

Index

- accidents, 4, 94, 97–98, 310–311, 315–316, 322–323, 326–327, 350–352
- Ackermann angle, 65–69
- active safety technologies (AST), 322–323, 350
- actuator, 7–9, 16, 25, 30, 133, 137, 152, 198, 217
- adaptive cruise control. *See* autonomous cruise control
- adhesion coefficient. *See* tire-road friction coefficient
- advanced traffic management systems (ATMS), 310–312
- advanced traveler information systems (ATIS), 312–314
- advanced vehicle control systems (AVCS), 314–318
- aerodynamic drag force, 5, 57–59, 153
- air supply system, 39–41, 43, 190, 198
- air-fuel ratio, 9, 11–16, 33–38, 49, 119
- airbags, 93–94
- algebraic Ricatti equation, 289, 291, 295
- algorithm development, 26–27
- algorithm implementation, 27–28
- algorithm in the loop testing, 29
- all-electric range, 178
- all-wheel drive (AWD), 8, 131–138, 148, 257
- anode, 188, 191–195
- anthropometry, 93
- anti-lock braking system (ABS), 8, 15–17, 93–97, 102, 232–234, 236, 241–254, 257, 263, 323
- anti-skid braking. *See* anti-lock braking system
- anti-spin acceleration, 233, 250–251. *See also* control, traction
- autocoding, 27–28
- Autocruise, 332–333, 337
- automated highway system (AHS), 4, 94, 345, 350
- automated lane following, 352–356
- automated steering, 315, 352–358
- autonomous cruise control (ACC), 213, 219, 224–229, 332, 337, 345
- autonomous guided vehicles, 323–324
- battery charge sustainability, 183
- battery tax, 158, 163
- beta (β) method, 258
- bicycle model, 63–64
- biomechanics, 93
- block diagram, 363, 375–376
- body. *See* chassis
- bottom dead center (BDC), 35
- brake force, 60, 233, 257–258
- brake pressure, 16, 232–234, 258, 261
- brake specific fuel consumption (BSFC), 12, 37, 155–159, 166, 169–170
- brake steer, 257
- brakes, 7
- camber angle, 57, 389
- camshaft, 15, 34
- CAN bus, 16–17, 30, 152
- cascade studies, 25
- catalytic converter. *See* two-way catalytic converter (TWC)
- cathode, 188–198
- cell temperature, 191, 195
- center of gravity (CG), 54–55, 385
- certainty equivalence principle, 289
- characteristic speed, 66–67
- charge depleting (CD) mode, 178, 181
- charge sustaining (CS) mode, 178, 181, 183
- chassis, 6
- choked flow, 40, 47–48
- crashworthiness, 322
- circadian dip of alertness, 99
- closed-loop testing, 28–29
- closed-loop. *See* control, feedback
- cognitive engineering, 93
- collision avoidance, 102, 314–315, 322–328
- combined-slip tire model, 263–268
- combustion, 6, 9, 13, 36–37, 41, 44, 48, 119, 124
- commercial vehicle operation (CVO), 314–315
- communication network, 16–18

