

BIOGRAPHY

Johan H. Huijsing was born on May 21, 1938.

He received the M.Sc. degree in Electrical Engineering from the Delft University of Technology, Delft, the Netherlands in 1969, and the Ph.D. degree for this University in 1981 for his thesis on operational amplifiers.

He has been an assistant and associate professor in Electronic Instrumentation in the Faculty of Electrical Engineering of the Delft University of Technology since 1969, where he is a full professor in the chair of Electronic Instrumentation since 1990. From 1982 through 1983 he was a senior scientist at Philips Research Labs. in Sunnyvale, California, USA. Since 1983 he is a consultant for Philips, Sunnyvale and since 1998 also a consultant for Maxim, Sunnyvale, Ca.

The research work of Johan Huijsing is focussed on the systematic analysis and design of operational amplifiers, analog-to-digital converters and integrated smart sensors. He is author or co-author of some 200 scientific papers, 20 US-patents and 6 books, and co-editor of 8 books. He is fellow of IEEE for contributions to the design and analysis of analog integrated circuits. He received the title of Simon Stevin Meester for applied Research by the Dutch Technology Foundation.

He is initiator and co-chairman of the international Workshop on Advances in Analog Circuit Design, which has been held annually since 1992. He is a member of the programme committee of the European Solid-State Circuits Conference and of Eurosensors. He is chairman of the biennial national Workshop on Sensor Technology, since 1991, and chairman of the Dutch STW Platform on Sensor Technology.

October 2, 2000

INDEX

1GHz, all-NPN class-AB OpAmp with MNMC 308
1 volt R-R-in/out bipolar class-AB OpAmp with MNMC 338
1 volt R-R-out CMOS class-AB OpAmp with MNMC 324
1.2 volt R-R-out CMOS class-AB OpAmp with MHNMC 344
1.8 volt R-R-in/out bipolar class-AB OpAmp (NE5234) with NMC 332
2 volt power-efficient all-NPN class-AB OpAmp with MDNMC 308

A

all-NPN

1GHz, all-NPN class-AB OpAmp with MNMC 308
2 volt power-efficient all-NPN class-AB OpAmp with MDNMC 308
high-frequency all-NPN OpAmp with mixed PC and MC 294
LM101 class-AB all-NPN OpAmp with MC 298
NE5534 class-AB OpAmp with bypassed NMC 300
precision all-NPN class-AB OpAmp with NMC 302
precision HF all-NPN class-AB OpAmp with MNMC 305

applications 39

B

back-gate influence 96
balancing techniques 77, 86, 90
basic bipolar R-R-out class-A OpAmp 277
bias
 feedback class-AB biasing 161
 feedforward class-AB biasing 140
 offset, bias, and drift 75
boosting
 input class-AB boosting 273
 voltage-gain boosting 275
bridge instrumentation amplifier 44

C

cascode
 folded-cascode OpAmp 265

telescopic-cascode OpAmp 268

classification

classification based on number of floating ports 2

classification of output stages 137

classification of overall topologies 197

CM-out control

fully differential CMOS OpAmp with linear-mode CM-out control
366

fully differential CMOS OpAmp with LTP CM-out control 369

fully differential CMOS OpAmp with R-R buffered resistive CM-out
control 372

fully differential CMOS OpAmp with R-R resistive CM-out control
375

fully differential CMOS OpAmp with switched-capacitor CM-out
control 378

fully differential GA-CF CMOS OpAmp with input-CM feedback
CM-out 371

fully differential telescopic CMOS OpAmp with linear-mode CM-out
control 368

common-mode

common-mode rejection ratio (CMRR) 88

common-mode cross-talk ratios (CMCR) 91

extension of the common-mode input range 118

voltage range

instrumentation amplifier bipolar with common-mode voltage
range including negative rail voltage 406

instrumentation amplifier CMOS with common-mode voltage
range including negative rail voltage 408

