Why do I work with electronics?

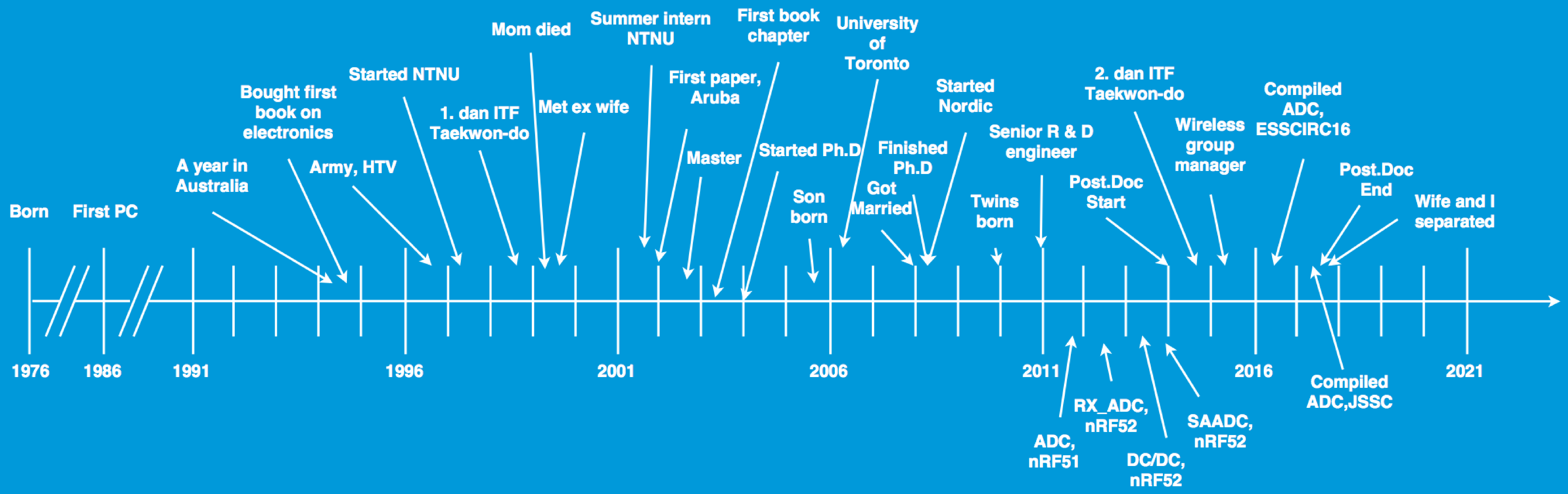
Specifically who are we, why do I do what I do, how it's made, and what we make

NORDIC SEMICONDUCTOR

Smarter Things

Carsten Wulff, 2018-08-29

Who am I : Carsten Wulff



Who

NORDIC SEMICONDUCTOR

Smarter Things

Svenn-Tore Larsen (CEO)

Nordic Semicondcutor

659 employees

Svein-Egil Nielsen (CTO)

