LM124/LM224/LM324/LM2902
Low Power Quad Operational Amplifiers

General Description
The LM124 series consists of four 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. Application areas 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 LM124 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.

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 cross frequency is temperature compensated
- The input bias current is also temperature compensated

Advantages
- Eliminates need for dual supplies
- Four internally compensated op amps in a single package
- Allows directly sensing near GND and VOUT also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

Features
- 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 or dual supplies ±1.5V to ±16V
- Very low supply current drain (700 µA)—essentially independent of supply voltage
- Low input biasing current 45 nA (temperature compensated)
- Low input offset voltage 2 mV and offset current: 5 nA
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing 0V to V+ - 1.5V
Connection Diagrams (Continued)

Order Number LM124AW883, LM124AWG883, LM124W883 or LM124WG883
LM124AWGML and LM124AWGMLV (Note 3)
See NS Package Number W14B
LM124AWGML and LM124AWGMLV (Note 3)
See NS Package Number WG14A

Note 1: LM124A available per NS850101000
Note 2: LM124A available per NS850101000
Note 3: See STD M1 DWG 596299034 for Radiation Tolerant Device

Schematic Diagram (Each Amplifier)
**Absolute Maximum Ratings** (Note 12)  
If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Supply Voltage, V^+</td>
<td>32V</td>
<td>26V</td>
</tr>
<tr>
<td>Differential Input Voltage</td>
<td>32V</td>
<td>26V</td>
</tr>
<tr>
<td>Input Voltage</td>
<td>+0.3V to +32V</td>
<td>-0.3V to +26V</td>
</tr>
<tr>
<td>Input Current (V_in = -0.3V)</td>
<td>50 mA</td>
<td>50 mA</td>
</tr>
<tr>
<td>Power Dissipation (Note 4)</td>
<td>1130 mW</td>
<td>1130 mW</td>
</tr>
<tr>
<td>Molded DIP</td>
<td>1260 mW</td>
<td>1260 mW</td>
</tr>
<tr>
<td>Cavity DIP</td>
<td>800 mW</td>
<td>800 mW</td>
</tr>
<tr>
<td>Small Outline Package</td>
<td>Continuous</td>
<td>Continuous</td>
</tr>
<tr>
<td>Output Short-Circuit to GND</td>
<td></td>
<td></td>
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<tr>
<td>(One Amplifier) (Note 5)</td>
<td></td>
<td></td>
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<tr>
<td>V^+ ≤ 15V and T_A = 25°C</td>
<td>Continuous</td>
<td>Continuous</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM324/LM324A</td>
<td>0°C to +70°C</td>
<td></td>
</tr>
<tr>
<td>LM224/LM224A</td>
<td>-25°C to +70°C</td>
<td></td>
</tr>
<tr>
<td>LM124/LM124A</td>
<td>-55°C to +125°C</td>
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<tr>
<td>Storage Temperature Range</td>
<td>-65°C to +150°C</td>
<td>-65°C to +150°C</td>
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<tr>
<td>Lead Temperature (Soldering, 10 seconds)</td>
<td>250°C</td>
<td>260°C</td>
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<td>Soldering Information:</td>
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<tr>
<td>D-Shaped-Outline Package</td>
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<tr>
<td>Soldering (10 seconds)</td>
<td>260°C</td>
<td>260°C</td>
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<tr>
<td>Small Outline Package</td>
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<tr>
<td>Vapor Phase (100 seconds)</td>
<td>215°C</td>
<td>215°C</td>
</tr>
<tr>
<td>Infrared (15 seconds)</td>
<td>220°C</td>
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<tr>
<td>See AN450 “Surface Mounting Methods and Their Effect on Product Reliability” for other methods of soldering surface mount devices.</td>
<td></td>
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<tr>
<td>ESD Tolerance (Note 13)</td>
<td>250V</td>
<td>200V</td>
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**Electrical Characteristics**  
V^+ = +5.5 V, (Note 7), unless otherwise stated.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM124A</th>
<th>LM224A</th>
<th>LM324A</th>
<th>Units</th>
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<tbody>
<tr>
<td>Input Offset Voltage</td>
<td>(Note 8) T_A = 25°C</td>
<td>1 2</td>
<td>1 3</td>
<td>2 3</td>
<td>mV</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>I_{in} 0, 1, V_{os} = 0, T_A = 25°C</td>
<td>20 50</td>
<td>40   50</td>
<td>45 100</td>
<td>nA</td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>I_{in} 0, 1, V_{os} = 0, T_A = 25°C</td>
<td>2 10</td>
<td>2 15</td>
<td>5 30</td>
<td>nA</td>
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<tr>
<td>Input Common-Mode Voltage Range</td>
<td>V^+ = 36V, (LM324A, V^+ = 28V), T_A = 25°C</td>
<td>0 0.15</td>
<td>0 0.15</td>
<td>0 0.15</td>
<td>V</td>
</tr>
<tr>
<td>Supply Current</td>
<td>Over Full Temperature Range</td>
<td>1.5 3</td>
<td>1.5 3</td>
<td>1.5 3</td>
<td>mA</td>
</tr>
<tr>
<td>Large Signal</td>
<td>V^+ = 15V, R_L &gt; 2kΩ</td>
<td>50 100</td>
<td>50 100</td>
<td>25 100</td>
<td>V/mW</td>
</tr>
<tr>
<td>Voltage Gain</td>
<td>(V_{op} = 1V to 11V), T_A = 25°C</td>
<td>70 85</td>
<td>70 85</td>
<td>65 85</td>
<td>dB</td>
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<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM124A</th>
<th>LM224A</th>
<th>LM324A</th>
<th>Units</th>
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<tbody>
<tr>
<td>Common-Mode Voltage</td>
<td>DC, V_{os} = 0V to V^+ - 1.5V</td>
<td>70 85</td>
<td>70 85</td>
<td>65 85</td>
<td>dB</td>
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### Electrical Characteristics (Continued)

<table>
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<th>Parameter</th>
<th>Conditions</th>
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<th>LM224A</th>
<th>LM204A</th>
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<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
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<tr>
<td>Rejection Ratio</td>
<td>T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
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<tr>
<td>Power Supply</td>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 5V to 30V</td>
<td>65</td>
<td>160</td>
<td>65</td>
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<tr>
<td>(LM20302, V&lt;sup&gt;+&lt;/sup&gt; = 5V to 20V),</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td>65</td>
<td>100</td>
<td>65</td>
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<tr>
<td>Amplifier-to-Amplifier Coupling (Note 11)</td>
<td>f = 1 kHz to 20 kHz, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td>-120</td>
<td></td>
<td>-120</td>
</tr>
<tr>
<td>Source Output Current</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt; = 1V, V&lt;sub&gt;OUT&lt;/sub&gt; = 0V,</td>
<td>20</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 15V, V&lt;sub&gt;IND&lt;/sub&gt; = 2V, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td></td>
<td></td>
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<tr>
<td>Sink</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt; = 1V, V&lt;sub&gt;OUT&lt;/sub&gt; = 0V,</td>
<td>10</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 15V, V&lt;sub&gt;IND&lt;/sub&gt; = 2V, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
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<tr>
<td>Short Circuit to Ground (Note 5)</td>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 15V, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td>40</td>
<td>60</td>
<td>40</td>
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<tr>
<td>Input Offset Voltage (Note 8)</td>
<td>7</td>
<td>20</td>
<td>7</td>
<td>20</td>
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<tr>
<td>Vos Drift</td>
<td>R&lt;sub&gt;0&lt;/sub&gt; = 5k</td>
<td>100</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>i&lt;sub&gt;IN&lt;/sub&gt; = i&lt;sub&gt;OUT&lt;/sub&gt;, V&lt;sub&gt;C&lt;/sub&gt; = 0V</td>
<td>10</td>
<td>200</td>
<td>10</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>i&lt;sub&gt;IN&lt;/sub&gt; = i&lt;sub&gt;OUT&lt;/sub&gt;,</td>
<td>40</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>Input Common-Mode Voltage Range (Note 10)</td>
<td>V&lt;sup&gt;+&lt;/sup&gt; = ±30V (LM20202, V&lt;sup&gt;+&lt;/sup&gt; = 26V)</td>
<td>0</td>
<td>V&lt;sup&gt;+&lt;/sup&gt;-2</td>
<td>0</td>
</tr>
<tr>
<td>Large Signal Voltage Gain</td>
<td>V&lt;sup&gt;+&lt;/sup&gt; = ±15V (V&lt;sub&gt;OUT&lt;/sub&gt;=0V to 11V)</td>
<td>25</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>R&lt;sub&gt;0&lt;/sub&gt; = 2 kΩ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Voltage Swing</td>
<td>V&lt;sub&gt;OUT&lt;/sub&gt; = 30V</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>(LM20920, V&lt;sup&gt;+&lt;/sup&gt; = 26V)</td>
<td></td>
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<tr>
<td>R&lt;sub&gt;L&lt;/sub&gt; = 10 kΩ</td>
<td></td>
<td>27</td>
<td>28</td>
<td>27</td>
</tr>
<tr>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 6V, R&lt;sub&gt;L&lt;/sub&gt; = 10 kΩ</td>
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<td>5</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Output Current Source</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt; = 2V</td>
<td>10</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 11V,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 0V,</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 15V</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Sink</td>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 11V,</td>
<td>10</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 0V,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 15V</td>
<td></td>
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### Electrical Characteristics

