## LM358, LM258, LM2904, LM2904V

## Dual Differential Input, Low Power Operational Amplifiers

Utilizing the circuit designs perfected for recently introduced Quad Operational Amplifiers, these dual operational amplifiers feature low power drain, a common mode input voltage range extending to ground/ $\mathrm{V}_{\mathrm{EE}}$, single supply or split supply operation and pinouts compatible with the popular MC1558 dual operational amplifier. The LM358 series is equivalent to one-half of an LM324.

These amplifiers have several distinct advantages over standard operational amplifier types in single supply applications. They can operate at supply voltages as low as 3.0 V or as high as 32 V , with quiescent currents about one-fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

- Short Circuit Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V (LM258/LM358) 3.0 V to 26 V (LM2904, V)
- Low Input Bias Currents
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Single and Split Supply Operation
- Similar Performance to the Popular MC1558
- ESD Clamps on the Inputs Increase Ruggedness of the Device without Affecting Operation

ON Semiconductor ${ }^{\text {T }}$
http://onsemi.com


ORDERING INFORMATION
See detailed ordering and shipping information in the package dimensions section on page 9 of this data sheet.

## DEVICE MARKING INFORMATION

See general marking information in the device marking section on page 10 of this data sheet.

## LM358, LM258, LM2904, LM2904V




Split Supplies

Figure 1.


Figure 2. Representative Schematic Diagram
(One-Half of Circuit Shown)

MAXIMUM RATINGS $\left(\mathrm{T}_{\mathrm{A}}=+25^{\circ} \mathrm{C}\right.$, unless otherwise noted.)

| Rating | Symbol | $\begin{aligned} & \text { LM258 } \\ & \text { LM358 } \end{aligned}$ | $\begin{aligned} & \text { LM2904 } \\ & \text { LM2904V } \end{aligned}$ | Unit |
| :---: | :---: | :---: | :---: | :---: |
| Power Supply Voltages Single Supply Split Supplies | $\begin{gathered} \mathrm{v}_{\mathrm{CC}} \\ \mathrm{v}_{\mathrm{CC}}, \mathrm{v}_{\mathrm{EE}} \end{gathered}$ | $\begin{gathered} 32 \\ \pm 16 \end{gathered}$ | $\begin{gathered} 26 \\ \pm 13 \end{gathered}$ | Vdc |
| Input Differential Voltage Range (Note 1.) | $\mathrm{V}_{\text {IDR }}$ | $\pm 32$ | $\pm 26$ | Vdc |
| Input Common Mode Voltage Range (Note 2.) | $V_{\text {ICR }}$ | -0.3 to 32 | -0.3 to 26 | Vdc |
| Output Short Circuit Duration | tsc | Continuous |  |  |
| Junction Temperature | $\mathrm{T}_{\mathrm{J}}$ | 150 |  | ${ }^{\circ} \mathrm{C}$ |
| Storage Temperature Range | $\mathrm{T}_{\text {stg }}$ | -55 to +125 |  | ${ }^{\circ} \mathrm{C}$ |
| Operating Ambient Temperature Range LM258 LM358 LM2904/LM2904A LM2904V | $\mathrm{T}_{\text {A }}$ | $\begin{gathered} -25 \text { to }+85 \\ 0 \text { to }+70 \\ - \\ - \end{gathered}$ | $\begin{gathered} - \\ - \\ -40 \text { to }+105 \\ -40 \text { to }+125 \end{gathered}$ | ${ }^{\circ} \mathrm{C}$ |

1. Split Power Supplies.
2. For Supply Voltages less than 32 V for the LM258/358 and 26 V for the LM2904, the absolute maximum input voltage is equal to the supply voltage.