compact

compact 1.2 volt R-R-out BiCMOS class-AB OpAmp with MNMC
329

compact 1.2 volt R-R-out CMOS class-AB OpAmp with MC 322

compact 1.2 volt R-R-out CMOS class-A OpAmp with MC 311

compact 2 volt R-R-in/out CMOS class-AB OpAmp with MC 318

compact 2 volt R-R-out CMOS class-AB OpAmp with MC 315

compensation

- frequency compensation 205
- input voltage and current compensation 204
- compound output stages
 - FBB compound output stages 163
 - FFB compound output stages 146
- configuration
 - fully differential GA-CF configuration 365
 - fully differential GA-CF-GA configuration 375
 - fully differential GA-GA-GA-GA configuration 378
 - GA-CF configuration 262
 - GA-CF-GA configuration 311
 - GA-CF-VF configuration 283
 - GA-CF-VF/GA configuration 294
 - GA-GA configuration 277
 - GA-GA-GA configuration 324
 - GA-GA-GA-GA configuration 337
 - GA-GA-VF configuration 288
 - GA-GA-VF/GA configuration 298
- constant g_m input stages
 - constant g_m by constant sum of tail-currents 102
 - constant g_m by constant sum of roots of tail currents 105
 - constant g_m by spill-over control 106
 - constant g_m in CMOS by multiple input stages 114
 - constant g_m in CMOS by saturation control 112
 - constant g_m in CMOS by constant sum of V_{GS} 114
- current
 - current amplifier 6, 46
 - current followers (CF) 7
 - current mirror 62
 - current-to-voltage converter 3, 39
 - input voltage and current compensation 204
 - saturation protection and current limitation 176
 - output current limitation circuits 179

D

definition of OpAmps 1

design examples 261

differential V-I converter

 differential accurate V-I converter 397

 differential CMOS accurate V-I converter 398

 differential simple V-I converter 396

 differential voltage-to-current converter 50

 differential voltage-to-current converters 396

drift

 offset, bias, and drift 75

dynamic range 56

dynamic range over supply-power ratio 56

E

ESD protection 332

extension of the common-mode input range 118

F

feedback biasing (FBB) 161

 feedback class-AB biasing 161

 FBB compound output stages 163

 FBB rail-to-rail general amplifier output stages 169

 FBB voltage-follower output stages 162

feedforward biasing (FFB) 140

 feedforward class-AB biasing 140

 FFB compound output stages 146

 feedforward HF compensation 270

 FFB rail-to-rail general-amplifier output stages 149

 FFB voltage follower output stages 140

floating ports

 classification based on number of floating ports 2

folded-cascode OpAmp 265

four-GA-stage

 four-GA-stage conditionally stable multipath hybrid nested Miller compensation (MHNMC) 237

 four-GA-stage frequency compensation 232

 four-GA-stage hybrid nested Miller compensation (HNMC) 232

- four-GA-stage multipath hybrid nested Miller compensation (MHNMC) 235
- frequency compensation 205
 - four-GA-stage frequency compensation 232
 - one-GA-stage frequency compensation 207
 - three-GA-stage frequency compensation 224
 - two-GA-stage frequency compensation 211
- fully differential OpAmps 365
 - fully differential CMOS OpAmp with linear-mode CM-out control 366
 - fully differential CMOS OpAmp with LTP CM-out control 369
 - fully differential CMOS OpAmp with R-R buffered resistive CM-out control 372
 - fully differential CMOS OpAmp with R-R resistive CM-out control 375
 - fully differential CMOS OpAmp with switched-capacitor CM-out control 378
 - fully differential GA-CF CMOS OpAmp with input-CM feedback CM-out 371
 - fully differential GA-CF configuration 365
 - fully differential GA-CF-GA configuration 375
 - fully differential GA-GA-GA-GA configuration 378
 - fully differential telescopic CMOS OpAmp with linear-mode CM-out control 368

G

gain

- definition of: offset voltage and current, input and output impedance, gain 16

gain boosting

- voltage and current gain boosting 203
- voltage-gain boosting 275

general bipolar class-AB OpAmp with Miller compensation 289

gyrator floating 54

H

high frequency (HF) compensation

 feedforward HF compensation 270

 high-frequency all-NPN OpAmp with mixed PC and MC 294

high-slew-rate bipolar class-AB voltage-follower buffer 287

high-speed bipolar class-AB OpAmp 283

hybrid nested Miller compensation (HNMC)

 four-GA-stage hybrid nested Miller compensation (HNMC) 232

I

improved basic

 improved basic bipolar R-R-out class-A OpAmp 279

 improved basic CMOS R-R-out class-A OpAmp 280

input and output impedance

 definition of: offset voltage and current, input and output impedance,
 gain 16

input bias current

 definition of: input bias current, input common-mode rejection ratio
 17

input class-AB boosting 273

input common-mode rejection ratio

 definition of: input bias current, input common-mode rejection ratio
 17

input stages 75

input voltage compensation 271

input voltage and current compensation 204

instrumentation current amplifier 53

instrumentation voltage amplifier 52

instrumentation amplifiers 400

 instrumentation amplifier bipolar with common-mode voltage range
 including negative rail voltage 406

