

Index

Page numbers of Figures are shown in **bold**, those for Tables in *italic*.

- Acceleration components, body axes 110–113
- Accelerometers
spring restrained pendulous 253, 254
torque balance pendulous 254–257
- Actuators, FBW servo 162, 163
- Adiabatic process 369, 372, 376
- Aerodynamic centre 103
- Aerodynamic derivatives
basic concepts 117, 118
forward force 119
side force 121, 125
vertical force 119, 121
pitching moment 119, 120, 121
rolling moment 123, 124, 125
yawing moment 122, 123, 124, 125
- Air data
formulae 379
importance and use 355–360
- Air data gain scheduling 164, 165
- Air data/inertial mixing 309–312
- Air density, altitude relationship 367, 368
- Air density ratio 368
- Air density reduction factor
see Air density ratio
- ATC transponder 358, 359
- Aliasing 208–210
- Angle of attack
see Incidence angle
- ARINC specifications 435
- Artificial feel unit 131
- Attitude algorithms
see Strap down systems
- Attitude derivation
stable platform systems 260, 261, **262**
strap-down systems 261–273
attitude with respect to local North,
East, Down axes 273–277
- Attitude direction indicator 66, 67
- Attitude heading reference systems 323–333
vertical monitoring 323–327
heading monitoring 328–333
- Automatic landing
automatic flare 415–417
autopilot requirements 413, 414
BLEU system 414, 415
visibility categories 413
- Autopilots
bank angle command loop 397, 398
glide slope coupling loop 410–412
heading control loop 396–398
height control loop 395–396
localiser coupling loop 409, 410
pitch attitude command loop 395, 396
worked example, heading control
autopilot 398–406
- Auto-stabilisation
full authority systems 158
limited authority systems 153–155
worked example 156, 157
- Auto-throttle systems 418, 419
- Axis systems
aircraft body axes 110–113
platform axes 302–305
direction cosine co-ordinates 312, 313
local North, East, Down axes 273–276
- Bank angle, definition 113, **114**
- Bank to turn 144, 145
- Baro/inertial mixing 309–312
- Beam index CRT 83
- Bernoulli's equation 372
- Binocular HMDs 50–54
- BLEU automatic landing system
see Automatic landing
- Bode's stability criterion 405
- Bus controller 441

- Calibrated airspeed
computation **388**, 389, 390
definition **357**
impact pressure relationship **374**, **375**,
376
'Care free' manoeuvring **168**
Cat. I, II and III visibility
 see Automatic landing
Centre of pressure **103**
Chemosphere **363**
Collimated displays **18**–**21**
Collimation **22**, **23**, **24**, **29**, **30**
Combiners
 function **21**, **22**
 holographic **29**–**35**
 thin spherical, with Rugate coating
44, **45**
Common mode failures
 see Failure survival redundancy
Commutation errors, attitude
 computation **270**
Complementary filtering
 introduction **277**–**280**
Computer generated holograms **32**, **33**
Coning motion **271**–**273**
Consolidation of multiple outputs **202**
Constructor holograms **32**, **33**
Control and data entry
 direct voice input **90**–**93**
 eye trackers **94**–**96**
 tactile control panels **90**
Control laws
 basic concepts **172**, **173**
 phase advance **173**–**174**
 pitch rate manoeuvre command **177**–
 179
 proportional plus derivative **173**–**175**
 proportional plus integral **175**, **176**,
 177
Control stick, FBW **167**
Cooper-Harper rating **193**, **194**
Co-ordinated turn **145**
Coriolis accelerations **296**, **303**–**305**
Coriolis forces **232**, **233**
local North, East, Down axes
(local level, North slaved axes)
 components **303**–**305**
Covariance matrix **321**, **322**
'C star' control **179**

Damping ratio, second order system
139, **140**
Data bus systems
 ARINC **429** **440**
 ARINC **629** **440**
FBW flight control systems **161**
high speed ring **450**
linear token passing high speed **451**,
452
MIL STD 1553B **440**–**455**
STANAG 3910 **450**, **451**
Data fusion **78**, **79**, **80**
Data staleness **210**, **211**
Decision height **408**
Derivatives
 see Aerodynamic derivatives
Diffractive HUDs
 see Holographic HUDs
Direct voice input **90**–**93**
Doppler/inertial mixing **282**, **323**, **324**
DR navigation
 air data based **290**, **291**
 basic principles **287**–**289**
 Doppler/heading reference **289**, **290**
Dutch roll **148**
Dutch roll ratio **148**
Dynamically tuned gyro
 basic principles and construction
 228–**232**
 integrating rate gyro operation
 231–**232**