ELECTRICAL CHARACTERISTICS $\left(\mathrm{V}_{\mathrm{CC}}=5.0 \mathrm{~V}, \mathrm{~V}_{\mathrm{EE}}=\mathrm{Gnd}, \mathrm{T}_{\mathrm{A}}=25^{\circ} \mathrm{C}\right.$, unless otherwise noted.)

| Characteristic | Symbol | LM258 |  |  | LM358 |  |  | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Min | Typ | Max | Min | Typ | Max |  |
| Input Offset Voltage $\begin{aligned} & \mathrm{V}_{C C}=5.0 \mathrm{~V} \text { to } 30 \mathrm{~V}(26 \mathrm{~V} \text { for LM2904, } \mathrm{V}), \\ & \mathrm{V}_{\text {IC }}=0 \mathrm{~V} \text { to } \mathrm{V}_{\mathrm{CC}}-1.7 \mathrm{~V}, \mathrm{~V}_{\mathrm{O}}=1.4 \mathrm{~V}, R_{S}=0 \Omega \\ & \mathrm{~T}_{\mathrm{A}}=25^{\circ} \mathrm{C} \\ & \mathrm{~T}_{\mathrm{A}}=\mathrm{T}_{\text {high }}(\text { Note 1. }) \\ & \mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {low }}(\text { Note 1. }) \end{aligned}$ | $\mathrm{V}_{10}$ | - | $2.0$ | $\begin{aligned} & 5.0 \\ & 7.0 \\ & 2.0 \\ & \hline \end{aligned}$ | - | 2.0 - | $\begin{aligned} & 7.0 \\ & 9.0 \\ & 9.0 \\ & \hline \end{aligned}$ | mV |
| Average Temperature Coefficient of Input Offset Voltage $T_{A}=T_{\text {high }} \text { to } T_{\text {low }} \text { (Note 1.) }$ | $\Delta \mathrm{V}_{10} / \Delta \mathrm{T}$ | - | 7.0 | - | - | 7.0 | - | $\mu \mathrm{V} /{ }^{\circ} \mathrm{C}$ |
| Input Offset Current $\mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { to } \mathrm{T}_{\text {low }} \text { (Note 1.) }$ <br> Input Bias Current $T_{A}=T_{\text {high }} \text { to } T_{\text {low }} \text { (Note 1.) }$ | 10 $I_{\mathrm{IB}}$ |  | $\begin{gathered} 3.0 \\ - \\ -45 \\ -50 \end{gathered}$ | $\begin{gathered} 30 \\ 100 \\ -150 \\ -300 \end{gathered}$ | - | $\begin{gathered} 5.0 \\ - \\ -45 \\ -50 \end{gathered}$ | $\begin{gathered} 50 \\ 150 \\ -250 \\ -500 \end{gathered}$ | nA |
| Average Temperature Coefficient of Input Offset Current $T_{A}=T_{\text {high }}$ to $T_{\text {low }}$ (Note 1.) | $\Delta l_{10} / \Delta T$ | - | 10 | - | - | 10 | - | $\mathrm{pA} /{ }^{\circ} \mathrm{C}$ |
| ```Input Common Mode Voltage Range (Note 2.), , VCC = 30 V (26 V for LM2904, V) VCC}=30\textrm{V (26 V for LM2904, V), TA}=\mp@subsup{T}{\mathrm{ high to }}{\mathrm{ tow}``` | VICR | 0 <br> 0 |  | $\begin{gathered} 28.3 \\ 28 \end{gathered}$ | 0 0 |  | $\begin{gathered} 28.3 \\ 28 \end{gathered}$ | V |
| Differential Input Voltage Range | $V_{\text {IDR }}$ | - | - | $\mathrm{V}_{\mathrm{CC}}$ | - | - | $\mathrm{V}_{\mathrm{CC}}$ | V |
| Large Signal Open Loop Voltage Gain $\begin{aligned} & \mathrm{R}_{\mathrm{L}}=2.0 \mathrm{k} \Omega, \mathrm{~V}_{\mathrm{CC}}=15 \mathrm{~V}, \text { For Large } \mathrm{V}_{\mathrm{O}} \text { Swing, } \\ & \mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { to } \mathrm{T}_{\text {low }} \text { (Note 1.) } \end{aligned}$ | Avol | $\begin{aligned} & 50 \\ & 25 \end{aligned}$ | $100$ | - | $\begin{aligned} & 25 \\ & 15 \end{aligned}$ | $100$ | $\begin{aligned} & - \\ & - \end{aligned}$ | V/mV |
