±30V ), ( T_A = 25C ) \quad (\text{LM2904, } V^+ = 28V)</td>
<td>65</td>
<td>100</td>
</tr>
<tr>
<td>Amplifier-to-Amplifier Coupling</td>
<td>( f = 1 , kHz \text{ to } 20 , kHz, \quad T_A = 25^\circ C ), (Input Referred), (Note 6)</td>
<td>-120</td>
<td>-120</td>
</tr>
<tr>
<td>Output Current Source</td>
<td>V_{IN}^+ = ±1V, ( V_{IN}^- = 0V ), ( V^+ = ±15V, V_O = 2V ), ( T_A = 25^\circ C )</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>V_{IN}^+ = ±1V, ( V_{IN}^- = 0V ), ( V^+ = ±15V, V_O = 2V ), ( T_A = 25^\circ C )</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>( V_{IN}^+ = ±1V, V_{IN}^- = 0V ), ( V_{CM}^- = 0V \text{ to } V^+ = ±15V )</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>Short Circuit to Ground</td>
<td>( T_A = 25^\circ C ), (Note 2), ( V^+ = ±15V )</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Input Offset Voltage</td>
<td>(Note 5) \quad R_B = 0 , \Omega</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Input Offset Voltage Drift</td>
<td>( R_B = 0 , \Omega )</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>( I_{IN}^+ - I_{IN}^- )</td>
<td>150</td>
<td>45</td>
</tr>
<tr>
<td>Input Offset Current Drift</td>
<td>( R_B = 0 , \Omega )</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>( I_{IN}^+ ) or ( I_{IN}^- )</td>
<td>40</td>
<td>500</td>
</tr>
<tr>
<td>Input Common-Mode Voltage Range</td>
<td>( V^+ = ±30V ), (Note 7) \quad (\text{LM2904, } V^+ = 28V)</td>
<td>0</td>
<td>V^+ = 2</td>
</tr>
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</table>
## Electrical Characteristics (Continued)

V<sub>n</sub> = +5.0V, (Note 4), unless otherwise stated

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM358 Min</th>
<th>LM358 Typ</th>
<th>LM358 Max</th>
<th>LM2904 Min</th>
<th>LM2904 Typ</th>
<th>LM2904 Max</th>
<th>Units</th>
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<tbody>
<tr>
<td>Large Signal Voltage</td>
<td>Gain</td>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V/mV</td>
</tr>
<tr>
<td></td>
<td>(V&lt;sub&gt;g&lt;/sub&gt; = 1V to 1V)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R&lt;sub&gt;i&lt;/sub&gt; ≥ 2 kΩ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Voltage Swing</td>
<td>V&lt;sub&gt;OH&lt;/sub&gt;</td>
<td>28</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>(LM2904, V&lt;sub&gt;n&lt;/sub&gt; = 26V)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R&lt;sub&gt;L&lt;/sub&gt; = 2 kΩ</td>
<td>27</td>
<td>28</td>
<td>23</td>
<td>24</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>R&lt;sub&gt;L&lt;/sub&gt; = 10 kΩ</td>
<td>5</td>
<td>20</td>
<td>5</td>
<td>100</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Output Current Source</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;&lt;sup&gt;+&lt;/sup&gt; = +1V, V&lt;sub&gt;IN&lt;/sub&gt;&lt;sup&gt;-&lt;/sup&gt; = 0V, V&lt;sub&gt;n&lt;/sub&gt; = 15V, V&lt;sub&gt;O&lt;/sub&gt;&lt;sup&gt;+&lt;/sup&gt; = 2V</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;&lt;sup&gt;+&lt;/sup&gt; = +1V, V&lt;sub&gt;IN&lt;/sub&gt;&lt;sup&gt;-&lt;/sup&gt; = 0V, V&lt;sub&gt;n&lt;/sub&gt; = 15V, V&lt;sub&gt;O&lt;/sub&gt;&lt;sup&gt;-&lt;/sup&gt; = 2V</td>
<td>5</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
</tbody>
</table>

Note 1: For operating at high temperatures, the LM358/LM358A/LM358D must be derated based on a +125°C maximum junction temperature and a thermal resistance of 127°C/W for MSOP, 162°C/W for Metal Can, 185°C/W for Small Outline package and 230°C/W for Mini SMD, which applies for the device soldered in a printed circuit board, operating in still air embitters. The LM5531/LM5530A and LM150/LM156A can be derated based on a +150°C maximum junction temperature. The diode is the total of both amplifiers — use external resistors, where possible, to allow the amplifier to operate or to reduce the power which is dissipated in the integrated circuit.