V<sup>+</sup> = ±5.0V, (Note 7), unless otherwise stated

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM124A</th>
<th>LM224A</th>
<th>LM204A</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
</tr>
<tr>
<td>Input Offset Voltage</td>
<td>(Note 8) T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td>2</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Input Bias Current (Note 9)</td>
<td>i&lt;sub&gt;IN&lt;/sub&gt; = i&lt;sub&gt;OUT&lt;/sub&gt;, V&lt;sub&gt;C&lt;/sub&gt; = 0V, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td>45</td>
<td>150</td>
<td>45</td>
</tr>
<tr>
<td>Input Offset Current (Note 9)</td>
<td>i&lt;sub&gt;IN&lt;/sub&gt; = i&lt;sub&gt;OUT&lt;/sub&gt;, V&lt;sub&gt;C&lt;/sub&gt; = 0V, T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td>45</td>
<td>250</td>
<td>45</td>
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<tr>
<td>Input Common-Mode Voltage Range (Note 10)</td>
<td>V&lt;sup&gt;+&lt;/sup&gt; = ±30V (LM20202, V&lt;sup&gt;+&lt;/sup&gt; = 26V), T&lt;sub&gt;A&lt;/sub&gt; = 25°C</td>
<td>0</td>
<td>V&lt;sup&gt;+&lt;/sup&gt;-1.5</td>
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### Electrical Characteristics (Continued)

**V**<sub>ref</sub> = ±5.0V, (Note 7), unless otherwise stated

<table>
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<th>Parameter</th>
<th>Conditions</th>
<th>LM1124/LM2244</th>
<th>LM324</th>
<th>LM2902</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td><strong>Supply Current</strong></td>
<td>Over Full Temperature Range, R&lt;sub&gt;L&lt;/sub&gt; = 1 kΩ, (V&lt;sub&gt;ref&lt;/sub&gt; = 1V)</td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 36V, V&lt;sup&gt;-&lt;/sup&gt; = 24V, V&lt;sup&gt;+&lt;/sup&gt; = 20V</td>
<td>1.5</td>
<td>3</td>
<td>1.5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>V&lt;sup&gt;-&lt;/sup&gt; = 5V</td>
<td>0.7</td>
<td>1.2</td>
<td>0.7</td>
<td>1.2</td>
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<tr>
<td><strong>Large Signal</strong></td>
<td>GG, V&lt;sub&gt;in&lt;/sub&gt; = 0V to V&lt;sup&gt;+&lt;/sup&gt; = 15V, TA = 25°C</td>
<td>50</td>
<td>100</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td><strong>Voltage Gain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Common-Mode</strong></td>
<td>V&lt;sup&gt;-&lt;/sup&gt; = 0V to V&lt;sup&gt;+&lt;/sup&gt; = 15V, TA = 25°C</td>
<td>70</td>
<td>95</td>
<td>65</td>
<td>95</td>
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<tr>
<td><strong>Rejection Ratio</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power Supply</strong></td>
<td>V&lt;sup&gt;-&lt;/sup&gt; = 5V to 30V</td>
<td>65</td>
<td>100</td>
<td>65</td>
<td>100</td>
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<tr>
<td><strong>Rejection Ratio</strong></td>
<td>(LM2902, V&lt;sup&gt;-&lt;/sup&gt; = 5V to 26V, TA = 25°C)</td>
<td></td>
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<tr>
<td><strong>Amplifier-to-Amplifier</strong></td>
<td>f = 1 kHz to 20 kHz, TA = 25°C</td>
<td>-120</td>
<td>-120</td>
<td>-120</td>
<td>-120</td>
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<tr>
<td><strong>Coupling</strong></td>
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<tr>
<td><strong>Output Current</strong></td>
<td>Source: V&lt;sub&gt;in&lt;/sub&gt; = 1V, V&lt;sub&gt;ref&lt;/sub&gt; = 0V</td>
<td>20</td>
<td>40</td>
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<td>40</td>
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<tr>
<td></td>
<td>V&lt;sup&gt;+&lt;/sup&gt; = 15V, V&lt;sub&gt;ref&lt;/sub&gt; = 2V, TA = 25°C</td>
<td>10</td>
<td>20</td>
<td>11</td>
<td>20</td>
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<tr>
<td></td>
<td>V&lt;sup&gt;-&lt;/sup&gt; = 15V, V&lt;sub&gt;ref&lt;/sub&gt; = 2V, TA = 25°C</td>
<td>10</td>
<td>20</td>
<td>11</td>
<td>20</td>
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<tr>
<td></td>
<td>V&lt;sup&gt;-&lt;/sup&gt; = 15V, V&lt;sub&gt;ref&lt;/sub&gt; = 2V, TA = 25°C</td>
<td>12</td>
<td>20</td>
<td>12</td>
<td>20</td>
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<tr>
<td></td>
<td>V&lt;sup&gt;-&lt;/sup&gt; = 15V, V&lt;sub&gt;ref&lt;/sub&gt; = 2V, TA = 25°C</td>
<td>12</td>
<td>20</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td><strong>Short Circuit to Ground</strong></td>
<td>V&lt;sup&gt;-&lt;/sup&gt; = 15V, TA = 25°C</td>
<td>40</td>
<td>60</td>
<td>40</td>
<td>60</td>
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<tr>
<td><strong>Input Offset Voltage</strong></td>
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<td>7</td>
<td>9</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td><strong>Input Offset Current</strong></td>
<td></td>
<td>100</td>
<td>500</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td><strong>Input Bias Current</strong></td>
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<td>100</td>
<td>500</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td><strong>Input Common-Mode Voltage</strong></td>
<td>V&lt;sup&gt;-&lt;/sup&gt; = ±30V</td>
<td>0</td>
<td>V&lt;sup&gt;-&lt;/sup&gt;-2</td>
<td>0</td>
<td>V&lt;sup&gt;-&lt;/sup&gt;-2</td>
</tr>
<tr>
<td><strong>Voltage Range</strong></td>
<td>(Note 10)</td>
<td>0</td>
<td>V&lt;sup&gt;-&lt;/sup&gt;-2</td>
<td>0</td>
<td>V&lt;sup&gt;-&lt;/sup&gt;-2</td>
</tr>
<tr>
<td><strong>Large Signal</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Voltage Gain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Output Voltage</strong></td>
<td>V&lt;sub&gt;out&lt;/sub&gt; = 0.5V</td>
<td>25</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>(LM2902, V&lt;sub&gt;out&lt;/sub&gt; = 26V)</td>
<td>26</td>
<td>26</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(LM2902, V&lt;sub&gt;out&lt;/sub&gt; = 26V)</td>
<td>27</td>
<td>29</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V&lt;sub&gt;out&lt;/sub&gt; = 0.5V</td>
<td>26</td>
<td>26</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V&lt;sub&gt;out&lt;/sub&gt; = 0.5V</td>
<td>27</td>
<td>29</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td><strong>Output Current</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Source</strong></td>
<td>V&lt;sub&gt;in&lt;/sub&gt; = ±1V</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>V&lt;sub&gt;ref&lt;/sub&gt; = 0V, V&lt;sup&gt;+&lt;/sup&gt; = 15V</td>
<td>5</td>
<td>8</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td><strong>Sink</strong></td>
<td>V&lt;sub&gt;in&lt;/sub&gt; = ±1V</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>V&lt;sub&gt;ref&lt;/sub&gt; = 0V, V&lt;sup&gt;+&lt;/sup&gt; = 15V</td>
<td>5</td>
<td>8</td>
<td>5</td>
<td>8</td>
</tr>
</tbody>
</table>

**Note 4:** For operation at high temperatures, the LM324/LM2902 family must be derated based on a +125°C maximum junction temperature and a thermal resistance of 190°C/W which applies for the device situated in a printed circuit board, operating in a still air ambient. The LM224/LM2244 and LM318/LM3184 can be derated based on a +120°C maximum junction temperature. This is the total of all four amplifiers—see external resistors, where possible, to allow the amplifier to saturate to reduce the power which is dissipated in the integrated circuit.