 instrumentation amplifier CMOS with common-mode voltage range
 including negative rail voltage 408

 instrumentation amplifier (semi) with three OpAmps 400

 instrumentation amplifier simplified diagram and general symbol 409

 instrumentation amplifier with differential V-I converters for input

- and output sensing 403
 - instrumentation amplifier with a differential V-I converter for input sensing 401
 - universal class-AB voltage-to-current converter design using an instrumentation amplifier 410
 - universal class-AB voltage-to-current converter with instrumentation amplifier 432
 - universal V-I converter design with real instrumentation amplifier 412
 - universal V-I converter design with semi-instrumentation amplifier 411
- inverting
- inverting current amplifier 49
 - inverting voltage amplifier 41, 59
 - inverting voltage integrator 61
- isolation techniques 76, 84, 89
- L**
- LM101 class-AB all-NPN OpAmp with MC 298
- M**
- μ A741 OpAmp with Miller compensation (MC) 292
- macromodels 15
- macromodels in Spice 22
 - macromodel mathematical 22
 - macromodel Miller-compensated 23
 - macromodel nested-Miller-compensated 24
- measurement techniques for OpAmps 26
- gain measurement of an OTA 26
 - gain measurement of an OpAmp 28
 - gain and offset measurements of an OpAmp 29
 - general measurement setup for an OpAmp 30
- Miller compensation (MC)
- compact 1.2 volt R-R-out CMOS class-AB OpAmp with MC 322
 - compact 1.2 volt R-R-out CMOS class-A OpAmp with MC 311
 - compact 2 volt R-R-in/out CMOS class-AB OpAmp with MC 318

- compact 2 volt R-R-out CMOS class-AB OpAmp with MC 315
 - general bipolar class-AB OpAmp with Miller compensation 289
 - LM101 class-AB all-NPN OpAmp with MC 298
 - μ A741 OpAmp with Miller compensation (MC) 292
 - two-GA-stage Miller compensation (MC) 215
 - multi-GA-stage compensations 238
 - multipath hybrid nested Miller compensation (MHNMC)
 - 1.2 volt R-R-out CMOS class-AB OpAmp with MHNMC 344
 - four-GA-stage conditionally MHNMC 237
 - four-GA-stage MHNMC 235
 - multipath nested Miller compensation (MNMC)
 - 1GHz, all-NPN class-AB OpAmp with MNMC 308
 - 1 volt R-R-in/out bipolar class-AB OpAmp with MNMC 338
 - 1 volt R-R-out CMOS class-AB OpAmp with MNMC 329
 - compact 1.2 volt R-R-out BiCMOS class-AB OpAmp with MNMC 329
 - precision HF all-NPN class-AB OpAmp with MNMC 305
 - three-GA-stage multipath nested Miller compensation (MNMC) 228
- N**
- NE5534 class-AB OpAmp with bypassed NMC 300
 - nested Miller compensation (NMC)
 - 1.8 volt R-R-in/out bipolar class-AB OpAmp (NE5234) with NMC 332
 - NE5534 class-AB OpAmp with bypassed NMC 300
 - precision all-NPN class-AB OpAmp with NMC 302
 - reverse nested Miller compensation (RNMC) 238
 - three-GA-stage nested Miller compensation (NMC) 225
 - no internal poles 210
 - noise 84
 - non-ideal OpAmps 64
 - non-inverting voltage amplifier 4, 42, 60
 - non-linear distortion 242
 - nullor concept 1

O

offset, bias, and drift 75

offset voltage and current

definition of: offset voltage and current, input and output impedance,
gain 16

one-GA-stage frequency compensation 207

operational current amplifier (OCA) 6, 46

definition of: output bias current, output common-mode current
rejection ratio 19

operational floating amplifier (OFA) 8, 48, 387

using all definitions 21

operational inverting amplifier (OIA) 3, 39

definition of: offset voltage and current, input and output impedance,
gain 16

operational voltage amplifier (OVA) 4, 42

definition of: input bias current, input common-mode rejection ratio
17

operational transconductance amplifier (OTA) 262

output bias current

definition of: output bias current, output common-mode current
rejection ratio 19

output common-mode current rejection ratio

definition of: output bias current, output common-mode current
rejection ratio 19

output stages 131

FBB compound output stages 163

FBB rail-to-rail general amplifier output stages 169

FBB voltage-follower output stages 162

FFB compound output stages 146

FFB rail-to-rail general-amplifier output stages 149

FFB voltage follower output stages 140

overall design 197

overall topologies

classification of overall topologies 197

P

parallel compensation (PC)

two-GA-stage parallel compensation (PC) 212

power efficiency of output stages 131

precision all-NPN class-AB OpAmp with NMC 302

precision HF all-NPN class-AB OpAmp with MNMC 305

R

rail-to-rail (R-R) input stages

rail-to-rail in CMOS by back-gate driving 118

rail-to-rail input stages 100

rail-to-rail-in/out (R-R-in/out)