Earth's magnetic field **328**, **330**
Earth radius pendulum
 see Schuler pendulum
Earth's rate correction terms **273**, **274**

EFIS

see Primary flight displays

EICAS 67, **69**

Enhanced vision systems 21, 43, **44**

Environmental requirements,
avionics 14

Ephemeris parameters – GPS 340, 341

Epoch time – GPS 339

Equations of motion, aircraft

lateral 126

longitudinal 126

Euler angles 113, **114**

Euler symmetrical parameters

definition 263, 264

use in attitude computation 264–266

Exit pupil diameter 48

Eye trackers 57, 94–96

FADEC 9

Failure mode categories 200

Failure modes and effects analysis 218

Failure survival redundancy

common mode failures 204

dissimilar redundancy 204–207

monitored triplex systems 198

quadruplex systems 197–203

safety and integrity requirements

196, 197

Failure transients 200

Fibre optic gyros

interferometric type 244–252

ring resonator type 238

Field emission displays 85, 86

Field of view

HUD 23–29

FLIR

HUD display **28**, 29

Flight management systems

flight path optimisation 426–428

flight planning 423, **424**, **425**

4D flight management 429–432

introduction 420–422

navigation and guidance 425, **426**

operational modes 429, **430**

vertical flight path control 428–429

Flight path kinematics

ILS coupled approach 408, 409

Fluxgates 329, 331

Fly-by-light

EMI effects 218, 219

use of optical fibres 219, 220

passive optical sensors 221, 222, **223**,
224

Fly-by-wire flight control

advantages 166–172

basic concepts and features 160–165

control laws 172–182

digital implementation 207–218

redundancy and failure survival
196–207

worked example, control law for agile
fighter pitch rate command loop
182, 187

Formal methods 216, 217

Foucault, J 227

4D flight management

see Flight management systems

‘Free azimuth’ axis system

see Axis Systems

Frequency response methods

worked example of heading control
autopilot 398–406

Gabor, D 31

Galileo satellite navigation system 349

Geometric dilution of precision – GPS
341, 342

Geopotential altitude 363

Gimbal lock 260, 261, **262**

Glide slope guidance

see ILS

GPS global positioning system

basic principles 334–341

differential GPS 343–348

integration with INS 342, 343

introduction and system description
334–336

- solution of navigation equations 341, 342
'God's eye view' displays 59, 60
Gravitational acceleration
variation with altitude 303, 304, 309, 363
Gravity monitoring
vertical reference 327
Great circles 287
Ground pressure correction 366, 367
Gyro compassing 305–308
Gyroscopes
angular momentum types 226–232
introduction 225, 226
micro-machined vibrating mass
rate gyro 232–236
optical types 236–252
Gyroscopic reaction torque 227, 228
- Head motion box – HUDs 30
Head tracking systems 56, 57
Head down displays
civil 66–68, 69
digitally generated colour maps 72–76
military 68, 70
raster display generation 71, 72
Head up displays
basic principles 21–29
civil HUDs 20, 21, 41–45
electronics 35–37
holographic HUDs 29–35
introduction 18–21
worked example 37–41
Helmet mounted displays
design factors 47, 48
head tracking systems 56, 57
helmet mounted displays 50–56
helmet mounted sights 48–50
introduction 45–47
virtual cockpits 58–60
Helmet mounted sights 48–50
High speed databases 450–451, 452
Holographic HUDs 29–35
Holographic optical elements 31–33
- Horizontal situation indicator
see Navigation displays
House-keeping management 9
- ILS, instrument landing system 406–408
Image intensifier tubes 51, 52, 53, 54
Impact pressure
definition 355
calibrated airspeed relationship 374, 375, 376
Incidence angle 99
Incidence sensors 164, 165, 390, 391
Indicated airspeed 358
Indirect viewing systems 47, 65
Inertial navigation
aided systems and Kalman filters 314–322
basic principles and Schuler tuning 292–303
choice of navigation co-ordinates 312, 313
platform axes 302, 305
effect of azimuth gyro drift 308, 309
initial alignment and gyro compassing 305–308
introduction 291, 292
strap down system computing 313, 314
Instantaneous field of view 24–26
Integral of error control term 175, 176
Intelligent displays management 80, 81
- Joule's constant 377
- Kalman filters
aided IN systems 314–322
baro/inertial mixing 311, 312
gyro compassing 305–308
Kalman, R 317
'Kick-off' drift 147, 415
Knot 16