- communication
 - intervehicle, 317–318, 338, 340, 345
 - vehicle-to-infrastructure, 317–318, 338
- compensatory behavior, 102–103, 106
- compression stroke, 33–35
- compressor, 190–192, 196–201
- congestion, 3–5, 309–312, 332
- constant time-gap headway policy, 345
- constant-spacing headway policy, 345
- control, 363
 - adaptive, 11, 219–223, 302
 - air-fuel ratio, 8–9, 11–12, 37, 119–122
 - body, 7–8
 - clutch, 131–146
 - cruise, 5, 8, 14, 213–219, 332–337
 - derivative (D), 11
 - electronic transmission, 8–9, 14, 38
 - engine, 5–7, 33, 126, 232–233, 333
 - exhaust gas recirculation, 4, 7–9, 13, 16, 33–38, 40, 44, 126, 153, 177
 - feedback, 8, 11, 107, 119, 141, 178, 226, 290, 294, 335, 355, 364–369
 - feedforward, 14, 138, 163, 274, 335, 365
 - fuel injection, 7, 33
 - headway, 213, 224–229, 317
 - idle speed, 8–9, 14, 38, 126–128
 - Integral (I), 11
 - integrated vehicle, 132
 - lambda, 119
 - line pressure, 133
 - load-leveling, 148, 166–168
 - lockup, 131–133
 - optimal. *See* optimal control
 - piecewise, 138–146
 - point-follower, 338
 - powertrain, 7–8
 - preview, 107, 333–337
 - proportional (P), 8, 11, 369, 377–381
 - proportional plus derivative (PD), 11
 - proportional plus integral (PI), 8, 11, 14, 120–122, 141, 214–222, 333–335, 377–381
 - proportional plus integral plus derivative (PID), 8, 11, 217–219, 222–223, 377–381
 - roll. *See* rollover prevention
 - rule-based, 176, 244–248, 254
 - self-tuning, 220
 - sideslip, 267
 - sliding mode, 249–250
 - spark timing, 8–9, 13–14, 124–125, 126–128
 - state-feedback, 226–229, 290–291, 294, 382–384
 - supervisory, 17, 152–153, 157, 178–179
 - thermostat, 157–164
 - traction, 6, 232–234, 247–254
 - vehicle stability (VSC), 257–261, 266–268
 - vehicle-follower, 338
 - vehicle, 7–8
 - yaw, 266–267
- controlled system, 8
- controlled variable, 8
- controlled vehicle, 225–228
- controller, 8, 11
 - in the loop testing, 29
 - module, 21, 28
- convolution, 372
- cooling, 190, 198, 204
- cornering forces, 65
- cornering stiffness, 65–66
- corporate average fuel economy (CAFE), 322
- course angle, 55
- crank angle domain, 47–49
- crankshaft, 15, 33–34
- critical speed, 66–67
- crossover frequency, 95, 100
- crossover model principle, 95
- cycle beating, 177
- damping ratio, 121, 218, 222, 383
- dead reckoning. *See* inertial navigation
- degree-of-freedom (DOF), 70, 385
- delay, 36, 43–44, 49, 103–110, 119–122, 138–146
- development cycle, 22–24
- difference equations, 210–221
- differential, 6, 257
- differential braking, 3, 257–258, 266, 326–327, 352
- distributed computing, 17
- disturbance input, 8–9, 364
- dog actuator, 133–134
- drag torque. *See* torque, load
- drawbar force, 58
- drivability, 4, 33, 131, 178, 204
- drive cycle, 153, 160, 163, 165, 168, 203, 207–208
- driver adaptation, 94–95, 97–98
- driver model, longitudinal, 109–111
 - MacAdam’s, 102, 106–107
 - predictive or preview, 106–109
 - transfer function, 102–104
- driveshaft, 6, 14–15, 62
- drivetrain, 6, 62–63, 132, 148, 205
- driving simulators, 94–95, 97–98, 100–101, 352
- earth-fixed reference frame. *See* inertial reference frame
- eigenvalue assignment. *See* pole placement
- electro-rheological fluid, 288
- electrolysis, 187
- electronic control unit (ECU), 7, 16, 21, 152–153, 177
- electronic rumble strip, 327, 352
- Electronic Stability Program (ESP). *See* control, vehicle stability
- electronic transmission control, 131–132
- emissions, 4, 9, 12–13, 35–38, 119, 124, 131, 148, 158, 180, 311
- energy management algorithms, 18
- energy storage device, 148
- engine, 6, 33–37
 - block vibrations, 124
 - control unit (ECU). *See* electronic control unit
 - crank, 38