1 volt R-R-in/out bipolar class-AB OpAmp with MNMC 338

1.8 volt R-R-in/out bipolar class-AB OpAmp (NE5234) with NMC
332

compact 2 volt R-R-in/out CMOS class-AB OpAmp with MC 318

rail-to-rail-out (R-R-out)

1 volt R-R-out CMOS class-AB OpAmp with MNMC 324

1.2 volt R-R-out CMOS class-AB OpAmp with MHNMC 344

basic bipolar R-R-out class-A OpAmp 277

compact 1.2 volt R-R-out BiCMOS class-AB OpAmp with MNMC
329

compact 1.2 volt R-R-out CMOS class-AB OpAmp with MC 322

compact 1.2 volt R-R-out CMOS class-A OpAmp with MC 311

compact 2 volt R-R-out CMOS class-AB OpAmp with MC 315

improved basic bipolar R-R-out class-A OpAmp 279

improved basic CMOS R-R-out class-A OpAmp 281

reverse nested Miller compensation (RNMC) 238

S

saturation

output current limitation circuits 179

output saturation protection circuits 177

saturation protection and current limitation 176

slew rate 239

high-slew-rate bipolar class-AB voltage-follower buffer 287

T

telescopic-cascode OpAmp 268

total CMCR 98

three-GA-stage

three-GA-stage frequency compensation 224

three-GA-stage multipath nested Miller compensation (MNMC) 225

three-GA-stage nested Miller compensation (NMC) 228

two-GA-stage

two-GA-stage frequency compensation 211

two-GA-stage Miller compensation (MC) 215

two-GA-stage parallel compensation (PC) 212

U

unipolar

unipolar bipolar accurate V-I converter 394

unipolar CMOS accurate V-I converter 393

unipolar OpAmp accurate V-I converter 395

unipolar OpAmp-gain-boosted accurate V-I converter 392

unipolar single-transistor V-I converter 391

unipolar voltage-to-current converter 389

universal

universal class-A OFA design 414

universal class-A OFA design with a long-tail-pairs 417

universal class-A OFA design with floating zener-diode supply 414

universal class-A OFA design with supply current followers 415

universal class-AB OFA design 425

universal class-AB OFA design with current mirrors 429

universal class-AB OFA design with output-current equalization 430

universal class-AB OFA design with total-output-supply-current equalization 426

universal class-AB OFA realization with power-supply isolation 423

universal class-AB voltage-to-current converter design using an instrumentation amplifier 410

universal class-AB voltage-to-current converter with instrumentation amplifier 432

universal floating power supply design 424

- universal V-I converter design with real instrumentation amplifier 412
- universal V-I converter design with semi-instrumentation amplifier 411

V

- voltage and current follower (VCF) 10
- voltage and current gain boosting 203
- voltage compensation
 - input voltage compensation 271
- voltage follower (VF) 5, 44
 - FBB voltage-follower output stages 162
 - FFB voltage follower output stages 140
- voltage-follower buffer
 - high-slew-rate bipolar class-AB voltage-follower buffer 287
- voltage-gain boosting 275
- voltage-to-current converter 9, 48, 58, 389
 - differential
 - differential accurate V-I converter 398
 - differential CMOS accurate V-I converter 397
 - differential simple V-I converter 396
 - differential voltage-to-current converters 396
 - unipolar
 - unipolar bipolar accurate V-I converter 394
 - unipolar CMOS accurate V-I converter 393
 - unipolar OpAmp accurate V-I converter 395
 - unipolar OpAmp-gain-boosted accurate V-I converter 392
 - unipolar single-transistor V-I converter 391
 - unipolar voltage-to-current converter 389
- universal
 - universal class-AB voltage-to-current converter design using an instrumentation amplifier 410
 - universal class-AB voltage-to-current converter with instrumentation amplifier 432