**Note 5:** Short circuits from the output to V<sup>-</sup> can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately +100 mA independent of the magnitude of V<sup>-</sup>. All values of output voltage in excess of +100 V will continue until the output current exceeds the power dissipation rating and cause eventual destruction. Distinctive dissipation can result from simultaneous shorts on all amplifiers.

**Note 6:** This input current will only exist when the voltage at any of the input leads is driven negative, this is due to the collector-base junction of the input PNP. The current becomes forward biased and thereby acting as an input diode clamp. In addition to this diode action, there is also lateral effect transistor action.
Typical Single-Supply Applications \((V^+ = 5.0 \text{ Vdd})\) (Continued)

**LED Driver**

**“BI-QUAD” RC Active Bandpass Filter**

\[ I_e = \frac{1}{\pi Q} \]

\[ Q = 50 \]

\[ A_v = 100 \text{ (40 dB)} \]

**Fixed Current Sources**

**Lamp Driver**

\[ I_e = \frac{V_1}{R_2} \times I_f \]
Typical Single-Supply Applications

Current Monitor

\[ V_0 = \frac{1.05 V_l}{1 k} \]

\[ V_l = V^- - 2 V \]

Driving TTL

Voltage Follower

Pulse Generator

Squarewave Oscillator

Pulse Generator

Incorporate R1 for \( I_l \) small
Typical Single-Supply Applications \((V^* = 5.0 \, V_{CC})\) (Continued)

High Compliance Current Sink

\[i_n = 1 \, \text{amp} / V_{CC}\]

(Increase \(i_n\) for \(V_{CC}\) small)

Low Drift Peak Detector

Physical Dimensions [inches (millimeters)] unless otherwise noted (Continued)

Molded Dual-In-Line Package (N)
Order Number LM324N, LM324AN or LM3202N
NS Package Number N14A
Features

- Compatible with MCS-51® Products
- 8K bytes of In-System Programmable (ISP) Flash Memory
  - Endurance: 10,000 Write/Erase Cycles
- 4.6V to 5.5V Operating Range
- Fully Static Operation: 0 Hz to 33 MHz
- Three-level Program Memory Lock
- 256 x 8-bit Internal RAM
- 32 Programmable I/O Lines
- Three 16-bit Timer/Counters
- Eight Interrupt Sources
- Full Duplex UART Serial Channel
- Low-power Idle and Power-down Modes
- Interrupt Recovery from Power-down Mode
- Watchdog Timer
- Dual Data Pointer
- Power-off Flag

Description

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set and pinout. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications.

The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In addition, the AT89S52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

Pin Configurations
Pin Description

VCC
Supply voltage.

GND
Ground.

Port 0
Port 0 is an 8-bit open drain bidirectional I/O port. As an output port, each pin can sink eight TTL inputs. When 1s are written to port 0 pins, the pins can be used as high-impedance inputs.

Port 0 can also be configured to be the multiplexed low-order address/data bus during accesses to external program and data memory. In this mode, P0 has internal pullups.

Port 0 also receives the code bytes during Flash programming and outputs the code bytes during program verification. External pullups are required during program verification.

Port 1
Port 1 is an 8-bit bidirectional I/O port with internal pullups. The Port 1 output buffers can sink/source four TTL inputs. When 1s are written to Port 1 pins, they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 1 pins that are externally being pulled low will source current (1\n) because of the internal pullups.

In addition, P1.0 and P1.1 can be configured to be the timer/counter 2 external count input (P1.0/T2) and the timer/counter 2 trigger input (P1.1/T2EX), respectively, as shown in the following table.

Port 1 also receives the low-order address bytes during Flash programming and verification.

<table>
<thead>
<tr>
<th>Port Pin</th>
<th>Alternate Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1.0</td>
<td>T2 (external count input to Timer/Counter 2), clock-out</td>
</tr>
<tr>
<td>P1.1</td>
<td>T2EX (Timer/Counter 2 capture/Reload trigger and direction control)</td>
</tr>
<tr>
<td>P1.5</td>
<td>MOSI (used for In-System Programming)</td>
</tr>
<tr>
<td>P1.6</td>
<td>MISO (used for In-System Programming)</td>
</tr>
<tr>
<td>P1.7</td>
<td>SCK (used for In-System Programming)</td>
</tr>
</tbody>
</table>

Port 2
Port 2 is an 8-bit bidirectional I/O port with internal pullups. The Port 2 output buffers can sink/source four TTL inputs. When 1s are written to Port 2 pins, they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 2 pins that are externally being pulled low will source current (1\n) because of the internal pullups.

Port 2 emits the high-order address byte during fetches from external program memory and during accesses to external data memory that use 16-bit addresses (MOVX @ DPTR). In this application, Port 2 uses 8-bit internal pullups when emitting 1s. During accesses to external data memory that use 8-bit addresses (MOVX @ RI), Port 2 emits the contents of the P2 Special Function Register.

Port 2 also receives the high-order address bits and some control signals during Flash programming and verification.

Port 3
Port 3 is an 8-bit bidirectional I/O port with internal pullups. The Port 3 output buffers can sink/source four TTL inputs. When 1s are written to Port 3 pins, they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (1\n) because of the pullups.

Port 3 also serves the functions of various special features of the AT89S852, as shown in the following table.

Port 3 also receives some control signals for Flash programming and verification.

<table>
<thead>
<tr>
<th>Port Pin</th>
<th>Alternate Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>P3.0</td>
<td>RXD (serial input port)</td>
</tr>
<tr>
<td>P3.1</td>
<td>TXD (serial output port)</td>
</tr>
<tr>
<td>P3.2</td>
<td>INT0 (external interrupt 0)</td>
</tr>
<tr>
<td>P3.3</td>
<td>INT1 (external interrupt 1)</td>
</tr>
<tr>
<td>P3.4</td>
<td>T0 (timer 0 output)</td>
</tr>
<tr>
<td>P3.5</td>
<td>T1 (timer 1 output)</td>
</tr>
<tr>
<td>P3.6</td>
<td>WR (external data memory write strobe)</td>
</tr>
<tr>
<td>P3.7</td>
<td>RD (external data memory read strobe)</td>
</tr>
</tbody>
</table>

RST
Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device. This pin drives high for 96 oscillator periods after the Watchdog times out. The DISRTO bit in SFR AUXR (address 8EH) can be used to disable this feature. In the default state of bit DISRTO, the RESET HIGH output feature is enabled.

ALE/PROG
Address Latch Enable (ALE) is an output pulse for latching the low byte of the address during accesses to external memory. This pin is also the program pulse input (PROG) during Flash programming.

In normal operation, ALE is emitted at a constant rate of 1/6 the oscillator frequency and may be used for external timing or clocking purposes. Note, however, that one ALE pulse is skipped during each access to external data memory.

If desired, ALE operation can be disabled by setting bit 0 of SFR location 8EH. With the bit set, ALE is active only during a MOVX or MOVC instruction. Otherwise, the pin is
weakly pulled high. Setting the ALE disable bit has no
effect if the microcontroller is in external execution mode.

**PSEN**
Program Store Enable (PSEN) is the read strobe to exter-
nal program memory.

When the AT89S52 is executing code from external pro-
gram memory, PSEN is activated twice each machine

machine cycle, except that two PSEN activations are skipped during each access to external data memory.

**EAP**
External Access Enable. EX must be strapped to GND in
order to enable the device to fetch code from external pro-
gram memory locations starting at $0000H$ up to FFFFH.

<table>
<thead>
<tr>
<th>SR Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>00000000</td>
</tr>
<tr>
<td>ACK</td>
<td>00000000</td>
</tr>
<tr>
<td>PSEN</td>
<td>00000000</td>
</tr>
<tr>
<td>EX</td>
<td>00000000</td>
</tr>
<tr>
<td>PSW</td>
<td>00000000</td>
</tr>
<tr>
<td>TCON</td>
<td>00000000</td>
</tr>
<tr>
<td>IE</td>
<td>00000000</td>
</tr>
<tr>
<td>PS</td>
<td>00000000</td>
</tr>
<tr>
<td>PCON</td>
<td>00000000</td>
</tr>
<tr>
<td>P0</td>
<td>00000000</td>
</tr>
</tbody>
</table>

Note, however, that if lock bit 1 is programmed, EX will be
internally latched on read.

EX should be strapped to VCC for internal program execu-
tions.

This pin also receives the 12-volt programming enable volt-
age ($V_{pp}$) during Flash programming.