- Lapse rate 363
- Laser eye damage weapons 64, 65
- Latency
 - in digital control systems 189, 210
- Lateral control and response, basic aircraft 144–149
- Latitude definition 286, 287
- LCD displays 66, 82, 83, 84, 85, 87, 88
- LED displays 86
- Lift coefficient 99, 100, 101
- Lift force 98, 99, 100
- Linear token passing bus
 - see* High speed data buses
- Localizer guidance system
 - see* ILS
- Longitude definition 287
- Longitudinal control and response, basic aircraft 130–143
- Longitudinal stability 106–109
- Long period pitch motion 132, 133
- LORAN C 285
- Macek and Davis 238
- Mach number
 - computation 388, 389
 - definition 356
 - pressure ratio relationship 374
- Magnetic deviation 328
- Magnetic dip angle 328, 330
- Magnetic variation 328
- Manchester bi-phase encoding 441, 442
- Manoeuvre command control
 - basic principles 168–172
 - lags in the control loop 187–191
 - pitch rate 177–182
 - roll rate 192
 - worked example 182–187
- Map displays 72–76
- Marker beacons
 - see* ILS
- Material dispersion
 - optical fibres 448
- Mean aerodynamic chord 103
- Measured air temperature 356, 357
- Measurement matrix in Kalman filtering 320, 321
- Meridian, definition 273
- Meridian convergency 289
- Meridian convergency term 276
- Michelson and Gale 238
- MIL STD 1533B data bus 440–445
- MLS 406
- Modern control theory 195, 196
- Multi layer coatings
 - HUD combiners 26, 27
- Multi-mode optical fibre 446, 447, 448, 449
- Multi-version software
 - see* Software – flight control
- Navigation displays 67, 68
- Neutral point 107
- Newton, force 16
- Newton's second law of motion 113
- Nichol's chart 190, 191, 402, 403
- Night viewing goggles 51, 52, 53, 54
- Notch filters 181, 182, 189, 190, 191
- NBC protection 47
- Nuisance disconnects 200, 202
- Numerical aperture 448, 449
- OMEGA 285
- Optical data bus systems
 - see* Data bus systems
- Optical fibres, data transmission 445–451
- Optical gyros
 - basic principles 236–238
 - see* Ring laser gyros, Fibre optic gyros
- Organic light emitting diodes 86
- Pascal, definition 16
- Penetron CRT 83
- Phase advance 173, 174, 175
- Phugoid motion 133
- Pitch angle definition 113, 114
- Pitching moment 103–105

- Pitching moment coefficient
of complete aircraft 105
of wing at zero lift 103
- Pitch rate command control
see Manoeuvre command control
- Pitch response, basic aircraft
assuming constant forward speed
134–141
- short period and long period motion
132, 133
- worked example 141–143
- Precession 227, 228
- Pressure altitude
computation 388
definition 357
importance of 358, 359, 360, **361**
law constants 365
static pressure relationship
361–365, **366**
- Pressure error 378, 381
- Pressure sensors
requirements 380–382
vibrating type 382–384
'solid state' capsule types 384–387
- Primary flight displays 66, 67
- Prime meridian 286, **287**
- Projected large flat panel displays
miniature flat panel LCD
projected displays 87, 88
laser scanner projected displays 88,
89
- Proportional plus derivative control
173, 174, **175**
- Proportional plus integral
control 175, 176, **177**
- Pulse broadening in optical fibres 447
- Quadruplex redundancy
see Failure survival redundancy
- Quaternions 266
- QFE – ground pressure 366, **367**
- QNE – mean sea level pressure 366,
367
- Radio navigation aids
see **286**
DME 284
GPS 334–349
ILS 406, 407
LORAN C 285
OMEGA 285
TACAN 284
VOR 284
- Raster overlay display generation
71, 72
- Recovery factor 377
- Rectification of vibration,
accelerometers 256, 257
- Reliability 14, 15
- Reliability shake-down testing 15
- Remote terminal MIL STD 1553B 441
- Ring laser gyro
basic principles 239–241
construction 241, **242**
'lock-in' problems and solutions
242, 243
performance characteristics 243, 244
- Ring resonator fibre optic gyro 238
- Roll rate command control
see Manoeuvre command control
- Roll response, basic aircraft
combined roll–yaw–sideslip motion
148, 149
neglecting cross coupling 145, 146
- Rudder function 146, 147
- Rugate dielectric coatings, HUD
combiners 27, 44
- Runge-Kutta algorithms 271, 314
- Runway visual range 413
- Safety and integrity
FBW system requirements 196, 197
- Sagnac, G 236
- Sagnac effect 236
- Sagnac interferometer 236
- Sagnac phase shift 246, 247