- cycle, 33–35
- damage, 124
- diagnostics, 46–47
- four stroke, 33, 39
- friction, 36
- induction map, 44
- inertia, 36, 41, 45
- internal combustion (ICE), 6, 33–37, 39, 148–150, 155–158, 163, 166
- load, 41, 45, 126
- pumping, 36, 43
- spark ignition (SI), 6, 33–37, 39
- sweet spot, 155, 158
- volumetric efficiency, 47–48
- warm-up, 38
- Environmental Protection Agency (EPA) Cycle.
 See drive cycle
- equilibrium, 214–218
- equivalent consumption minimization strategy (ECMS), 173–175
- equivalent fuel consumption, 172
- erasable programmable read only memory (EPROM), 332
- ergonomics, 93
- error signal, 365
- exhaust gas recirculation (EGR), 7–9, 13, 16, 33–38
- exhaust stroke, 33–35
- expansion stroke. *See* power stroke
- fail-safe characteristics, 150
- final value theorem, 371
- fishhook maneuver, 262, 264
- flexible driving, 131–132
- Flexray, 16
- foolproof design, 132
- four-wheel drive (4WD), 7–8, 135–137, 232
- four-wheel-steering (4WS), 6, 8, 272–283
- frequency response, 100, 273, 278, 292, 374
- friction ellipse tire model, 57–58
- friction plate, 133–137
- front wheel drive (FWD), 7, 64, 69, 89
- front wheel steering (FWS), 272–283
- fuel
 - economy, 4, 153, 163–166, 172–178, 180–183
 - efficiency, 5, 208, 322
 - injection, 4, 16, 36, 44
 - system, 36, 48–49
- fuel-cell stack, 187–193
- fuel-cell vehicle, 4–5, 187–188, 201–208
- fuel-cell, 151, 158, 176, 187–188
- generalized coordinate, 385
- generalized force, 385
- generator, 148–152, 177–181
- global positioning system (GPS), 7, 94, 225, 312–314, 348
- grade, 59–62, 163, 213–214, 225, 333–336
- handcoding, 27
- hardware in the loop (HIL), 28–31
- heading angle, 55, 105, 328
- heave, 81
- Hough transformation, 349
- human factors engineering, 93
- humidification, 189–190, 196, 198
- hybrid electric vehicle (HEV), 5, 148, 201
- hybrid electric vehicle, micro, 149
 - parallel, 148–153, 166–172
 - power split, 148–153, 177–178
 - series, 148–153, 157–166
- hybrid electric vehicle, plug-in (PHEV), 178–183
- hybrid vehicle, 5, 17, 148–152
- hydrogen supply system, 190, 196, 198
- hysteresis, 120, 158
- ideal gas law, 35, 40, 43, 48
- ignition timing. *See* spark timing
- in-hub motors, 148–149
- incident management, 311–312
- induction stroke, 33–35
- induction-to-power (IP) delay, 36, 43–44, 138–146
- inertial navigation, 313, 328
- inertial reference frame, 55–56, 385–386
- initial value theorem, 371
- inputs, 8–9, 363
- instability, 368–369
- instrumentation, 7
- integrated motor assist (IMA), 150
- intelligent cruise control. *See* autonomous cruise control
- intelligent transportation system (ITS), 4–5, 94, 309–318, 324, 332, 348
- intelligent vehicle-highway system (IVHS).
 See intelligent transportation system
- invariant equation, 85
- ionization reaction, 189
- Kalman filter, 294–296, 351–352
- kinetic energy, 385–388
- knock, 36–37, 124–125
- Lagrange’s method, 56, 385–387
- lambda-mu curve, 236–237
- lane
 - change maneuver, 281–283
 - geometry, 351–352
 - markers, 349, 351
 - sensing, 348–352
 - tracking, 348, 350–351
- lane-departure accidents. *See* single-vehicle road-departure (SVRD) accidents
- Laplace transform, 10, 370–372
- Laplace transform, properties, 371
- lateral acceleration, 15, 67–68, 74, 258, 267–268, 273–274, 284
- lead vehicle, 213, 224–230
- level-holding phase, 133
- LIN bus, 16

- linear quadratic (LQ) control. *See* optimal control
- linearization, 42, 72, 90, 214
- loop gain, 367
- lumped parameter models, 54
- Lyapunov equation, 86
- Lyapunov stability, 139, 145

- magic formula. *See* Pacejka tire model
- manifold air pressure (MAP), 8, 10, 14, 37
- manifold filling dynamics, 41, 43
- manifold, intake, 35, 41, 43
 - supply and return, 191–192
- map matching, 312
- mass airflow, 42–43, 47–48, 128
- maximum percentage overshoot, 121
- measurement noise, 368
- mechatronics, 3–5
- membrane hydration model, 193, 195
- message chips, 332–333
- minimum spark advance for best torque (MBT), 12–13, 36–37
- mobility, 3–5
- model-based design, 21–22
- motion sickness, 86
- multi-input multi-output (MIMO), 9–10, 199–203