**XTAL1**
Input to the inverting oscillator amplifier and input to the
internal clock operating circuit.

**XTAL2**
Output from the inverting oscillator amplifier.

<table>
<thead>
<tr>
<th>Table 1. AT89S52 SFR Map and Reset Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>08H</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>ACK</td>
</tr>
<tr>
<td>PSEN</td>
</tr>
<tr>
<td>EX</td>
</tr>
<tr>
<td>PSW</td>
</tr>
<tr>
<td>TCON</td>
</tr>
<tr>
<td>IE</td>
</tr>
<tr>
<td>PS</td>
</tr>
<tr>
<td>PCON</td>
</tr>
<tr>
<td>P0</td>
</tr>
</tbody>
</table>
Special Function Registers

A map of the on-chip memory area called the Special Function Register (SFR) space is shown in Table 1. Note that not all of the addresses are occupied, and unoccupied addresses may not be implemented on the chip. Read accesses to these addresses will in general return random data, and write accesses will have an indeterminate effect.

User software should not write 1's to these unimplemented locations, since they may be used in future products to invoke new features. In that case, the reset or inactive values of the new bits will always be 0.

Timer 2 Registers: Control and status bits are contained in registers T2CON (shown in Table 2) and T2MOD (shown in Table 3) for Timer 2. The register pair (RCA2H, RCA2L) are the Capture/Reload registers for Timer 2 in 16-bit capture mode or 16-bit auto-reload mode.

Interrupt Registers: The individual interrupt enable bits are in the IE register. Two priorities can be set for each of the six interrupt sources in the IE register.

<table>
<thead>
<tr>
<th>Bit</th>
<th>TF2</th>
<th>EXF2</th>
<th>RCLK</th>
<th>TCLK</th>
<th>EXEN2</th>
<th>TF1</th>
<th>CD2</th>
<th>CD4</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. T2CON — Timer/Counter 2 Control Register

Symbol | Function
--- | ---
TF2 | Timer 2 overflow flag; set by a Timer 2 overflow and must be cleared by software. TF2 will not be set when either RCLK = 1 or TCLK = 1.
EXF2 | Timer 2 external flag; set when either a capture or reload is caused by a negative transition on T2EX and EXEN2 = 1. When Timer 2 interrupt is enabled, EXF2 = 1 will cause the CPU to vector to the Timer 2 interrupt routine. EXF2 must be cleared by software. EXF2 does not cause interrupt in up/down counter mode (UCEN = 1).
RCLK | Receive clock enable. When set, causes the serial port to use Timer 2 overflow pulses for its receive clock in serial port Modes 1 and 5. RCLK = 0 causes Timer 1 overflow to be used for the receive clock.
TCLK | Transmit clock enable. When set causes the serial port to use Timer 2 overflow pulses for its transmit clock in serial port Modes 1 and 5. TCLK = 0 causes Timer 1 overflow to be used for the transmit clock.
EXEN2 | Timer 2 external enable. When set, allows a capture or reload to occur as a result of a negative transition on T2EX if Timer 2 is not being used to clock the serial port. EXEN2 = 0 causes Timer 2 to ignore events at T2EX.
TF1 | Start/Stop control for Timer 2. TF1 = 1 starts the timer.
CD2 | Timer or counter select for Timer 2. CD2 = 0 for Timer function, CD2 = 1 for external event counter (falling edge triggered).
CD4 | Capture/Reload select. CD4 = 0 causes capture to occur on positive transitions at T2EX if EXEN2 = 1. CD4 = 0 causes automatic reload to occur when Timer 2 overflows or negative transitions occur at T2EX when EXEN2 = 1. When either RCLK or TCLK = 1, this bit is ignored and the timer is forced to auto-reload on Timer 2 overflow.
### Table 3a. AUXR: Auxiliary Register

<table>
<thead>
<tr>
<th>Bit</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Not Bit Addressable</th>
<th>WCDLE</th>
<th>DISRT0</th>
<th>DISALE</th>
<th>Reset Value = XXXX0XX0BE</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>6</td>
<td></td>
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<td>3</td>
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<td>1</td>
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<td>0</td>
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</tr>
</tbody>
</table>

- **Reserved for future expansion**
- **DISALE**: Disable/Enable ALE
  - 0: ALE is emitted at a constant rate of 1/2 the oscillator frequency
  - 1: ALE is active only during a MOVX or MOVYC instruction
- **DISRT0**: Disable/Enable Reset out
  - 0: Reset pin is driven high after WDT times out
  - 1: Reset pin is input only
- **WCDLE**: Disable/Enable WDT in IDLE mode
  - 0: WDT continues to count in IDLE mode
  - 1: WDT halts counting in IDLE mode

### Dual Data Pointer Registers:
To facilitate accessing both internal and external data memory, two banks of 16-bit Data Pointer Registers are provided. DPO at SFR address locations 82H-83H and DP1 at 84H-85H. Bit DPS = 0 in SFR AUXR1 selects DP0 and DPS = 1 selects DP1.

The user should always initialize the DPS bit to the appropriate value before accessing the respective Data Pointer Register.

**Power Off Flag**: The Power Off Flag (POF) is located at bit 4 (PCON.4) in the PCON SFR. POF is set to "1" during power up. It can be set and reset under software control and is not affected by reset.

### Table 3b. AUXR1: Auxiliary Register 1

<table>
<thead>
<tr>
<th>Bit</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Not Bit Addressable</th>
<th>DPS</th>
<th>Reset Value = XXXXXX0BE</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>6</td>
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<td>5</td>
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<td></td>
<td></td>
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<tr>
<td>1</td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>0</td>
<td></td>
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</tr>
</tbody>
</table>

- **Reserved for future expansion**
- **DPS**: Data Pointer Register Select
  - 0: Selects DPTR Registers DP0, DP0H
  - 1: Selects DPTR Registers DP1, DP1H
Programmable Clock Out

A 60% duty cycle clock can be programmed to come out on 
P10, as shown in Figure 8. This pin, besides being a regu-
lar IO pin, has two alternate functions. It can be pro-
grammed to input the external clock for TimerCounter 2 or
to output a 50% duty cycle clock ranging from 0.1 Hz to 4 
MHz at a 16 MHz operating frequency.

To configure the TimerCounter 2 as a clock generator, bit
C72 (T2CON.1) must be cleared and bit T2OE (T2MOD.1) 
must be set. Bit TF2 (T2CON.2) starts and stops the timer.
The clock-out frequency depends on the oscillator fre-
cuency and the reload value of Timer 2 captures registers 
(RCAP2H, RCAF2L) as shown in the following equation:

\[
\text{Clock Out Frequency} = \frac{\text{Oscillator Frequency}}{4 \times (\text{RCAP2H}, \text{RCAP2L})}
\]

In the clock-out mode, Timer 2 rollovers will not generate
an interrupt. This behavior is similar to when Timer 2 is
used as a baud-rate generator. It is possible to use Timer 2
as a baud-rate generator and a clock generator simulta-
neously. Note, however, that the baud-rate and clock-out
frequencies cannot be determined independently from one
another since they both use RCAP2H and RCAP2L.

Interrupts

The AT90S52 has a total of six interrupt vectors: two exter-
nal interrupts (INT0 and INT1), three timer interrupts (Tim-
ers 0, 1, and 2), and the serial port interrupt. These
interrupts are all shown in Figure 10.

Each of these interrupt sources can be individually enabled
doing completely or clearing a bit in Special Function
Register IE. IE also contains a global disable bit, EA, which
disables all interrupts at once.

Note that Table 5 shows that bit position IE.6 is unimp-
lemented. In the AT90S52, bit position IE.6 is also unim-
plemented. User software should not write 1 to those bit
positions, since they may be used in future AT90 products.

Timer 2 interrupt is generated by the logical OR of bits TF2
and EXF2 in register T2CON. Neither of these flags is
cleared by hardware when the service routine is vectored
to. In fact, the service routine may have to determine
whether it was TF2 or EXF2 that generated the interrupt,
and that bit will have to be cleared in software.

The Timer 0 and Timer 1 flags, TF0 and TF1, are set at
S7P2 of the cycle in which the timer overflows. The values
are then polled by the circuit in the next cycle. However,
the Timer 2 flag, TF2, is set at S7P2 and is polled in the
same cycle in which the timer overflows.

Table 5. Interrupt Enable (IE) Register

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Position</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA</td>
<td>IE 7</td>
<td>Disables all interrupts. If EA = 0, no interrupts are acknowledged. If EA = 1, each interrupt source is individually enabled or disabled by setting or clearing its enable bit.</td>
</tr>
<tr>
<td>IE.6</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>IE.5</td>
<td>Timer 2 interrupt enable bit</td>
<td></td>
</tr>
<tr>
<td>IE.4</td>
<td>Serial Port interrupt enable bit</td>
<td></td>
</tr>
<tr>
<td>IE.3</td>
<td>Timer 1 interrupt enable bit</td>
<td></td>
</tr>
<tr>
<td>IE.2</td>
<td>External interrupt enable bit</td>
<td></td>
</tr>
<tr>
<td>IE.1</td>
<td>Timer 0 interrupt enable bit</td>
<td></td>
</tr>
<tr>
<td>IE.0</td>
<td>External interrupt enable bit</td>
<td></td>
</tr>
</tbody>
</table>

User software should never write 1 to unimplemented bits, because they may be used in future AT90 products.