R & D

498 employees

IC Finland Long - Range

Test

Sofware

IC Norway Short - Range

Support

Architecture

Digital

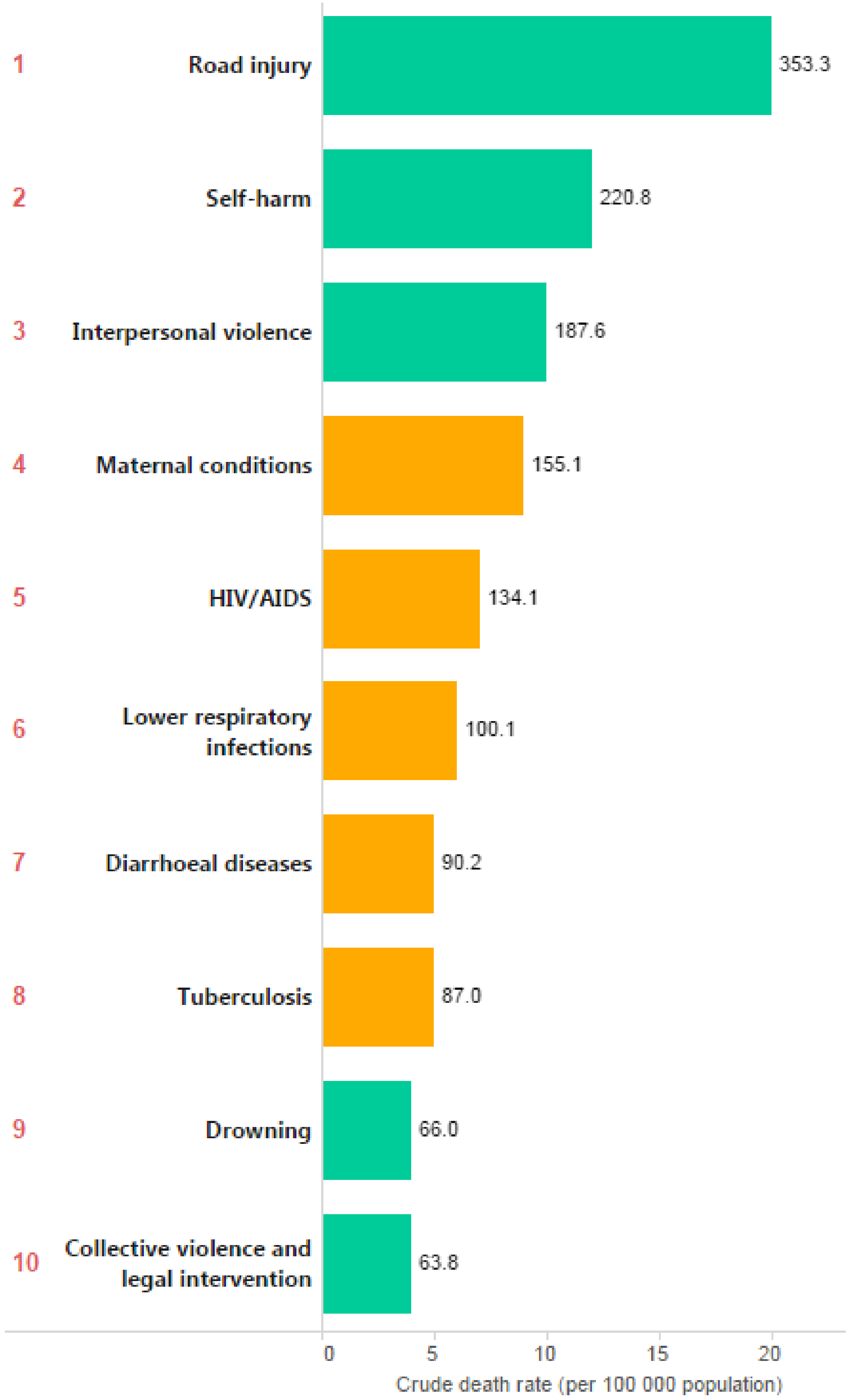
Wireless

37 employees

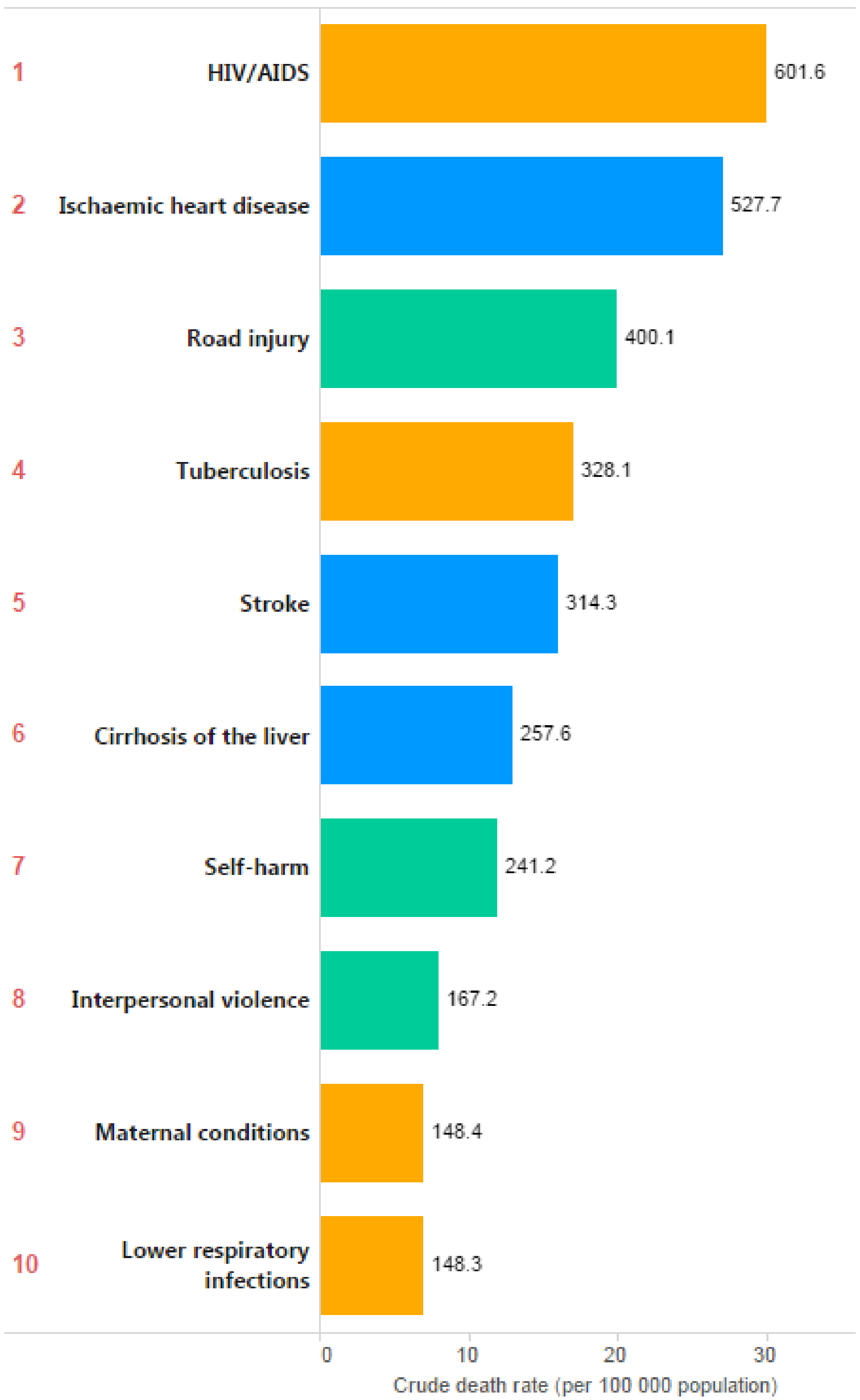