| Channel Separation <br> $1.0 \mathrm{kHz} \leq \mathrm{f} \leq 20 \mathrm{kHz}$, Input Referenced | CS | - | -120 | - | - | -120 | - | dB |
| Common Mode Rejection $\mathrm{R}_{\mathrm{S}} \leq 10 \mathrm{k} \Omega$ | CMR | 70 | 85 | - | 65 | 70 | - | dB |
| Power Supply Rejection | PSR | 65 | 100 | - | 65 | 100 | - | dB |
| $\begin{aligned} & \text { Output Voltage-High Limit } \\ & \mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { to } \mathrm{T}_{\text {Iow }}(\text { Note } 1 .) \\ & \mathrm{V}_{\mathrm{CC}}=5.0 \mathrm{~V}, \mathrm{R}_{\mathrm{L}}=2.0 \mathrm{k} \Omega, \mathrm{~T}_{\mathrm{A}}=25^{\circ} \mathrm{C} \\ & \mathrm{~V}_{\mathrm{CC}}=30 \mathrm{~V}(26 \mathrm{~V} \text { for } \mathrm{LM} 2904, \mathrm{~V}), \mathrm{R}_{\mathrm{L}}=2.0 \mathrm{k} \Omega \\ & \mathrm{~V}_{\mathrm{CC}}=30 \mathrm{~V}(26 \mathrm{~V} \text { for } \mathrm{LM} 2904, \mathrm{~V}), \mathrm{R}_{\mathrm{L}}=10 \mathrm{k} \Omega \end{aligned}$ | $\mathrm{V}_{\mathrm{OH}}$ | $\begin{aligned} & 3.3 \\ & 26 \\ & 27 \end{aligned}$ | $\begin{gathered} 3.5 \\ - \\ 28 \end{gathered}$ | - | $\begin{aligned} & 3.3 \\ & 26 \\ & 27 \end{aligned}$ | $\begin{gathered} 3.5 \\ - \\ 28 \end{gathered}$ | - | V |
| Output Voltage-Low Limit $\begin{gathered} \mathrm{V}_{\mathrm{CC}}=5.0 \mathrm{~V}, \mathrm{R}_{\mathrm{L}}=10 \mathrm{k} \Omega, \\ \mathrm{~T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { to } \mathrm{T}_{\text {low }} \text { (Note 1.) } \end{gathered}$ | $\mathrm{V}_{\mathrm{OL}}$ | - | 5.0 | 20 | - | 5.0 | 20 | mV |
| Output Source Current $\mathrm{V}_{\mathrm{ID}}=+1.0 \mathrm{~V}, \mathrm{~V}_{\mathrm{CC}}=15 \mathrm{~V}$ | $\mathrm{l}+$ | 20 | 40 | - | 20 | 40 | - | mA |
| Output Sink Current $\begin{aligned} & \mathrm{V}_{I D}=-1.0 \mathrm{~V}, \mathrm{~V}_{\mathrm{CC}}=15 \mathrm{~V} \\ & \mathrm{~V}_{\mathrm{ID}}=-1.0 \mathrm{~V}, \mathrm{~V}_{\mathrm{O}}=200 \mathrm{mV} \end{aligned}$ | $10-$ | $\begin{aligned} & 10 \\ & 12 \end{aligned}$ | $\begin{aligned} & 20 \\ & 50 \end{aligned}$ | - | $\begin{aligned} & 10 \\ & 12 \end{aligned}$ | $\begin{aligned} & 20 \\ & 50 \end{aligned}$ | $-$ | $\begin{aligned} & \mathrm{mA} \\ & \mu \mathrm{~A} \end{aligned}$ |
| Output Short Circuit to Ground (Note 3.) | $\mathrm{I}_{\text {SC }}$ | - | 40 | 60 | - | 40 | 60 | mA |
| $\begin{aligned} & \text { Power Supply Current } \\ & \mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { to } \mathrm{T}_{\text {low }} \text { (Note 1.) } \\ & \mathrm{V}_{\mathrm{CC}}=30 \mathrm{~V}(26 \mathrm{~V} \text { for } \mathrm{LM} 2904, \mathrm{~V}), \mathrm{V}_{\mathrm{O}}=0 \mathrm{~V}, \mathrm{R}_{\mathrm{L}}=\infty \\ & \mathrm{V}_{\mathrm{CC}}=5 \mathrm{~V}, \mathrm{~V}_{\mathrm{O}}=0 \mathrm{~V}, \mathrm{R}_{\mathrm{L}}=\infty \end{aligned}$ | $I_{C C}$ | - | $\begin{aligned} & 1.5 \\ & 0.7 \end{aligned}$ | $\begin{aligned} & 3.0 \\ & 1.2 \end{aligned}$ | - | $\begin{aligned} & 1.5 \\ & 0.7 \end{aligned}$ | $\begin{aligned} & 3.0 \\ & 1.2 \end{aligned}$ | mA |