- National Advanced Driving Simulator, 98
- National Highway Transportation Safety Association (NHTSA), 4, 232, 352
- natural frequency, 121, 382–383
- navigation, 93–94, 101, 312–313, 324
- near obstacle detection, 324
- networked control system, 18
- neutral steer, 65–67
- Newton’s second law, 36, 45, 54–56, 58, 63–64, 66–67, 69–70, 234
- noise vibration harshness (NVH), 153, 167
- non-minimum phase (NMP), 273

- observer, 138–141, 356
 - disturbance, 141, 365
 - open-loop, 138
- open-loop. *See* control, feedforward
- optimal control, 8, 11, 289–290
 - dynamic programming (DP), 176–178
 - frequency shaped linear quadratic (FSLQ), 355
 - linear quadratic (LQ), 126–127, 289, 291
 - linear quadratic Gaussian (LQG), 294–295
- optimal operating points line (OOP-Line), 179–180
- Otto gasoline engine, 33
- outputs, 8–9, 363
- oversteer, 65–67
- oxygen, 187–189

- Pacejka tire model, 57, 236–238, 258–260, 264
- Padé approximation, 104

- path planning, 101
- path projection, 350–352
- percentage of road departure (PRD), 99–101
- performance index, 291
- piecewise affine system (PWA), 138–141
- pitch, 55, 386
- planetary gear, 149–151, 177–178
- plant, 10, 364
- plate friction coefficient, 140
- platooning, 224, 315, 317–318, 337–343
- plug-n-play, 18
- pneumatic tire, 55, 57, 234–235
- pole placement, 222, 226, 230, 382–384
- poles, 376–377
- power management, 176, 203–204
- power spectral density (PSD), 77–79
- power stroke, 33–35
- powertrain, 6
- precognitive behavior, 102
- primary power source, 148, 155
- proton exchange membrane (PEM), 189
- pursuit behavior, 102

- quantization, 340
- quarter-car model, 81

- ramp following, 133
- ramp-metering, 310–311
- range, 110, 213, 225–227, 324–326
 - extender, 148
 - rate, 110, 324–326
- rattle space. *See* suspension stroke
- reactant partial pressure, 191, 195
- rear-wheel drive (RWD), 64, 89
- rear-wheel steering (RWS), 272–283
- recursive least squares (RLS), 50, 219–221, 355
- reference (set-point) input, 8–9, 108, 203, 213, 224, 226, 364, 383
- regenerative braking, 148–149, 181, 184
- requirements, 21–25
- reversible power source, 148
- ride model, 81–86
- ride quality, 85–86, 287
- risk homeostasis theory, 95–97, 101
- road condition, 232, 250
- road departure accidents. *See* single-vehicle road-departure (SVRD) accidents
- road model, 77–79
- roll, 55, 385
- rolling resistance force, 57–59, 153–155, 181
- rollover prevention, 261, 266–268
- root locus method, 215, 379–382
- route planning, 312
- run-off-road. *See* single-vehicle road departure