Why

Challenge Number 1

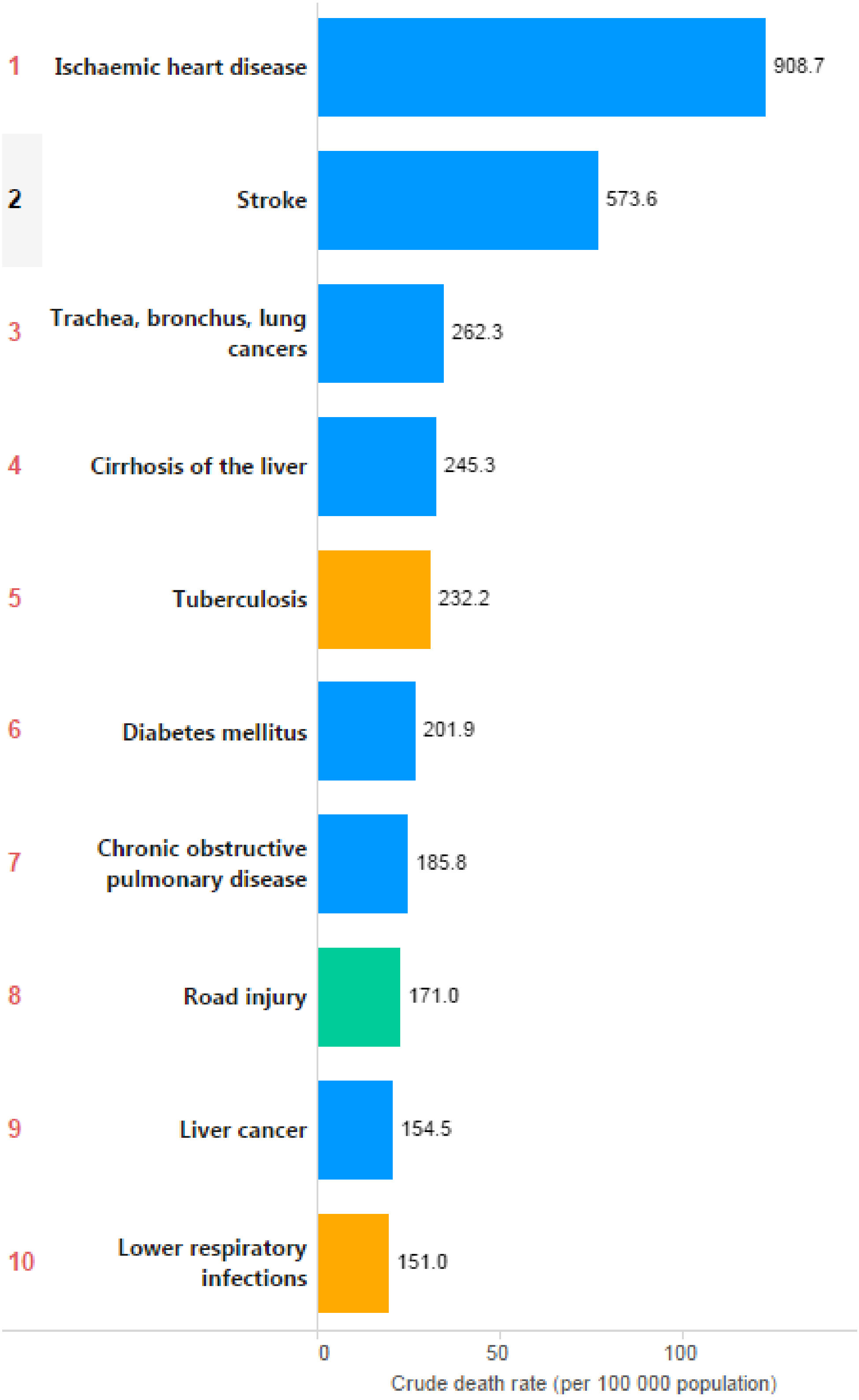
Source WHO



15 – 29 years of age