1. $\mathrm{LM} 258: \mathrm{T}_{\text {low }}=-25^{\circ} \mathrm{C}, \mathrm{T}_{\text {high }}=+85^{\circ} \mathrm{C}$

LM358: $\mathrm{T}_{\text {low }}=0^{\circ} \mathrm{C}, \mathrm{T}_{\text {high }}=+70^{\circ} \mathrm{C}$
LM2904/LM2904A: $\mathrm{T}_{\text {low }}=-40^{\circ} \mathrm{C}, \mathrm{T}_{\text {high }}=+105^{\circ} \mathrm{C}$
LM2904V: $\mathrm{T}_{\text {low }}=-40^{\circ} \mathrm{C}, \mathrm{T}_{\text {high }}=+125^{\circ} \mathrm{C}$
2. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V . The upper end of the common mode voltage range is $\mathrm{V}_{\mathrm{CC}}-1.7 \mathrm{~V}$.
3. Short circuits from the output to $\mathrm{V}_{\mathrm{CC}}$ can cause excessive heating and eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

ELECTRICAL CHARACTERISTICS $\left(\mathrm{V}_{\mathrm{CC}}=5.0 \mathrm{~V}, \mathrm{~V}_{\mathrm{EE}}=\mathrm{Gnd}, \mathrm{T}_{\mathrm{A}}=25^{\circ} \mathrm{C}\right.$, unless otherwise noted. $)$