Figure 10. Interrupt Sources

![Diagram of interrupt sources](image)
Oscillator Characteristics

XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier that can be configured to use as an on-chip oscillator, as shown in Figure 11. Either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven, as shown in Figure 12. There are no requirements on the duty cycle of the external clock signal, since the output to the internal clocking circuitry is through a divide-by-two flip-flop, but minimum and maximum voltage high and low time specifications must be observed.

Idle Mode

In idle mode, the CPU puts itself to sleep while all the on-chip peripherals remain active. The mode is invoked by software. The content of the on-chip RAM and all the special functions registers remain unchanged during this mode. The idle mode can be terminated by any enabled interrupt or by a hardware reset. Note that when idle mode is terminated by a hardware reset, the device normally resumes program execution from where it left off, up to two machine cycles before the internal reset algorithm takes control. On-chip hardware inhibits access to internal RAM in this event, but access to the port pins is not inhibited. To eliminate the possibility of an unexpected write to a port pin when idle mode is terminated by a reset, the instruction following the one that invokes idle mode should not write to a port pin or to external memory.

Power-down Mode

In the Power-down mode, the oscillator is stopped, and the instruction that invokes Power-down is the last instruction executed. The on-chip RAM and Special Function Registers retain their values until the Power-down mode is terminated. Exit from Power-down mode can be initiated either by a hardware reset or by an enabled external interrupt. Reset redefines the SFRs but does not change the on-chip RAM. The reset should not be activated before $V_{CC}$ is restored to its normal operating level and must be held active long enough to allow the oscillator to restart and stabilize.

Figure 11. Oscillator Connections

![Oscillator Connections Diagram]

Note: $C1, C2 = 36 \, \text{pf} \leq 10 \, \text{pf}$ for Crystals
$= 46 \, \text{pf} \leq 10 \, \text{pf}$ for Ceramic Resonators

Figure 12. External Clock Drive Configuration

![External Clock Drive Configuration Diagram]

Table 6. Status of External Pins During Idle and Power-down Modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Program Memory</th>
<th>AL</th>
<th>DSR</th>
<th>PARE</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle</td>
<td>Internal</td>
<td>1</td>
<td>1</td>
<td>Data</td>
<td>Data</td>
<td>Data</td>
<td>Data</td>
</tr>
<tr>
<td>Idle</td>
<td>External</td>
<td>1</td>
<td>1</td>
<td>Data</td>
<td>Data</td>
<td>Data</td>
<td>Data</td>
</tr>
<tr>
<td>Power-down</td>
<td>Internal</td>
<td>0</td>
<td>0</td>
<td>Data</td>
<td>Data</td>
<td>Data</td>
<td>Data</td>
</tr>
<tr>
<td>Power-down</td>
<td>External</td>
<td>0</td>
<td>0</td>
<td>Data</td>
<td>Data</td>
<td>Data</td>
<td>Data</td>
</tr>
</tbody>
</table>
Program Memory Lock Bits

The AT89S52 has three lock bits that can be left unprogrammed (U) or can be programmed (P) to obtain the additional features listed in the following table.

<table>
<thead>
<tr>
<th>Program Lock Bits</th>
<th>Protection Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>LB1</td>
<td>LB2</td>
</tr>
<tr>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>P</td>
<td>U</td>
</tr>
<tr>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>P</td>
<td>P</td>
</tr>
</tbody>
</table>

When lock bit 1 is programmed, the logic level of the EA pin is sampled and latched during reset. If the device is powered up without a reset, the latch initializes to a random value and holds that value until reset is activated. The output of EA must agree with the current logic level at that pin in order for the device to function properly.

Programming the Flash – Parallel Mode

The AT89S52 is shipped with the on-chip Flash memory array ready to be programmed. The programming interface needs a high-voltage (12-volt) program enable signal and is compatible with conventional parallel-programmable Flash or EPROM programmers.

The AT89S52 code memory array is programmed byte-by-byte.

Programming Algorithm: Before programming the AT89S52, the address, data, and control signals should be set up as described in the Flash programming mode table and Figures 13 and 14. To program the AT89S52, take the following steps:

1. Input the desired memory location on the address lines.
2. Input the appropriate data byte on the data lines.
3. Activate the correct combination of control signals.
4. Raise \( \text{AV}_{DD} \) to 12V.
5. Pulse \( \text{ALE/PROG} \) once to program a byte in the Flash array or the lock bits. The byte-write cycle is self-timed and typically takes no more than 30 \( \mu \text{s} \).

Repeat steps 1 through 5, changing the address and data for the entire array or until the end of the object file is reached.

Data Polling: The AT89S52 features data polling to indicate the end of a byte write cycle. During a write cycle, an attempted read of the last byte written will result in the complement of the written data on P0.7. After the write cycle has been completed, true data is valid on all outputs, and the next cycle may begin. Data polling may begin any time after a write cycle has been initiated.

Ready Bits: The progress of byte programming can also be monitored by the RDY/BSY output signal. P3.0 is pulled low after ALE goes high during programming to indicate BSY. P3.0 is pulled high again when programming is done to indicate READY.

Program Verify: If lock bits LB1 and LB2 have not been programmed, the programmed code data can be read back while the address and data lines for verification. The status of the individual lock bits can be verified directly by reading them back.

Reading the Signature Bytes: The signature bytes are read by the same procedure as a normal verification of locations 006H, 100H, and 200H, except that P3.0 and P3.7 must be pulled to a logic low. The values returned are as follows:

\[
\begin{align*}
000H &= 1EH \text{ Indicates manufacturer by Atmel} \\
100H &= 52H \text{ Indicates 68052} \\
200H &= 0EH
\end{align*}
\]

Chip Erase: In the parallel programming mode, a chip erase operation is initiated by using the proper combination of control signals and by pulsing ALE/PROG low for a duration of 1200 \( \mu \text{s} \) to 500 \( \mu \text{s} \).

In the serial programming mode, a chip erase operation is initiated by issuing the Chip Erase Instruction. In this mode, chip erase is self-timed and takes about 500 \( \mu \text{s} \). During chip erase, a serial read from any address location will return 00H at the data output.

Programming the Flash – Serial Mode

The code memory array can be programmed using the serial ISP interface while \( \text{RST} \) is pulled to \( \text{V}_{DD} \). The serial interface consists of pins SCK, MOSI (input) and MISO (output). After \( \text{RST} \) is set high, the Programming Enable instruction needs to be executed first before other operations can be executed. Before erasing or reprogramming sequence can occur, a Chip Erase operation is required.

The Chip Erase operation turns the content of every memory location in the Code array to FFH.

Either an external system clock can be supplied at pin \( \text{XTAL1} \) or a crystal needs to be connected across pins \( \text{XTAL1} \) and \( \text{XTAL2} \). The maximum serial clock (SCK)
frequency should be less than 1/10 of the crystal frequency. With a 33 MHz oscillator clock, the maximum SCK frequency is 2 MHz.

Serial Programming Algorithm

To program and verify the AT89S52 in the serial programming mode, the following sequence is recommended:

1. Power-up sequence:
   - Apply power between VCC and GND pins.
   - Set RST pin to “H”.
   - If a crystal is not connected across pins XTAL1 and XTAL2, apply a 3 MHz to 33 MHz clock to XTAL1 pin and wait for at least 10 milliseconds.
2. Enable serial programming by sending the Programming Enable serial instruction to pin MOSI/PA5. The frequency of the shift clock supplied at pin SCK/P1.7 needs to be less than the CPU clock at XTAL1 divided by 16.
3. The Code array is programmed one byte at a time by supplying the address and data together with the appropriate Write instruction. The write cycle is self-timed and typically takes less than 1 ms at 3V.
4. Any memory location can be verified by using the Read instruction which returns the content at the selected address at serial output MOSI/P1.6.
5. At the end of a programming session, RST can be set low to commence normal device operation.

Power-off sequence (if needed):
- Set XTAL1 to “L” (if a crystal is not used).
- Set RST to “L.”
- Turn Vcc Power off.

Data Polling: The Data Polling feature is also available in the serial mode. In this mode during a write cycle an attempted read of the last byte written will result in the complement of the MSB of the serial output byte on MOSI.