30 – 49 years of age



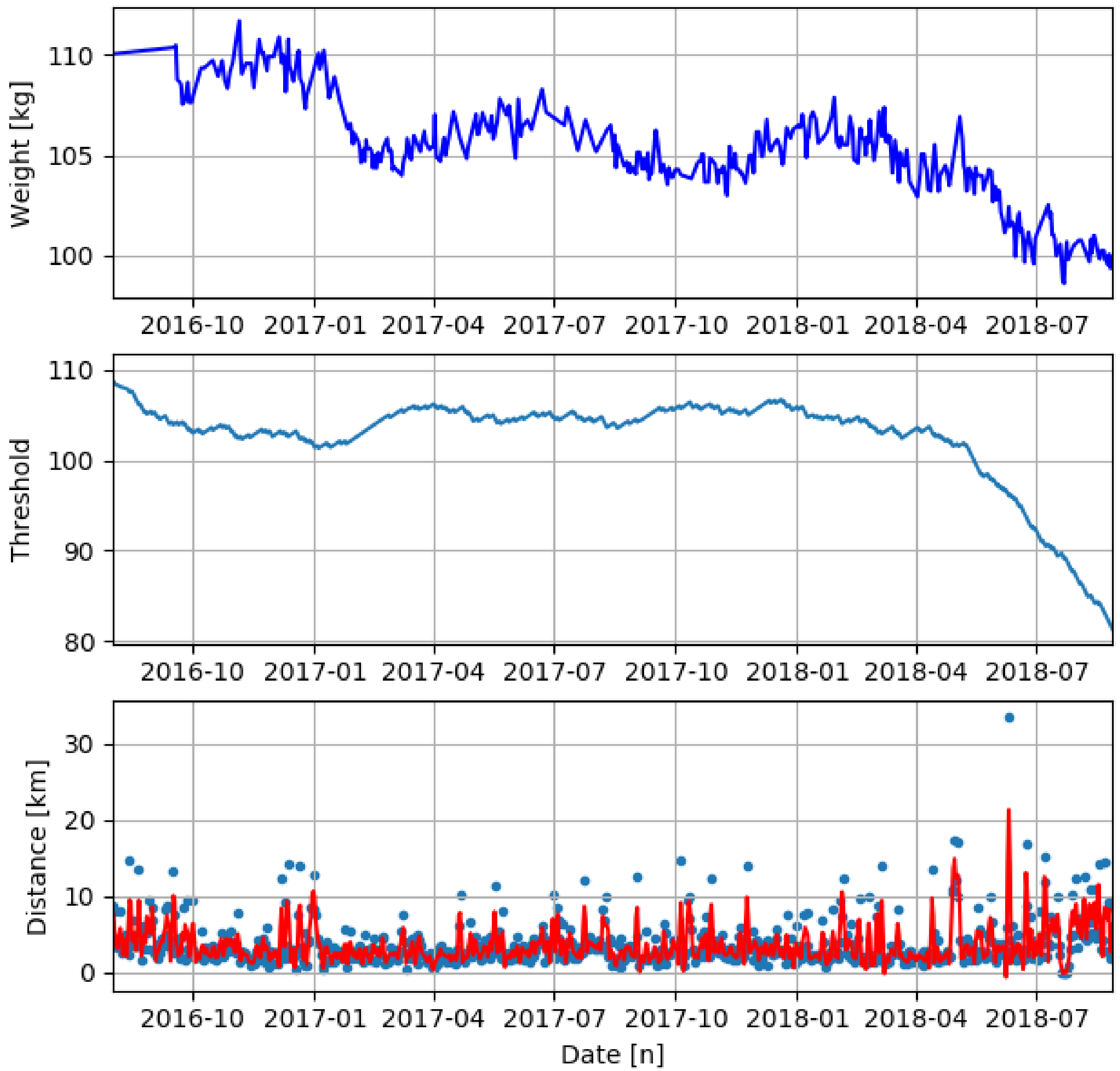
50 - 59 years of age

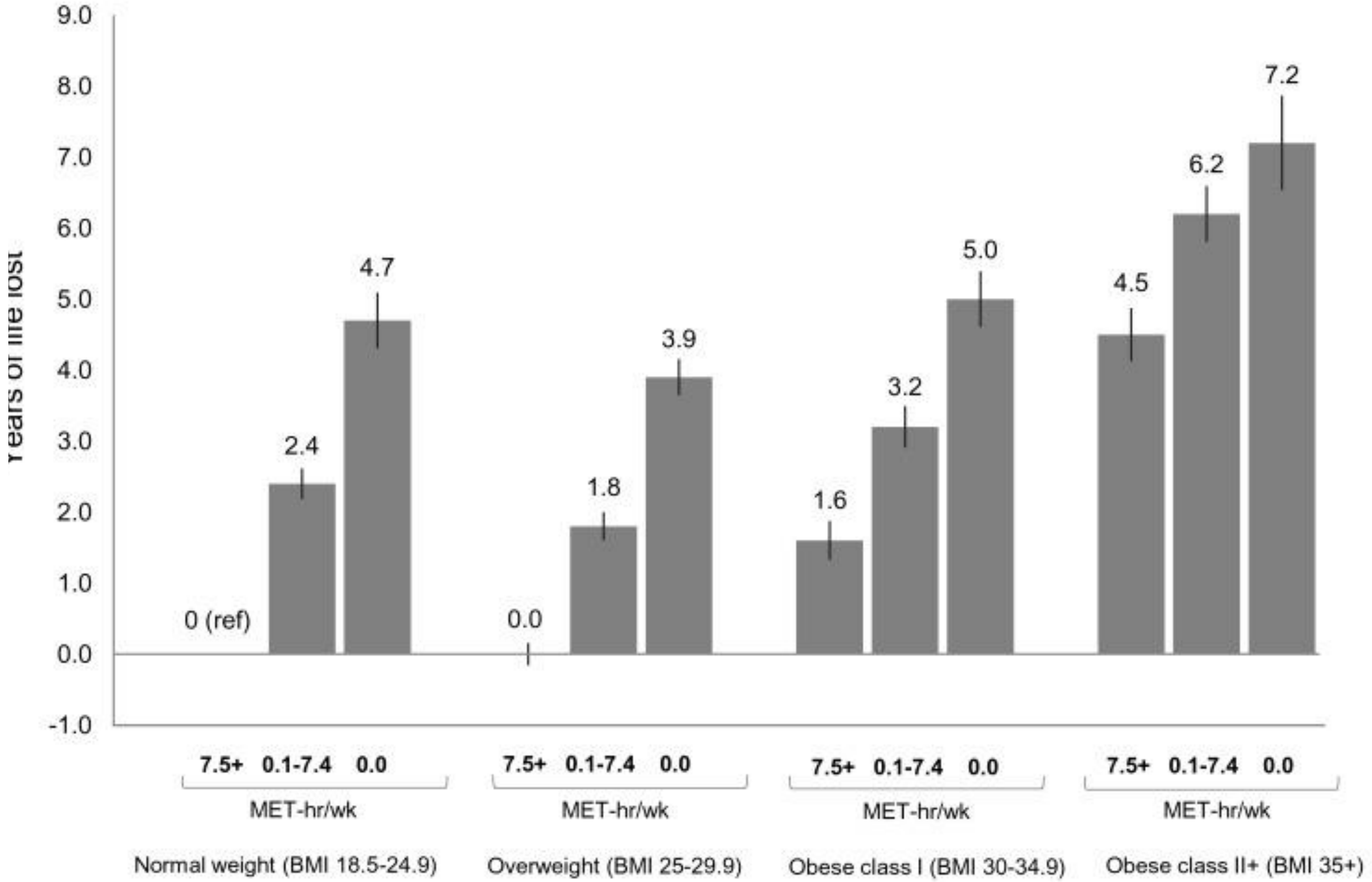
… cardiovascular diseases killed 17.689 million people in 2015, that's 31.3% of all deaths … WHO