Note 2: Short circuits from the output to V<sub>n</sub> can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V<sub>n</sub>. At values of supply voltage in the range of +15V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

Note 3: This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as an input diode. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the op-amps to go to the V<sub>n</sub>-voltage level (or higher) for large input signals for the time duration that one input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than +0.3V (at 25°C).

Note 4: These specifications are limited to -55°C ≤ T<sub>A</sub> ≤ +125°C for the LM358/LM358A. With the LM358/LM358A, all temperature specifications are limited to -25°C ≤ T<sub>A</sub> ≤ +85°C. For the LM358/LM358A temperature specifications are limited to -55°C ≤ T<sub>A</sub> ≤ +125°C. With the LM2904 temperature specifications are limited to -40°C ≤ T<sub>A</sub> ≤ +85°C.

Note 5: V<sub>g</sub> = 1.4V, R<sub>g</sub> = 0Ω with V<sub>n</sub> = 5V to 30V, and over the full input common-mode range (0V to V<sub>n</sub> - 1.5V) at 25°C. For LM2904, V<sub>n</sub> = 5V to 30V.

Note 6: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.

Note 7: The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.6V (at 25°C). The upper end of the common-mode voltage range is V<sub>n</sub> - 1.5V (at 25°C), but either or both inputs can go to +5V without damage (-2.6V for LM358A), independent of the magnitude of V<sub>n</sub>.

Note 8: Due to proximity of external components, it is assumed that coupling is not originating via stray capacitances between these external parts. This typically can be determined by type of capacitance increase at higher frequencies.

Note 9: Refer to FET358/56/56A for LM358A military specifications and to FET358/56/56X for LM56 military specifications.

Note 10: Human body model, 1.5 kΩ in series with 100 pF.
Typical Performance Characteristics (Continued)

Voltage Follower Pulse Response

Voltage Follower Pulse Response (Small Signal)

Large Signal Frequency Response

Output Characteristics Current Sourcing

Output Characteristics Current Sinking

Current Limiting
Application Hints

The LM158 series are op amps which operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of 0 V_{DC}. These amplifiers operate over a wide range of power supply voltages with little change in performance characteristics. At 25°C amplifier operation is possible down to a minimum supply voltage of 2.3 V_{DC}.

Precautions should be taken to ensure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test setup as an unlimited current surge through the resulting forward diode within the IC could cause burning of the internal conductors and result in a destroyed unit.

Large differential input voltages can be easily accommodated and, as input differential input voltage protection diodes are not needed, no large input current result from large differential input voltages. The differential input voltage may be larger than V_{P} without damaging the device. Protection should be provided to prevent the input voltages from going negative more than 0.3 V_{DC} (at 25°C). An input clamp diode with a resistor to the IC input terminal can be used.

To reduce the power supply current drain, the amplifier has a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifier to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifier. The output voltage needs to raise approximately 1 dV below ground to bias the on-chip vertical PNP transistor for output current sinking applications.

For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground, to increase the class A bias current and prevent crossover distortion. Where the load is directly coupled, as in dc applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of 50 pF can be accommodated using the worst-case non-inverting unity gain configuration. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.

The bias network of the LM158 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of 3 V_{DC} to 30 V_{DC}. Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing thermal damage, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output loads of the amplifiers. The larger value of output source current which is available at 25°C provides a larger output current capability at elevated temperatures (see typical performance characteristics) than a standard IC op amp.

The circuits presented in this section on typical applications emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (bias voltage reference of V_{P}) will allow operation above and below the bias voltage in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.
## Ordering Information

<table>
<thead>
<tr>
<th>Package</th>
<th>Temperature Range</th>
<th>NSC Drawing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-55°C to 125°C</td>
<td>LM204M</td>
</tr>
<tr>
<td>SC-8</td>
<td>-25°C to 85°C</td>
<td>LM2904MX</td>
</tr>
<tr>
<td>8-Pin Molded DIP</td>
<td>0°C to 70°C</td>
<td>LM358AM</td>
</tr>
<tr>
<td>8-Pin Ceramic DIP</td>
<td>-40°C to 85°C</td>
<td>LM358AN</td>
</tr>
<tr>
<td>TO-5, 8-Pin Metal Can</td>
<td></td>
<td>LM358N</td>
</tr>
<tr>
<td>9-Bump micro SMD</td>
<td></td>
<td>LM258H</td>
</tr>
<tr>
<td>9-Bump micro SMD Lead Free</td>
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<td>LM358H</td>
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<tr>
<td>14-Pin Ceramic SOIC</td>
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<td>LM358H</td>
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</tbody>
</table>

Note 11: LM150 is available per SMD #562-6771001
LM150A is available per SMD #562-6771002
Note 12: See STD NM DWG E626257710 for Radiation Tolerant Devices

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