Serial Programming Instruction Set

The Instruction Set for Serial Programming follows a 4-byte protocol and is shown in Table 19.
Octal High Voltage, High Current Darlington Transistor Arrays

The eight MN Darlington connected transistors in this family of arrays are ideally suited for interfacing between low level digital circuitry (such as TTL, CMOS or PMOS/NMOS) and the higher current/voltage requirements of relays, solenoids, power heaters or other similar loads for a broad range of computer, industrial, and consumer applications. All devices feature open-collector outputs and free-wheeling clamp diodes for transient suppression.

The ULN2803 is designed to be compatible with standard TTL families while the ULN2804 is optimized for 6 to 15 volt high level CMOS or PMOS.

MAXIMUM RATINGS (Ta = 25°C and rating apply to any one device in the package unless otherwise noted)

<table>
<thead>
<tr>
<th>Rating</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage</td>
<td>VO</td>
<td>50</td>
<td>V</td>
</tr>
<tr>
<td>Input Voltage Excess (ULN2803)</td>
<td>VIL</td>
<td>30</td>
<td>V</td>
</tr>
<tr>
<td>Collector Current - Continuous</td>
<td>Ic</td>
<td>600</td>
<td>mA</td>
</tr>
<tr>
<td>Base Current - Continuous</td>
<td>IB</td>
<td>25</td>
<td>mA</td>
</tr>
<tr>
<td>Operating Ambient Temperature-Range</td>
<td>TA</td>
<td>0 to +70</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>Tstg</td>
<td>-65 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>Junction Temperature</td>
<td>TJ</td>
<td>150</td>
<td>°C</td>
</tr>
</tbody>
</table>

*Note: Ta = 25°C

ORDERING INFORMATION

<table>
<thead>
<tr>
<th>Device</th>
<th>Characteristics</th>
<th>Input Compatibility</th>
<th>VIL (Max)/VIL (Min)</th>
<th>Operating Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>ULN2803A</td>
<td>ULN2804A</td>
<td>5V, 5V</td>
<td>5V</td>
<td>0 to +70 °C</td>
</tr>
<tr>
<td>ULN2804A</td>
<td>ULN2804A</td>
<td>5V, 5V</td>
<td>5V</td>
<td>0 to +70 °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ULN2803 ULN2804

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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Leakage Current (Figure 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(V_CE = 50 V, I_C = 0°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Types</td>
<td>I_CEX</td>
<td>–</td>
<td>–</td>
<td>100</td>
<td>µA</td>
</tr>
<tr>
<td>(V_CE = 50 V,</td>
<td>6°C)</td>
<td>All Types</td>
<td>–</td>
<td>–</td>
<td>50</td>
</tr>
<tr>
<td>(V_CE = 50 V,</td>
<td>70°C,</td>
<td>T_A = 0.5 V)</td>
<td>All Types</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>(V_CE = 50 V,</td>
<td>70°C,</td>
<td>T_A = 1.8 V)</td>
<td>ULN2802</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Collector-Emitter Saturation Voltage (Figure 2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(I_C = 200 mA,</td>
<td>500 µA)</td>
<td>All Types</td>
<td>–</td>
<td>1.1</td>
<td>0.5</td>
</tr>
<tr>
<td>(I_C = 200 mA,</td>
<td>500 µA)</td>
<td>All Types</td>
<td>–</td>
<td>0.95</td>
<td>1.3</td>
</tr>
<tr>
<td>(I_C = 100 mA,</td>
<td>250 µA)</td>
<td>All Types</td>
<td>–</td>
<td>0.65</td>
<td>1.1</td>
</tr>
<tr>
<td>Input Current - On Condition (Figure 4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(V_CE = 7 V,</td>
<td>–</td>
<td>ULN2802</td>
<td>–</td>
<td>6.35</td>
<td>0.5</td>
</tr>
<tr>
<td>(V_CE = 3.3 V,</td>
<td>–</td>
<td>ULN2803</td>
<td>–</td>
<td>6.35</td>
<td>0.5</td>
</tr>
<tr>
<td>(V_CE = 5 V,</td>
<td>–</td>
<td>ULN2804</td>
<td>–</td>
<td>1.0</td>
<td>1.46</td>
</tr>
<tr>
<td>(V_CE = 12 V,</td>
<td>–</td>
<td>ULN2804</td>
<td>–</td>
<td>1.0</td>
<td>1.46</td>
</tr>
<tr>
<td>Input Voltage - On Condition (Figure 5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(V_CE = 20 V,</td>
<td>–</td>
<td>ULN2802</td>
<td>–</td>
<td>13</td>
<td>–</td>
</tr>
<tr>
<td>(V_CE = 20 V,</td>
<td>–</td>
<td>ULN2803</td>
<td>–</td>
<td>2.4</td>
<td>–</td>
</tr>
<tr>
<td>(V_CE = 20 V,</td>
<td>–</td>
<td>ULN2804</td>
<td>–</td>
<td>2.7</td>
<td>–</td>
</tr>
<tr>
<td>(V_CE = 20 V,</td>
<td>–</td>
<td>ULN2804</td>
<td>–</td>
<td>3.0</td>
<td>–</td>
</tr>
<tr>
<td>(V_CE = 20 V,</td>
<td>–</td>
<td>ULN2804</td>
<td>–</td>
<td>5.0</td>
<td>–</td>
</tr>
<tr>
<td>(V_CE = 20 V,</td>
<td>–</td>
<td>ULN2804</td>
<td>–</td>
<td>10</td>
<td>–</td>
</tr>
<tr>
<td>(V_CE = 20 V,</td>
<td>–</td>
<td>ULN2804</td>
<td>–</td>
<td>2.0</td>
<td>–</td>
</tr>
<tr>
<td>Input Current - Off Condition (Figure 6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(I_C = 900 nA,</td>
<td>–</td>
<td>ULN2801</td>
<td>–</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>(V_CE = 50 V,</td>
<td>–</td>
<td>ULN2801</td>
<td>–</td>
<td>1000</td>
<td>–</td>
</tr>
<tr>
<td>DC Current Gain (Figure 2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(V_CE = 20 V,</td>
<td>–</td>
<td>ULN2802</td>
<td>–</td>
<td>50</td>
<td>–</td>
</tr>
<tr>
<td>(V_CE = 50 V,</td>
<td>–</td>
<td>ULN2803</td>
<td>–</td>
<td>50</td>
<td>–</td>
</tr>
<tr>
<td>(V_CE = 70 V,</td>
<td>–</td>
<td>ULN2804</td>
<td>–</td>
<td>50</td>
<td>–</td>
</tr>
<tr>
<td>Turn-On Delay Time (50% to 50% E_C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Capacitance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(50% E_C to 50% E_C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-Off Delay Time (50% to 50% E_C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clamp Collector Leakage Current (Figure 6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(V_CE = 20 V,</td>
<td>–</td>
<td>ULN2802</td>
<td>–</td>
<td>50</td>
<td>–</td>
</tr>
<tr>
<td>(V_CE = 50 V,</td>
<td>–</td>
<td>ULN2803</td>
<td>–</td>
<td>50</td>
<td>–</td>
</tr>
<tr>
<td>Clamp Collector Forward Voltage (Figure 7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(I_C = 500 mA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ULN2803 ULN2804

OUTLINE DIMENSIONS

A SUFFIX
PLASTIC PACKAGE
CASE 707-02
ISSUE C

NOTES:
2. TOLERANCES WHERE NOT SPECIFIED ARE ±0.25 mm (0.010 IN).
3. ALL DIMENSIONS ARE IN MILLIMETERS AND INCHES.
4. TOLERANCES WHERE NOT SPECIFIED ARE ±0.25 mm (0.010 IN).
5. MATERIAL CONDITION: MILL-FINISHED.
6. DIMENSIONS DO NOT INCLUDE MOLD FLASH.
Instruksi-instruksi Keluarga MCS51

A. Operasi Aritmatika

1. ADD

   **ADD A,Rn**
   
   Tambahkan Akumulator A dengan Rn di mana n = 0…7 dan simpan hasil di Akumulator A
   
   Contoh:
   
   Add A,R7
   
   Isi dari R7 akan ditambahkan dengan akumulator A dan hasilnya disimpan di Akumulator A

   **ADD A,direct**

   Tambahkan Akumulator A dengan data di alamat memori tertentu secara langsung.
   