| Characteristic | Symbol | LM2904 |  |  | LM2904A |  |  | LM2904V |  |  | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max |  |
| $\begin{aligned} & \text { Input Offset Voltage } \\ & \mathrm{V}_{\mathrm{CC}}=5.0 \mathrm{~V} \text { to } 30 \mathrm{~V}(26 \mathrm{~V} \text { for } \mathrm{LM} 2904, \mathrm{~V}) \text {, } \\ & \mathrm{V}_{\mathrm{IC}}=0 \mathrm{~V} \text { to } \mathrm{V} \mathrm{CC}-1.7 \mathrm{~V}, \mathrm{~V}_{\mathrm{O}} \simeq 1.4 \mathrm{~V}, \mathrm{R}_{\mathrm{S}}=0 \Omega \\ & \mathrm{~T}_{\mathrm{A}}=25^{\circ} \mathrm{C} \\ & \mathrm{~T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { (Note 4.) } \\ & \mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {low }} \text { (Note 4.) } \end{aligned}$ | $\mathrm{V}_{10}$ | - | 2.0 - | $\begin{gathered} 7.0 \\ 10 \\ 10 \end{gathered}$ | - | 2.0 - | $\begin{aligned} & 7.0 \\ & 10 \\ & 10 \end{aligned}$ | - | - | $\begin{aligned} & 13 \\ & 10 \end{aligned}$ | mV |
| Average Temperature Coefficient of Input Offset Voltage $\mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {high }}$ to $\mathrm{T}_{\text {low }}$ (Note 4.) | $\Delta \mathrm{V}_{10} / \Delta \mathrm{T}$ | - | 7.0 | - | - | 7.0 | - | - | 7.0 | - | $\mu \mathrm{V} /{ }^{\circ} \mathrm{C}$ |
| Input Offset Current $T_{A}=T_{\text {high }} \text { to } T_{\text {low }} \text { (Note 4.) }$ <br> Input Bias Current $\mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { to } \mathrm{T}_{\text {low }} \text { (Note 4.) }$ | $I_{\mathrm{IO}}$ $I_{\text {IB }}$ | - | $\begin{gathered} \hline 5.0 \\ 45 \\ -45 \\ -50 \end{gathered}$ | $\begin{gathered} 50 \\ 200 \\ -250 \\ -500 \end{gathered}$ | $\begin{aligned} & - \\ & - \\ & \text { - } \end{aligned}$ | $\begin{gathered} \hline 5.0 \\ 45 \\ -45 \\ -50 \end{gathered}$ | $\begin{gathered} 50 \\ 200 \\ -100 \\ -250 \end{gathered}$ | - | $\begin{gathered} 5.0 \\ 45 \\ -45 \\ -50 \end{gathered}$ | $\begin{gathered} \hline 50 \\ 200 \\ -250 \\ -500 \end{gathered}$ | nA |
| Average Temperature Coefficient of Input Offset Current $\mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { to } \mathrm{T}_{\text {low }} \text { (Note 4.) }$ | $\Delta \mathrm{l}_{\mathrm{IO}} / \Delta \mathrm{T}$ | - | 10 | - | - | 10 | - | - | 10 | - | $\mathrm{pA} /{ }^{\circ} \mathrm{C}$ |
| Input Common Mode Voltage Range (Note 5.), $\begin{aligned} & \mathrm{V}_{\mathrm{CC}}=30 \mathrm{~V}(26 \mathrm{~V} \text { for LM2904, } \mathrm{V}) \\ & \mathrm{V}_{\mathrm{CC}}=30 \mathrm{~V}(26 \mathrm{~V} \text { for LM2904, } \mathrm{V}), \\ & \mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { to } \mathrm{T}_{\text {low }} \end{aligned}$ | $V_{\text {ICR }}$ | $0$ <br> 0 | $\begin{aligned} & - \\ & - \end{aligned}$ | $\begin{gathered} 24.3 \\ 24 \end{gathered}$ | $0$ $0$ | - | $\begin{gathered} 24.3 \\ 24 \end{gathered}$ | $0$ <br> 0 | - | $\begin{gathered} 24.3 \\ 24 \end{gathered}$ | V |
| Differential Input Voltage Range | $V_{\text {IDR }}$ | - | - | $\mathrm{V}_{\mathrm{CC}}$ | - | - | $\mathrm{V}_{\mathrm{CC}}$ | - | - | $\mathrm{V}_{\mathrm{CC}}$ | V |
| Large Signal Open Loop Voltage Gain $\mathrm{R}_{\mathrm{L}}=2.0 \mathrm{k} \Omega, \mathrm{~V}_{\mathrm{CC}}=15 \mathrm{~V} \text {, For Large } \mathrm{V}_{\mathrm{O}} \text { Swing, }$ $\mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { to } \mathrm{T}_{\text {low }} \text { (Note 4.) }$ | Avol | $\begin{aligned} & 25 \\ & 15 \end{aligned}$ | $100$ | - | $\begin{aligned} & 25 \\ & 15 \end{aligned}$ | 100 | - | $\begin{aligned} & 25 \\ & 15 \end{aligned}$ | $100$ | - | V/mV |
