# Contents

**Preface**

1. Instrumentation amplifiers 1
   1.1 Single op amp instrumentation amplifiers 2
   1.2 Two op amp instrumentation amplifiers 6
   1.3 Three op amp instrumentation amplifiers 8
   1.4 Matched transistor instrumentation amplifiers 12
   1.5 Using instrumentation amplifiers with transducers 18
   1.6 Commercial single ic instrumentation amplifiers 18

2. Isolation amplifiers 25
   2.1 Isolation amplifier using modulation and demodulation 26
   2.2 Isolation amplifier using linearizing feedback 27
   2.3 Commercial isolation amplifiers 30

3. Charge amplifiers 31
   3.1 Current integrating charge amplifier 31
   3.2 High input impedance charge amplifier 34

4. Current-to-voltage and voltage-to-current converters 37
   4.1 A simple current-to-voltage converter 37
   4.2 A current-to-voltage converter using a single op amp 38
   4.3 Voltage-to-current conversion using a single op amp 43
   4.4 A unipolar transconductance amplifier 48
   4.5 A differential input voltage-to-current converter 52
   4.6 Operational transconductance amplifiers 55

5. Controlled amplifiers 59
   5.1 Some approaches to voltage controlled amplification 59
   5.2 Commercial voltage controlled amplifiers 61
   5.3 Automatic gain control (AGC) 62
   5.4 Digitally controlled amplifiers 63

6. Active filter design 71
   6.1 Filter transfer functions 72
   6.2 Filter circuits 80
      - Low pass filter circuits 80
      - High pass filter circuits 88
      - Bandpass filter circuits 94
      - Band reject filters 99
      - All pass filter circuits 104
Table of Contents

Contents

State variable filters 106
Summary 110

6.3 Controlled filters 111

6.4 Practical aspects of filter circuit design 119
  Sensitivity 119
  Tuning 120
  Component selection 123
  Stability of filters 125

6.5 Designing high order filters 125
  Determining the required transfer function 127
  Transformation and scaling 136
  From transfer function to circuitry 140

7 Integrators and differentiators 143
7.1 Integration 143
7.2 Differentiators 152

8 Log and antilog converters 161
8.1 Log converters 161
8.2 Antilog converters 177
8.3 Commercial log and antilog converters 183

9 Arithmetical operations 185
9.1 Addition and subtraction 185
9.2 Multipliers 189
  Multiplier operation and errors 190
  Converting a multiplier to a divider 193
  Summary of popular multiplier circuits 194
  FET controlled resistor multiplier 196
  Variable transconductance multiplier 196
  Log–antilog multiplier 200
  A pulse width/pulse height multiplier 203
  Multipliers using D/A and A/D converters 207
9.3 Commercial analog multipliers 207

10 Function generating circuits 209
10.1 Function generating circuits using analog multipliers 209
10.2 Log–antilog function generators 214
  Sine 217
  Cosine 218
  $\tan^{-1}$ (arctan) 218
10.3 Breakpoint function generators 219
10.4 Function generating circuits using A/D and D/A converters 222

11 Limiters, peak detectors and rectifiers 223
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.2 Peak detectors</td>
<td></td>
</tr>
<tr>
<td>Basic peak detectors</td>
<td>231</td>
</tr>
<tr>
<td>Two stage peak detectors</td>
<td>233</td>
</tr>
<tr>
<td>Overall feedback peak detector</td>
<td>234</td>
</tr>
<tr>
<td>Improving peak detector performance</td>
<td>236</td>
</tr>
<tr>
<td>Notes on component selection</td>
<td>242</td>
</tr>
<tr>
<td>Peak detectors using IC building blocks</td>
<td>245</td>
</tr>
<tr>
<td>11.3 Half wave precision rectifiers</td>
<td>246</td>
</tr>
<tr>
<td>11.4 Full wave rectifiers</td>
<td></td>
</tr>
<tr>
<td>Single op amp full wave rectifier</td>
<td>248</td>
</tr>
<tr>
<td>Current output full wave rectifier</td>
<td>249</td>
</tr>
<tr>
<td>Current input full wave rectifier</td>
<td>250</td>
</tr>
<tr>
<td>Two op amp full wave rectifier with minimum components</td>
<td>250</td>
</tr>
<tr>
<td>General purpose full wave rectifier</td>
<td>251</td>
</tr>
<tr>
<td>Current summing full wave rectifier</td>
<td>252</td>
</tr>
<tr>
<td>General notes on rectifier circuits</td>
<td>253</td>
</tr>
<tr>
<td>12 Peak, average and RMS circuits</td>
<td></td>
</tr>
<tr>
<td>12.1 Peak responding circuits</td>
<td>259</td>
</tr>
<tr>
<td>12.2 Mean absolute value circuits</td>
<td>262</td>
</tr>
<tr>
<td>12.3 Root mean square circuits</td>
<td>262</td>
</tr>
<tr>
<td>12.4 Thermal RMS converters</td>
<td>271</td>
</tr>
</tbody>
</table>

**Bibliography**

**Index**