   Contoh:
   
   Add A,00H
   
   Isi dari Akumulator A akan ditambahkan dengan isi dari memori RAM Internal di alamat 00H

   **ADD A,@Ri**

   Tambahkan Akumulator A dengan data yang berada di alamat Ri (ditunjuk oleh Ri) dan hasilnya disimpan di Akumulator A. Ri adalah Register Index di mana pada MCS51 adalah berupa R0 atau R1
   
   Contoh:
   
   Add A,@R0
   
   Isi dari Akumulator A akan ditambahkan dengan isi dari memori RAM Internal yang ditunjuk oleh R0. Apabila R0 berisi 05H maka, isi dari alamat 05H akan dijumlahkan dengan Akumulator A dan hasilnya disimpan di Akumulator A

   **ADD A,#data**

   Tambahkan Akumulator A dengan sebuah konstanta dan hasilnya disimpan dalam akumulator A.
Contoh:
Add A,#05H
Isi Akumulator A ditambah dengan data 05H dan hasilnya disimpan dalam Akumulator A

2. ADDC

ADDC A,Rn
Tambahkan Akumulator A dengan Rn di mana n = 0…7 dan simpan hasil di Akumulator A
Contoh:
Addc A,R7
Isi dari R7 akan ditambahkan dengan akumulator A beserta carry flag dan hasilnya disimpan di Akumulator A. Apabila carry flag set maka hasil yang tersimpan di Akumulator A adalah A + R7 + 1.

ADDC A,direct
Tambahkan Akumulator A dan carry flag dengan data di alamat memori tertentu secara langsung.
Contoh:
Addc A,00H
Isi dari Akumulator A akan ditambahkan dengan isi dari memori RAM Internal di alamat 00H beserta carry flag dan hasilnya disimpan di Akumulator A, Apabila carry flag set maka hasil yang tersimpan di Akumulator A adalah A + isi alamat 00H + 1

ADDC A,@Ri
Tambahkan Akumulator A beserta carry flag dengan data yang berada di alamat Ri (ditunjuk oleh Ri) dan hasilnya disimpan di Akumulator A. Ri adalah Register Index di mana pada MCS51 adalah berupa R0 atau R1

ADDC A,#data
Tambahkan Akumulator A beserta carry flag dengan sebuah konstanta dan hasilnya disimpan dalam akumulator A.
Contoh:
Addc A,#05H Isi Akumulator A beserta carry flag ditambah dengan data 05H dan hasilnya disimpan dalam Akumulator A. Apabila carry flag set maka hasil di Akumulator A adalah A + 5H + 1.

3. SUBB

**SUBB A,Rn**
Lakukan pengurangan data di Akumulator A dengan Rn (n = 0…7) dan simpan hasilnya di Akumulator A
Contoh:
Subb A,R0
Data di akumulator A beserta carry flagnya dikurangi dengan isi R0 dan hasilnya disimpan di Akumulator A

**SUBB A,direct**
Lakukan pengurangan data di Akumulator A dengan data di memori tertentu yang ditunjuk secara langsung.
Contoh:
Subb A,00H
Data di Akumulator A beserta carry flagnya dikurangi dengan data dialamat 00H dari RAM Internal dan hasilnya disimpan di Akumulator A

**SUBB A,@Ri**
Lakukan pengurangan data di Akumulator A beserta carry flag dengan data yang ditunjuk oleh Ri (Register Index) di mana Ri dapat berupa R0 atau R1
Contoh:
SUBB A,@R0
Data di Akumulator A beserta carry flagnya dikurangi dengan data yang ditunjuk oleh R0 dan hasilnya disimpan di Akumulator A

**SUBB A,#data**
Lakukan pengurangan data di Akumulator A beserta carry flag dengan sebuah konstanta dan hasilnya disimpan di Akumulator A
Contoh:
SUBB A,#05H
Data di Akumulator A beserta carry flag dikurangi dengan data 05H dan hasilnya disimpan di Akumulator A

4. INC

INC A
Tambahkan nilai Akumulator A dengan 1 dan hasilnya disimpan di Akumulator A

INC Rn
Tambahkan nilai Rn (n= 0…7) dengan 1 dan hasilnya disimpan di Rn tersebut

INC direct
Tambahkan data yang di RAM Internal yang alamatnya ditunjuk secara langsung dengan 1 dan hasilnya disimpan di alamat tersebut.

Contoh:
Inc 00H
Data di alamat 00H ditambah dengan 1 dan hasilnya disimpan di alamat 00H.

INC @Ri
Tambahkan data yang alamatnya ditunjuk oleh Ri (Register Index) dengan 1 dan simpan hasilnya di alamat tersebut.

Contoh:
Inc @R1
Data di alamat yang ditunjuk oleh R1 dan hasilnya disimpan di alamat tersebut, apabila R1 berisi 10H maka data di alamat 10H ditambah dengan 1 dan simpan kembali di alamat 10H.

INC DPTR

5. DEC

DEC A
Lakukan pengurangan pada nilai Akumulator A dengan 1 dan hasilnya disimpan di Akumulator A

DEC Rn
Lakukan pengurangan pada nilai Rn (n= 0…7) dengan 1 dan hasilnya disimpan di Rn tersebut
**DEC direct**
Lakukan pengurangan pada data yang di RAM Internal yang alamatnya ditunjuk secara langsung dengan 1 dan hasilnya disimpan di alamat tersebut.
Contoh:
Dec 00H
Data di alamat 00H dikurangi dengan 1 dan hasilnya disimpan di alamat 00H.

**DEC @Ri**
Lakukan pengurangan pada data yang alamatnya ditunjuk oleh Ri (Register Index) dengan 1 dan simpan hasilnya di alamat tersebut.
Contoh:
DEC @R1
Data di alamat yang ditunjuk oleh R1 dan hasilnya disimpan di alamat tersebut, apabila R1 berisi 10H maka data di alamat 10H dikurangi dengan 1 dan simpan kembali di alamat 10H.

**B. Operasi Logika dan Manipulasi Bit**

1. **ANL**

**ANL A,Rn**
Melakukan operasi AND antara akumulator A dan Rn (R0…R7) dan hasilnya disimpan di akumulator A

**ANL A,direct**
Melakukan operasi AND antara akumulator A dan alamat langsung dan hasilnya disimpan di akumulator A.
Contoh:
ANL A,05H
Akumulator A di AND dengan data di alamat 05H dan hasilnya disimpan di akumulator A

**ANL A,@Ri**
Melakukan operasi AND antara akumulator A dan data yang ditunjuk oleh Register Index (R0 atau R1) serta hasilnya disimpan di akumulator A.
Contoh:
ANL A,@R0
Akumulator A di AND dengan data yang ditunjuk oleh R0, misalkan R0 berisi 50H, maka akumulator A di AND dengan data yang tersimpan di alamat 50H dan hasilnya disimpan di akumulator A.

**ANL A,#data**
Melakukan operasi AND antara akumulator A dan immediate data serta hasilnya disimpan di akumulator A.

**ANL direct,A**
Melakukan operasi AND antara alamat langsung dengan akumulator A serta hasilnya disimpan di alamat langsung tersebut.

Contoh:
ANL 07H,A
Data di alamat 07H di AND dengan akumulator A dan hasilnya kembali disimpan di alamat 07H

**ANL direct,#data**
Melakukan operasi AND antara alamat langsung dengan immediate data serta hasilnya disimpan di alamat langsung tersebut.

2. **ORL**

**ORL A,Rn**
Melakukan operasi OR antara akumulator A dan Rn (R0…R7) dan hasilnya disimpan di akumulator A.

**ORL A,direct**
Melakukan operasi OR antara akumulator A dan alamat langsung dan hasilnya disimpan di akumulator A.

Contoh:
ORL A,05H
Akumulator A di OR dengan data di alamat 05H dan hasilnya disimpan di akumulator A.

**ORL A,@Ri**
Melakukan operasi OR antara akumulator A dan data yang ditunjuk oleh Register Index (R0 atau R1) serta hasilnya disimpan di akumulator A.
Contoh:

**ORL A, @R0**

Akumulator A di OR dengan data yang ditunjuk oleh R0, misalkan R0 berisi 50H, maka akumulator A di OR dengan data yang tersimpan di alamat 50H dan hasilnya disimpan di akumulator A.

**ORL A, #data**

Melakukan operasi OR antara akumulator A dan immediate data serta hasilnya disimpan di akumulator A.

**ORL direct, A**

Melakukan operasi OR antara alamat langsung dengan akumulator A serta hasilnya disimpan di alamat langsung tersebut.

Contoh:

**ORL 07H,A**

Data di alamat 07H di OR dengan akumulator A dan hasilnya kembali disimpan di alamat 07H.

**ORL direct, #data**

Melakukan operasi OR antara akumulator A dan immediate data serta hasilnya disimpan di akumulator A.

3. **CLR**

**CLR A**

Memberikan nilai 0 pada 8 bit Akumulator A.

4. **CPL**

**CPL A**

Melakukan komplemen pada setiap bit dalam akumulator A.

