Index

active filters, see filters
addition and subtraction
  basic circuits, 185, 189
  calculating resistor values, 187
design notes, 187–9
all-pass filter
  Bode plots, 74, 79
  current generalized immittance, 105
  ideal response, 72, 74
  single pole, 104
  tuning, 122
amplifier, see charge, controlled, instrumentation,
  transconductance, transresistance
analog filter, see filters
analog multiplier, see multiplier
analog switch, 63, 65, 145, 241, 259
analog to digital converter (ADC), 207, 222
analog converter
  basic circuit, 177
  commercial devices, selection of, 182
  component selection for, 181–3
  practical circuit, 180
SSM-2100 log converter, 183
transdiode and diode connected transistor circuits, 178
trimming the output of, 181
arctan, 211, 219
arithmetic operations, see addition
  and subtraction, division, multipliers
automatic gain control (AGC), 62
bipolar transistors
  bulk resistance of, 162, 166, 167
  for transconductance amplifier, 49,
  51
  increase slew rate with, 240
  log relationship of, 163–5
  matched pair, 12
  protection diodes for, 164–5
  selection of, 176, 181
  board cleaning, see printed circuit board
  bootstrap, 11
brick wall filter response, 71–2
Butterworth, 91, 127–33
cables (leads)
  droop from, 231, 236, 242
  for charge amplifier, 31
  for rms measurements, 269
  frequency response of, 42
capacitive coupling, 26
capacitors
  for charge amplifier, 33, 36
  for differentiator, 160
  for filter design, 124
  for integrator, 146, 152
  using T-network, 157
charge amplifier
  cable for, 31
  capacitors for, 33, 36
  current integrating type, 31–4
  defined, 31
  high input impedance type, 34–6
  noise performance, 33–4
Chebyshev, 128–35
  common mode rejection ratio, 2–5,
  7–9, 14–15, 16–17, 20–1, 25, 47,
  53–9, 158, 189
  controlled amplifier, see voltage controlled amplifier (VCA), digitally controlled amplifier, automatic gain control
  defined, 111–13
  digitally controlled, 113–14
  using switched capacitors, 115–18
  voltage controlled, 113–14
cosine, 211, 218
crest factor, 258, 267
current booster, 44
current generalized immittance, 87–8, 93–4, 97, 101, 105
current to voltage converter (transresistance)
  circuits, 38–43
  defined, 37–8
  frequency response, 42
  gain errors, 41
  interference, 42
  noise, 42
  offset errors, 40
  using a photodiode, 43
differentiator
  basic circuit, 152–3
  circuits, 156–9
  design problems with, 153–6
  frequency instability of, 153
  noise, 155
  offset errors, 155
  op amps and capacitors for, 159–60
differential amplifier, see instrumentation amplifier
digitally controlled amplifier
  switched in dB, 69
  using analog switches, 63–4
  using digital to analog converters, 65–9
digital filter, 71
digital to analog converter (DAC), 65, 69, 111, 114–15, 207, 222, 246
diode
  and droop, 238, 244
  and peak detection, 231
  and rectifiers, 247, 248, 252, 255
  bridge, 227, 249
  bulk resistance, 162, 166, 167
  diode connected transistor, 163
  diode equation, 161
  for limiters, 223, 230
  function generator, 221
  linearizing, 57
  photodiode, 43
  protection for transistors, 48, 164,
  202
  protection with inductive loads, 45
  transdiode connected transistor, 164
division, 193, 217
Index

electrical isolation, 25
error budget, 19–24

FET, 17, 60, 61, 145, 241
filters
and basic filter types, 71–2
and transfer functions, 72–80,
127–36
cascade design, 140–1
designing higher order filters,
125–41
RLC ladder simulation, 140–1
selection of capacitors for, 124
selection of op amps for, 123
selection of resistors for, 123–4
sensitivity, 119–20
stability of, 125
summary of active filter properties,
111
transformation and scaling, 136–9
tuning, 120–2
see also low pass, high pass, all pass, bandpass, band reject, state variable, controlled and switched capacitor
form factor, 258
frequency modulation (FM), 26
full wave rectifiers
current input, 250
current output, 249–50
current summing, 252–3
general notes on, 253–5
general purpose circuit, 251–2
single op amp circuits, 248–9
two op amp circuits, 250–1
function circuits
breakpoint approach, 219–22
cosine, 211, 218
hyperbolic, 210
multifunction design, 214–19
polynomials, 211
response curve point analysis, 213
sine, 211, 218
square root, 210
squaring, 210
tan⁻¹, 211, 218
using A/D and D/A converters, 222
using log/antilog converters, 214
using multipliers, 209–14
gain-bandwidth product, 3, 123, 145
Gilbert cell, 198
guard ring, 33, 36, 40, 145, 240
half wave rectifiers
basic circuits, 246–7
general notes on rectifier circuits,
253–5
Hall probe, 18, 22
high pass filters
Bode plot, 74, 76
current generalized immittance,
93–4
ideal response, 72
multiple loop feedback, 91–2
Sallen-Key, 89–91
single pole, 88–9
tuning, 122
hyperbolic, 210
hysteresis, 245
inductive loads, protection from, 45
instrumentation amplifiers
bias currents, 10
commercial devices, selection of,
18–24
common mode gain, 2, 7, 8, 13
common mode input capacitance, 11
common mode rejection ratio (CMRR), 2, 7, 14, 16, 20
defined, 1
differential gain of, 2, 7, 8, 13
differential gain example design based on OP07, 15
for voltage to current conversion,
55
matched transistor input stage,
12–18
single op amp circuits, 2–6
standard design, 8–9
two op amp circuits, 8–12
with transducers, 18–22
with bootstrap, 11–12
with guard driver, 11
with variable gain, 7–8
integrators
basic circuit, 143
circuit examples, 147–51
design problems with, 144–7
frequency response, 146
op amps and capacitors for, 151–2
isolation amplifier
block diagram, 25–6
commercial devices, selection of,
29–30
defined, 25
using linearizing feedback, 27–8
using modulation and
demodulation, 26–7