| Channel Separation <br> $1.0 \mathrm{kHz} \leq \mathrm{f} \leq 20 \mathrm{kHz}$, Input Referenced | CS | - | -120 | - | - | -120 | - | - | -120 | - | dB |
| Common Mode Rejection $R_{S} \leq 10 \mathrm{k} \Omega$ | CMR | 50 | 70 | - | 50 | 70 | - | 50 | 70 | - | dB |
| Power Supply Rejection | PSR | 50 | 100 | - | 50 | 100 | - | 50 | 100 | - | dB |
| $\begin{aligned} & \text { Output Voltage-High Limit } \\ & \mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { to } \mathrm{T}_{\text {low }}(\text { Note 4. }) \\ & \mathrm{V}_{\mathrm{CC}}=5.0 \mathrm{~V}, \mathrm{R}_{\mathrm{L}}=2.0 \mathrm{k} \Omega, \mathrm{~T}_{\mathrm{A}}=25^{\circ} \mathrm{C} \\ & \mathrm{~V}_{\mathrm{CC}}=30 \mathrm{~V}(26 \mathrm{~V} \text { for } \mathrm{LM} 2904, \mathrm{~V}), \mathrm{R}_{\mathrm{L}}=2.0 \mathrm{k} \Omega \\ & \mathrm{~V}_{\mathrm{CC}}=30 \mathrm{~V}(26 \mathrm{~V} \text { for } \mathrm{LM} 2904, \mathrm{~V}), \mathrm{R}_{\mathrm{L}}=10 \mathrm{k} \Omega \end{aligned}$ | $\mathrm{V}_{\mathrm{OH}}$ | $\begin{aligned} & 3.3 \\ & 22 \\ & 23 \end{aligned}$ | $\begin{gathered} 3.5 \\ - \\ 24 \end{gathered}$ | - | $\begin{aligned} & 3.3 \\ & 22 \\ & 23 \\ & \hline \end{aligned}$ | $\begin{gathered} 3.5 \\ - \\ 24 \end{gathered}$ | - | $\begin{aligned} & 3.3 \\ & 22 \\ & 23 \end{aligned}$ | $\begin{gathered} 3.5 \\ - \\ 24 \end{gathered}$ | - | V |
| Output Voltage-Low Limit $\begin{aligned} & \mathrm{V}_{\mathrm{CC}}=5.0 \mathrm{~V}, \mathrm{R}_{\mathrm{L}}=10 \mathrm{k} \Omega, \\ & \mathrm{~T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { to } \mathrm{T}_{\text {low }}(\text { Note }) \end{aligned}$ | $\mathrm{V}_{\mathrm{OL}}$ | - | 5.0 | 20 | - | 5.0 | 20 | - | 5.0 | 20 | mV |
| Output Source Current $\mathrm{V}_{I D}=+1.0 \mathrm{~V}, \mathrm{~V}_{\mathrm{CC}}=15 \mathrm{~V}$ | $\mathrm{I}_{+}+$ | 20 | 40 | - | 20 | 40 | - | 20 | 40 | - | mA |
| Output Sink Current $\begin{aligned} & \mathrm{V}_{\mathrm{ID}}=-1.0 \mathrm{~V}, \mathrm{~V}_{\mathrm{CC}}=15 \mathrm{~V} \\ & \mathrm{~V}_{\mathrm{ID}}=-1.0 \mathrm{~V}, \mathrm{~V}_{\mathrm{O}}=200 \mathrm{mV} \end{aligned}$ | $\mathrm{l}-$ | 10 | $20$ | - | $10$ | 20 | - | $10$ | 20 | - | $\begin{aligned} & \mathrm{mA} \\ & \mu \mathrm{~A} \end{aligned}$ |
| Output Short Circuit to Ground (Note 6.) | ISC | - | 40 | 60 | - | 40 | 60 | - | 40 | 60 | mA |
| $\begin{aligned} & \text { Power Supply Current } \\ & \mathrm{T}_{\mathrm{A}}=\mathrm{T}_{\text {high }} \text { to } \mathrm{T}_{\text {low }}(\text { Note 4.) } \\ & \mathrm{V}_{\mathrm{CC}}=30 \mathrm{~V}(26 \mathrm{~V} \text { for } \mathrm{LM} 2904, \mathrm{~V}), \mathrm{V}_{\mathrm{O}}=0 \mathrm{~V}, \mathrm{R}_{\mathrm{L}}=\infty \\ & \mathrm{V}_{\mathrm{CC}}=5 \mathrm{~V}, \mathrm{~V}_{\mathrm{O}}=0 \mathrm{~V}, \mathrm{R}_{\mathrm{L}}=\infty \end{aligned}$ | $I_{\text {cc }}$ | - | $\begin{aligned} & 1.5 \\ & 0.7 \end{aligned}$ | $\begin{aligned} & 3.0 \\ & 1.2 \end{aligned}$ | - | $\begin{aligned} & 1.5 \\ & 0.7 \end{aligned}$ | $\begin{aligned} & 3.0 \\ & 1.2 \end{aligned}$ | - | $\begin{aligned} & 1.5 \\ & 0.7 \end{aligned}$ | $\begin{aligned} & 3.0 \\ & 1.2 \end{aligned}$ | mA |