- Scene matching area correlation
 - see* Terrain reference navigation
- Schuler, M 293
- Schuler pendulum 293, 294
- Schuler period 294
- Schuler tuning 292–302
- Sensor tracking errors 199, 200
- Shadow-mask CRTs 83
- Short period motion
 - in pitch plane 132, 133
 - in yaw plane 147, 148
- Side slip, use of rudder 147
- Single mode optical fibre 448
- Snell's law 446
- Software – flight control
 - development process 214, 215
 - functions 211–214
 - multi-version software 217, 218
 - validation and verification 216, 217
- Specific force 253
- Specific heat of air
 - at constant pressure 377
 - at constant volume 377
 - ratio of specific heats 369
- Speed of sound
 - derivation 368–370
 - variation with altitude 370
- Spiral instability 149
- Stability
 - aerodynamically unstable aircraft 108, 109, **110**
 - basic concepts 105, 106
 - longitudinal 106, 107, **108**
- Stability axes 134
- Stable platforms 260, 261, **262**
- Stagnation point 376, 377
- STANAG 3910 data bus 450, **451**
- Standard atmospheric pressure 361
- Standby display instruments
 - solid state 76–78
- State coefficient matrix
 - 128, 129, 265, 318, 319
- State vector matrix
 - 128, 129, 265, 318, 319
- Static air temperature
 - computation **388**, 390
 - definition 357
 - measured air temperature, Mach number relationship 376, 377
- Static margin 107
- Static pressure
 - definition 355
 - pressure altitude relationship 361–365, **366**
- Stealth
 - need for FBW control 172, **173**
- Stick force/g 131, 132
- Strap-down IN system computing
 - 313, 314
- Strap-down systems
 - attitude algorithms 262–266
 - basic concepts 261, 262, **263**
 - generation of strap-down equivalent stable platform 268–270
 - worked example on attitude algorithms 266–268
- Stratopause 363
- Stratosphere 363
- Structural resonance modes
 - 179, 180, 182
- Symbol generation – HUDs 35, 36
- TACAN 284, **286**
- Tactile control panels 90
- Tailplane contribution 103–105
- Tailplane efficiency factor 104
- Tailplane volume 104
- Terrain following autopilot 168, 393
- Terrain reference navigation
 - scene matching area correlation 351
 - terrain characteristic matching, 352, **353**
 - terrain contour navigation 351, 352
- Time division multiplexing 436
- Total air temperature
 - definition 357
 - static air temperature, Mach number relationship 376–377

- Total field of view 24, 25, 26
Total pressure, definition 355
Total temperature sensor 380
Transition matrix
 use in attitude integration 265, 266
 use in IN system error model 319, 320
Trim angle of incidence 106, **107**
Triplex redundancy
 see Failure survival redundancy
Tropopause 363
Troposphere 363
True air speed
 computation 390
 definition 356
 Mach number, measured air
 temperature relationship 377, 378
Undamped natural frequency
 second order system 139
Unmanned aircraft 459–464
- Vali and Shorthill 238
Vector data bases – maps 73, 75
Vehicle rate correction terms
 274–276, 302
Velocity vector
 inertial derivation 312, **313**
- Vertical speed
 computation 389
 use by pilot 358, 359
Vibrating pressure sensors 382–384
Vibration induced errors
 see Rectification of vibration
Virtual cockpits 58–60
VOR 284
Voting algorithms 199–202
- Wash-out filter 155
Waveguide dispersion, optical fibres
 448
Waveguide parameter, optical fibres
 448
Weathercock stability 122, 123
Weight, gearing effect 13, 14
Wheatstone's bridge 386
Wide area augmentation system
 349, **350**
- Yaw angle definition 113, **114**
Yaw damper 153–155
- Z mathematical language, formal
 methods 217