JFET, 60, 61, 244
leads, see cables
limiters
basic circuits, 223–7
defined, 223
diode bridge type, 227–8
temperature controlled type, 228–31
linearizing diodes, 57
linearizing feedback, 27
log–antilog functions, 216
log–antilog multiplier, 200
log converter
bandwidth, 267
basic circuits, 161–3
commercial devices, selection of,
182–3
component selection for, 176–7
developed circuits, 163–72
frequency compensation, 170–2
log ratio amplifier, 175
offset nulling, 176
practical log converter circuits,
173–5
low pass filter
as a double integrator, 151
Bode plots, 73, 75
current generalized immittance,
87–8
ideal response, 72
multiple loop feedback, 84–5
Sallen-Key, 81–4
tuned, 80
zero offset, 86–7
matched transistor pairs, 12, 15, 17,
52, 173, 176, 181, 202, 215
mean absolute value (MAV), 257
measuring AC signals
commercial devices, selection of, 272
general notes on, 257–8, 261
mean absolute value (MAV)
circuits, 262
measurement parameters, 261
RMS to DC converter circuit, 270–1
root mean square fundamentals,
262–71
thermal RMS converters, 271–3
measuring currents, 38
MOSFET, 49, 241
multipliers
commercial devices, selection of,
204–5
converting for division, 193, 199
errors with, 191–3
FET controlled resistor, 196–7
for RMS measurements, 263
for voltage controlled amplifier,
113–15
four quadrant operation, 194
Gilbert cell element, 198
in voltage controlled filter, 113
log–antilog, 200–3
operation of, 189–91
pulse width/pulse height, 203–6
## Index

<table>
<thead>
<tr>
<th>Page</th>
<th>Index</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>59</td>
<td>peak responding circuits</td>
<td>259</td>
</tr>
<tr>
<td>127</td>
<td>photodiode amplifier</td>
<td>43</td>
</tr>
<tr>
<td>127</td>
<td>piezo electric crystal</td>
<td>31, 35</td>
</tr>
<tr>
<td>223</td>
<td>polynomials, 211</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>power measurement, see measuring</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>AC signals</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>power supplies, floating, 47, 51</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>programmable gain, 63–9</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>printed circuit board (PCB)</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>cleaning, 33, 40</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>guard ring, 33, 36, 40, 145, 240</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>layout of components on, 4</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>pulse width modulation (PWM), 26</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>Q of filter circuits all pass, 105, 111</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>bandpass, 77, 95–8, 111</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>band reject (notch), 79, 99–104, 111</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>filter design, 119–23, 125</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>high pass, 76, 89–94, 111</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>low pass, 75, 81, 83–8, 111</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>state variable, 107–10, 111</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>switched capacitor, 118</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>voltage controlled, 113</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>R–C filters, 71</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>R–2R ladders, 67, 68, 114</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>rectifiers, see half wave rectifiers, full wave rectifiers</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>reference level nulling, 6</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>resistors and common mode rejection ratio (CMRR), 3</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>for integrator, 146</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>matched, 4</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>noise from, 28</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>selection of, 41, 123–4, 147, 156, 177, 183</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>T-networks, 4, 41, 61, 147, 156</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>temperature sensitive, 177, 183</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>temperature tracking, 5, 11</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>4-terminal, 38, 51</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>tolerances, 4</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>response point curve analysis, 213</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>root mean square (RMS), 257, 263</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>RMS, measuring of, see measuring AC signals</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>Sallen-Key, 81–4, 89–91</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>sine, 211, 217</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>slew rate, 20–1</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>square root, 210, 217</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>squaring, 210, 217</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>state variable filters, 106–10</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>strain gauge, 18–19</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>subtraction, see addition and subtraction</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>summing amplifier, 148, 157, 185</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>see also addition and subtraction</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>switched capacitor, 115–18</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>tan⁻¹ (arctan), 211, 219</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>thermal RMS measurement, 271</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>transconductance, 37, 44, 48, 49, 53–7</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>see also voltage to current converter</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>transdiode, 164–5, 168–9, 178–9</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>transducers crystal, 135</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>Hall probe, 18</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>photodiode, 43</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>strain gauge, 18</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>transformer coupling, 25</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>transistor bulk resistance of, 166</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>equation, 179</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>matched pairs, 12, 15, 17, 52</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>transresistance, 37, 39</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>see also current to voltage converter</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>valley detector, 231, 242</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>voltage controlled amplifier</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>audio application, 62</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>using a FET, 60–1</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>using a multiplier, 59–60</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>using operational transconductance amplifier, 60–1</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>voltage to current (transconductance)</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>converter basic circuit, 43–5</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>defined, 37</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>differential input, 46, 52–5</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>feeding multiple loads, 51–2</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>for floating sources, 46–7</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>improving CMRR of, 53</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>large voltage swings, 54</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>using a bipolar transistor, 49</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>using a commercial device, 55</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>using a MOSFET, 49–50</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>using operational transconductance amplifier, 55–7</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>using a resistor divider network 44–5</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>with high output current, 51</td>
<td></td>
</tr>
</tbody>
</table>

Zener diode for breakpoints, 219

for limiters, 223, 228

in automatic gain control, 63

MOSFET protection, 49