Contoh:

Bila nilai akumulator A adalah 55H atau 01010101b, maka setelah terjadi proses komplemen nilai akumulator A berubah menjadi AAH atau 10101010b.

5. **RL**

**RL A**

Melakukan pergeseran ke kiri 1 bit untuk setiap bit dalam akumulator A.
Contoh:
Nilai Akumulator A adalah 05H atau 00000101b, setelah dilakukan proses pergeseran maka nilai Akumulator A akan berubah menjadi 00001010b atau 0AH.

6. **RR**

**RR A**
Melakukan pergeseran ke kanan 1 bit untuk setiap bit dalam akumulator A
Contoh:
Nilai Akumulator A adalah 05H atau 00000101b, setelah dilakukan proses pergeseran maka nilai Akumulator A akan berubah menjadi 10000010b atau 0AH.

7. **SWAP**

**SWAP A**
Melakukan operasi penukaran nibble tinggi dan nibble rendah di akumulator A
Contoh:
Isi akumulator A adalah 51H, setelah instruksi SWAP A dilakukan maka data 5 di nibble tinggi akan ditukar dengan data 1 di nibble rendah menjadi 15H

8. **SETB**

**SETB bit**
Set bit atau mengubah bit-bit pada RAM Internal maupun register yang dapat dialamat secara bit (bit addressable) menjadi 1

9. **JC**

**JC rel**
Melakukan lompatan ke suatu alamat yang didefinisikan apabila carry flag set. Apabila carry flag clear maka program akan menjalankan instruksi selanjutnya.
Contoh:
JC Alamat1
Mov A,#05H
Alamat1: Mov R1,#00H
Apabila carry flag set, maka program akan lompat label alamat 1 dan menjalankan instruksi Mov R1,#00H, namun bila carry flag clear maka program akan menjalankan instruksi Mov A,#05H terlebih dahulu sebelum menjalankan instruksi di label alamat 1.

10 JNC

JNC rel
Melakukan lompatan ke suatu alamat yang didefinisikan apabila carry flag clear. Apabila carry flag set maka program akan menjalankan instruksi selanjutnya.

Contoh:
Jnc Alamat1
Mov A,#05H
Alamat1: Mov R1,#00H

Apabila carry flag clear, maka program akan lompat label alamat 1 dan menjalankan instruksi Mov R1,#00H, namun bila carry flag set maka program akan menjalankan instruksi Mov A,#05H terlebih dahulu sebelum menjalankan instruksi di label alamat 1.

C. Transfer Data

1. MOV

MOV A,Rn
Melakukan pemindahan data dari Rn (R0…R7) menuju ke akumulator A

MOV A,direct
Melakukan pemindahan data dari alamat langsung ke akumulator A

Mov A,@Ri
Melakukan pemindahan data dari alamat yang ditunjuk oleh Register Index (R0 atau R1) menuju ke akumulator A

Mov A,#data
Melakukan pemindahan data dari immediate menuju ke akumulator A

Contoh:
Data EQU 05H
Mov A,#Data
Konstanta Data yang dideklarasikan sebagai 05H dipindah ke akumulator A sehingga nilai akumulator A menjadi 05H

**Mov Rn,A**

Melakukan pemindahan data dari akumulator A menuju ke Rn (R0…R7)

**Mov Rn,direct**

Melakukan pemindahan data dari alamat langsung menuju ke Rn (R0…R7)

Contoh:

Mov R7,10H

Data di alamat 10H dipindah ke dalam R7

**Mov Rn,#data**

Melakukan pemindahan data dari immediate menuju ke Rn (R0…R7)

Contoh:

Mov R7,#05H

Data 05H dipindah ke dalam R7

**Mov direct,A**

Melakukan pemindahan data dari akumulator A menuju ke alamat langsung

Contoh:

Mov 10H,A

Data di akumulator A dipindah ke alamat 10H

**Mov direct,Rn**

Melakukan pemindahan data dari Rn (R0…R7) menuju ke alamat langsung

**Mov direct,direct**

Melakukan pemindahan data dari alamat langsung menuju ke alamat langsung.

**Mov direct,@Ri**

Melakukan pemindahan data dari alamat yang ditunjuk oleh Register Index (R0 atau R1) ke alamat langsung

Contoh:

Mov 05H,@R0
Bila R0 sebelumnya berisi 20H, maka nilai atau data yang tersimpan di alamat 20H akan dipindah ke alamat 05H.

**Mov direct,#data**
Melakukan pemindahan data dari immediate ke alamat langsung.

**Mov @Ri,A**
Melakukan pemindahan data dari akumulator A menuju ke alamat yang ditunjuk oleh Register Index (R0 atau R1).

**Mov @Ri,direct**
Melakukan pemindahan data dari alamat langsung menuju ke alamat yang ditunjuk oleh Register Index (R0 atau R1)

**Mov @Ri,#data**
Melakukan pemindahan data immediate menuju ke alamat yang ditunjuk oleh Register Index (R0 atau R1)

**Mov DPTR,#data16**
Melakukan pemindahan data immediate 16 bit menuju ke DPTR.

Contoh:
Mov DPTR,#2000H
Data 2000H dalam bentuk 16 bit dipindah ke alamat Register DPTR

**Movc A,@A+DPTR**
Contoh:
Mov A,#50H
Mov DPTR,#2000H
Movc A,@A+DPTR
Data yang terletak di komponen memori di luar AT89S51 dan terletak pada alamat 2000H + 50H akan dibaca dan hasilnya disimpan di akumulator A

**D. Percabangan**

1. **ACALL**

   **ACALL addr11**
Melakukan lompatan ke suatu subroutine yang ditunjuk oleh alamat pada addr11. Lompatan yang dapat dilakukan berada di area sebesar 2K byte.
2. RET

RET
Instruksi ini digunakan pada saat kembali dari subroutine yang dipanggil dengan instruksi ACALL atau LCALL.

RETI
Instruksi ini digunakan untuk melompat ke alamat tempat akhir instruksi yang sedang dijalankan ketika.

3. JUMP

LJMP addr16
Long Jump, melompat dan menjalankan program yang berada di alamat yang ditentukan oleh addr16.
Contoh:
LJMP Lompatan2
Mov A,#05H
Lompatan2: Mov R0,#00H
Program akan melompat ke alamat lompatan 2 dan menjalankan instruksi Mov R0,#00H, tanpa melalui instruksi MOV A,#05H

JZ rel
Melakukan lompatan ke alamat yang ditentukan apabila akumulator A adalah 00H dan langsung meneruskan instruksi dibawahnya bila akumulator A tidak 00H.
Contoh:
JZ Lompat1
MOV A,#07H
Lompat1: MOV B,#00H
Apabila nilai akumulator A tidak 00H maka program akan langsung meneruskan instruksi dibawahnya yaitu MOV A,#07H dan program akan menjalankan instruksi di alamat Lompat1 yaitu MOV B,#00H apabila nilai akumulator A adalah 00H.
JNZ rel
Melakukan lompatan ke alamat yang ditentukan apabila akumulator A adalah bukan 00H dan langsung meneruskan instruksi dibawahnya bila akumulator A adalah 00H.
Contoh:
JNZ Lompat1
MOV A,#07H
Lompat1: MOV B,#00H
Apabila nilai akumulator A adalah 00H maka program akan langsung meneruskan instruksi dibawahnya yaitu MOV A,#07H dan program akan menjalankan instruksi di alamat Lompat1 yaitu MOV B,#00H apabila nilai akumulator A adalah bukan 00H.

4. CJNE
Instruksi ini melakukan perbandingan antara data tujuan dan data sumber serta melakukan lompatan ke alamat yang ditentukan apabila hasil perbandingan tidak sama.

CJNE A,#data,rel
Melakukan perbandingan antara akumulator A dan data immediate serta melakukan lompatan ke alamat yang ditentukan apabila hasil perbandingan tidak sama.
Contoh:
CJNE A,#00H,lompat1
Program akan menuju ke alamat lompat 1 apabila data akumulator A tidak sama dengan data 00H..

5. DJNZ

DJNZ Rn,rel
Melakukan pengurangan pada Rn (R0…R7) dengan 1 dan lompat ke alamat yang ditentukan apabila hasilnya bukan 00.
Apabila hasilnya telah mencapai 00, maka program akan terus menjalankan instruksi di bawahnya.
Contoh:
Tunggu: DJNZ R7,Tunggu
RET
Selalu melakukan lompatan ke alamat tunggu dan mengurangi R7 dengan 1 selama nilai R7 belum mencapai 00

6. NOP

NOP

Instruksi ini berfungsi untuk melakukan tundaan pada program sebesar 1 cycle tanpa mempengaruhi register-register maupun flag.