4. $\mathrm{LM} 258: \mathrm{T}_{\text {low }}=-25^{\circ} \mathrm{C}, \mathrm{T}_{\text {high }}=+85^{\circ} \mathrm{C}$

LM358: $\mathrm{T}_{\text {low }}=0^{\circ} \mathrm{C}, \mathrm{T}_{\text {high }}=+70^{\circ} \mathrm{C}$
LM2904/LM2904A: $\mathrm{T}_{\text {low }}=-40^{\circ} \mathrm{C}, \mathrm{T}_{\text {high }}=+105^{\circ} \mathrm{C}$
LM2904V: $T_{\text {low }}=-40^{\circ} \mathrm{C}, \mathrm{T}_{\text {high }}=+125^{\circ} \mathrm{C}$
5. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V . The upper end of the common mode voltage range is $\mathrm{V}_{\mathrm{CC}}-1.7 \mathrm{~V}$.
6. Short circuits from the output to $\mathrm{V}_{\mathrm{CC}}$ can cause excessive heating and eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

CIRCUIT DESCRIPTION
The LM358 series is made using two internally compensated, two-stage operational amplifiers. The first stage of each consists of differential input devices Q20 and Q18 with input buffer transistors Q21 and Q17 and the differential to single ended converter Q3 and Q4. The first stage performs not only the first stage gain function but also performs the level shifting and transconductance reduction functions. By reducing the transconductance, a smaller compensation capacitor (only 5.0 pF ) can be employed, thus saving chip area. The transconductance reduction is accomplished by splitting the collectors of Q20 and Q18. Another feature of this input stage is that the input common mode range can include the negative supply or ground, in single supply operation, without saturating either the input devices or the differential to single-ended converter. The second stage consists of a standard current source load amplifier stage.

Each amplifier is biased from an internal-voltage regulator which has a low temperature coefficient thus giving each amplifier good temperature characteristics as well as excellent power supply rejection.



Figure 3. Large Signal Voltage Follower Response


Figure 6. Large-Signal Frequency Response


Figure 7. Small Signal Voltage Follower Pulse Response (Noninverting)


Figure 9. Input Bias Current versus Supply Voltage

## LM358, LM258, LM2904, LM2904V



$$
\mathrm{V}_{0}=2.5 \mathrm{~V}\left(1+\frac{\mathrm{R} 1}{\mathrm{R} 2}\right)
$$

Figure 10. Voltage Reference


Figure 11. Wien Bridge Oscillator


$$
e_{0}=C(1+a+b)\left(e_{2}-e_{1}\right)
$$

Figure 12. High Impedance Differential Amplifier


Figure 13. Comparator with Hysteresis


Figure 14. Bi-Quad Filter


$$
f=\frac{R 1+R_{C}}{4 C R_{f} R 1} \quad \text { if, } R 3=\frac{R 2 R 1}{R 2+R 1}
$$

Figure 15. Function Generator


Given: $\quad f_{0}=$ center frequency
$A\left(f_{0}\right)=$ gain at center frequency
Choose value $f_{0}, C$
Then: $\quad R 3=\frac{Q}{\pi f_{0} C}$
$\mathrm{R} 1=\frac{\mathrm{R} 3}{2 \mathrm{~A}\left(\mathrm{f}_{0}\right)}$
$R 2=\frac{R 1 R 3}{4 Q^{2} R 1-R 3}$
For less than $10 \%$ error from operational amplifier. $\frac{Q_{0} f_{0}}{B W}<0.1$ Where $\mathrm{f}_{0}$ and BW are expressed in Hz .

If source impedance varies, filter may be preceded with voltage follower buffer to stabilize filter parameters.

Figure 16. Multiple Feedback Bandpass Filter

## LM358, LM258, LM2904, LM2904V

ORDERING INFORMATION

| Device | Package | Operating Temperature Range | Shipping |
| :---: | :---: | :---: | :---: |
| LM358D | SO-8 | $0^{\circ}$ to $+70^{\circ} \mathrm{C}$ | 98 Units/Rail |
| LM358DR2 | SO-8 |  | 2500 Tape \& Reel |
| LM358N | PDIP-8 |  | 50 Units/Rail |
| LM258D | SO-8 | $-25^{\circ}$ to $+85^{\circ} \mathrm{C}$ | 98 Units/Rail |
| LM258DR2 | SO-8 |  | 2500 Tape \& Reel |
| LM258N | PDIP-8 |  | 50 Units/Rail |
| LM2904D | SO-8 | $-40^{\circ}$ to $+105^{\circ} \mathrm{C}$ | 98 Units/Rail |
| LM2904DR2 | SO-8 |  | 2500 Tape \& Reel |
| LM2904N | PDIP-8 |  | 50 Units/Rail |
| LM2904AN | PDIP-8 |  | 50 Units/Rail |
| LM2904VD | SO-8 | $-40^{\circ}$ to $+125^{\circ} \mathrm{C}$ | 98 Units/Rail |
| LM2904VDR2 | SO-8 |  | 2500 Tape \& Reel |
| LM2904VN | PDIP-8 |  | 50 Units/Rail |