- safe distance, 326
- safety, 4, 309–318
 - active, 322–323
 - passive, 322–323

- saturation, 340
- sensitivity, 368
- sensor, 8, 14, 323–326
 - acceleration, 15
 - crankshaft angular position and speed, 15
 - exhaust gas oxygen (EGO), 8, 12, 15, 37, 119–121
 - forward-looking, 324
 - infrared, 324
 - knock, 15
 - laser, 323
 - linear variable differential transformer (LVDT), 15
 - manifold absolute pressure (MAP), 8, 10, 14, 37
 - mass airflow (MAS), 15, 37
 - radar, 324
 - slip, 15
 - throttle angle, 15, 126
 - ultrasonic, 323–324
 - vehicle speed, 15
 - vision, 323, 351
- settling time, 121, 215–216, 258, 378
- shift map, 38
- shift quality, 131
- side-slip angle, 55, 257–260, 262, 264, 266–267
- single-input single-output (SISO), 9–10, 95, 107, 198–199
- single-vehicle-road-departure (SVRD), 97–98, 326–327, 350–352
- site-specific information, 332–337
- skyhook damper, 287–290
- sliding surface, 267
- slip, 57
 - angle, 57, 267
 - lateral, 57
 - longitudinal, 60, 237–239
 - optimal, 234
 - slip ratio, 233–234
- Smith predictor, 120–122
- Society of Automotive Engineers (SAE), 54–55
- spacing, 337–345
- spark command, 36
- spark ignition (SI), 16, 33–35, 39, 124, 129
- spark timing, 13, 37–38, 124–125
 - advanced, 36–37, 124–125
 - retarded, 124–125
- speed ratio, 133–136
- sprung mass acceleration, 85–86, 287–290
- sprung mass, 81–82
- stability derivatives, 73, 389
- stack current, 191–192, 196, 200–202
- stack voltage, 191, 193–199
- state equation, 45–46, 82, 107, 126, 225–230, 289, 353, 369–370
- state estimation. *See* Kalman filter and observer, state
- state space, 369–370
- state variable, 370
- state-of-charge (SOC), 153, 157–166, 172–173, 176–184
- static stability factor (SSF), 267
- steer angle, 55, 64, 103
- steering, 6
- stoichiometric, 9, 12, 35–37, 119
- stopping distance and time, 61
- string stability, 343–345
- suspension, 6–7, 287–288
 - active, 7, 81–82, 287–303
 - passive, 81–82, 86–88, 287–290
 - semi-active, 7, 287–288
 - strut type, 7
- suspension actuator, 16
- suspension stroke, 81–82, 86, 290, 292, 294–296, 299
- swappable. *See* plug-n-play
- switching function, 249
- system, 363
- target hardware. *See* controller module
- Taylor series, 90, 214
- testing and validation, 21, 28–31
- thermal capacitance, 140
- thermal resistance, 140
- throttle, 39–40, 126–128
 - actuator, 16, 126–128
 - angle, 39–40, 42, 126–128
 - control, 126–128
 - motor, 126
- time delay. *See* delay
- time to collision (TTC), 326
- time to lane crossing (TLC), 326–327, 350–352
- tire axis system, 55–56
- tire deflection. *See* wheel hop
- tire-road friction coefficient, 57, 233–235, 250
- toll debiting, 312, 315
- top dead center (TDC), 10, 13, 35–36, 124
- torque converter, 7, 45, 63, 131–133, 150
- torque, load, 41, 45, 128
 - brake, 60
 - engine, 41, 44–45, 128
 - self-aligning, 56–57
- Toyota Hybrid System (THS), 150–151, 177
- traction control system (TCS). *See* control, traction
- tractive force, 56, 62
- transfer function, 372–374
- transmission control unit (TCU), 152–153
- transmission, automatic, 6, 131–132
 - continuously variable (CVT), 6, 131–133, 151
 - electronically controlled (ECT), 6, 131–133
 - manual, 6, 131
- two-way catalytic converter (TWC), 9, 12, 37, 119
- two-wheel drive (2WD), 135–137
- ultra low emission vehicles (ULEV), 4
- uncertainty, 365–367, 122, 138–146

understeer coefficient, 66	wall-wetting, 48–49
understeer, 65–67	waterfall model, 24
unsprung mass, 81–82, 287	wet-friction clutch, 137
upshift, 133	wheel hop, 81–82, 86, 291–292, 295, 299
v-diagram model, 24–25	x-by-wire, 16
vehicle coordinate system, 54–58, 385–386	yaw moment, 257–261, 264, 268
vehicle dynamics control (VDC). <i>See</i> control, vehicle stability	yaw rate following, 266–268
vehicle dynamics, lateral, 64–77	yaw-roll model, 261–264
longitudinal, 58–64	yaw, 55, 386
vertical, 77–88	zeros, 376–377
virtual desired trajectory (VDT), 356	Ziegler-Nichols tuning rules, 377–379