## LM358，LM258，LM2904，LM2904V

MARKING DIAGRAMS

| PDIP－8 N SUFFIX CASE 626 | PDIP－8 AN SUFFIX CASE 626 | PDIP－8 N SUFFIX CASE 626 | PDIP－8 <br> VN SUFFIX <br> CASE 626 |
| :---: | :---: | :---: | :---: |
| $8^{8}$ | ${ }^{8}$ ¢ ת ת لـ， |  | ${ }^{8}$ ¢ ת ת لـ |
| $0 \begin{array}{r} \text { LM×58N } \\ \text { AWL } \\ \mathrm{YYWW} \end{array}$ | $\left\lvert\, \begin{array}{r}\text { LM2904AN } \\ \text { AWL } \\ \text { YYWW }\end{array}\right.$ | $\|$LM2904N <br> AWL <br> YYWW | ｜rM2904VN $\begin{array}{r}\text { AWL } \\ \text { YYWW }\end{array}$ |
| 1『 W | 1『 『 | 1『 『 | 1『 『 |



> SO-8 D SUFFIX CASE 751

SO－8 VD SUFFIX CASE 751

| 8月 日（ |
| :---: |
| 290 |
| ALYW |
| 1甘日 日 |


| 8 8＿且＿日 |
| :---: |
| 2904 |
| ALYW |
| $1 甘 甘 甘 甘$ |

```
x =2 or 3
A = Assembly Location
WL, L = Wafer Lot
YY, Y = Year
WW,W = Work Week
```


## LM358, LM258, LM2904, LM2904V

PACKAGE DIMENSIONS
PDIP-8
N, AN, VN SUFFIX
CASE 626-05
ISSUE L


NOTES:

1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
2. PACKAGE CONTOUR OPTIONAL (ROUND OR

SQUARE CORNERS)
3. DIMENSIONING AND TOLERANCING PER ANSI

Y14.5M, 1982.

| DIM | MILLIMETERS |  | INCHES |  |
| :---: | :---: | :---: | :---: | :---: |
|  | MIN | MAX | MIN | MAX |
| A | 9.40 | 10.16 | 0.370 | 0.400 |
| B | 6.10 | 6.60 | 0.240 | 0.260 |
| C | 3.94 | 4.45 | 0.155 | 0.175 |
| D | 0.38 | 0.51 | 0.015 | 0.020 |
| F | 1.02 | 1.78 | 0.040 | 0.070 |
| G | 2.54 BSC |  | 0.100 BSC |  |
| H | 0.76 | 1.27 | 0.030 | 0.050 |
| J | 0.20 | 0.30 | 0.008 | 0.012 |
| K | 2.92 | 3.43 | 0.115 | 0.135 |
| L | 7.62 BSC |  | 0.300 BSC |  |
| M | --- | $10^{\circ}$ | --- | $10^{\circ}$ |
| N | 0.76 | 1.01 | 0.030 | 0.040 |

SO-8
D, VD SUFFIX
CASE 751-07
ISSUE W


NOTES

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER
3. CONTROLLING DIMENSION: MILLIMETER.
4. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
5. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
6. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR
PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

| DIM | MILLIMETERS |  | INCHES |  |
| :---: | :---: | :---: | :---: | :---: |
|  | MIN | MAX | MIN | MAX |
| A | 4.80 | 5.00 | 0.189 | 0.197 |
| B | 3.80 | 4.00 | 0.150 | 0.157 |
| C | 1.35 | 1.75 | 0.053 | 0.069 |
| D | 0.33 | 0.51 | 0.013 | 0.020 |
| G | 1.27 BSC |  | 0.050 BSC |  |
| H | 0.10 | 0.25 | 0.004 | 0.010 |
| J | 0.19 | 0.25 | 0.007 | 0.010 |
| K | 0.40 | 1.27 | 0.016 | 0.050 |
| M | $0^{\circ}$ | $8{ }^{\circ}$ | $0^{\circ}$ | $8^{\circ}$ |
| N | 0.25 | 0.50 | 0.010 | 0.020 |
| S | 5.80 | 6.20 | 0.228 | 0.244 |

LM358, LM258, LM2904, LM2904V

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