Personal motivation

Max: 2011 @ 122 Kg

Activity matters



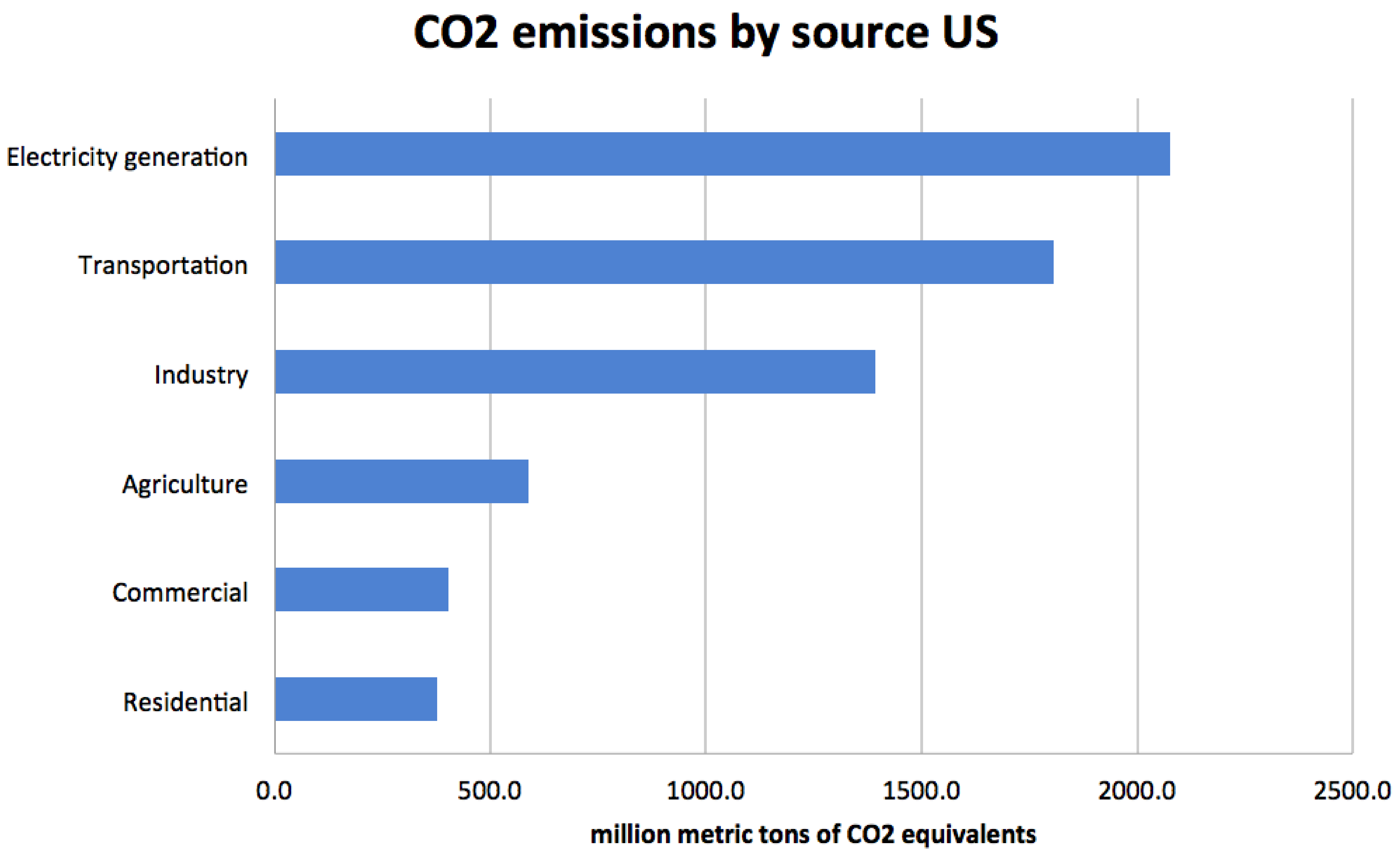


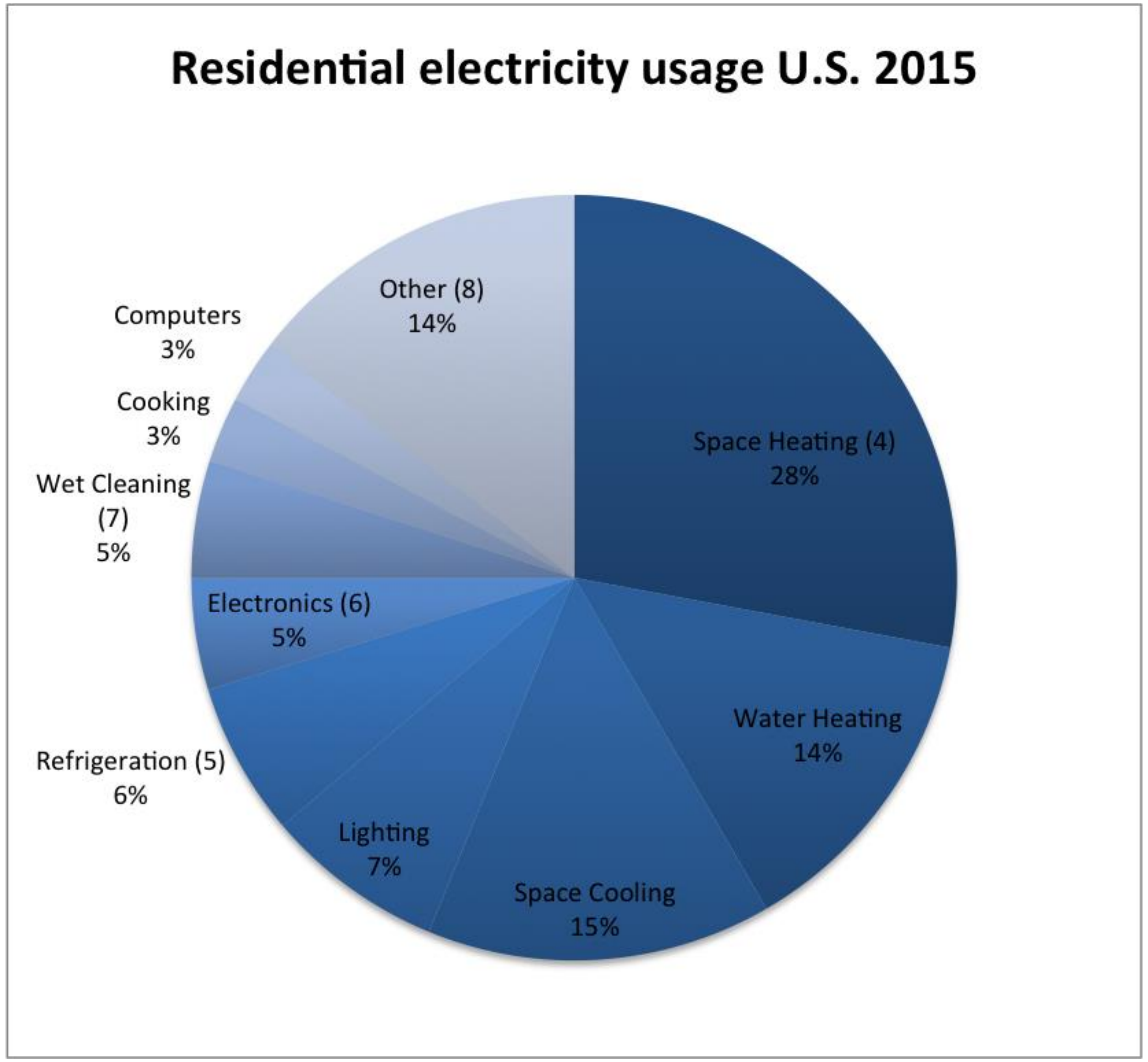
Threshold:
if(heart rate max on a day > 75 %){ thres[n] = thres[n-1] -0.3 }
else {thres[n] = thres[n-1] + 0.1 }

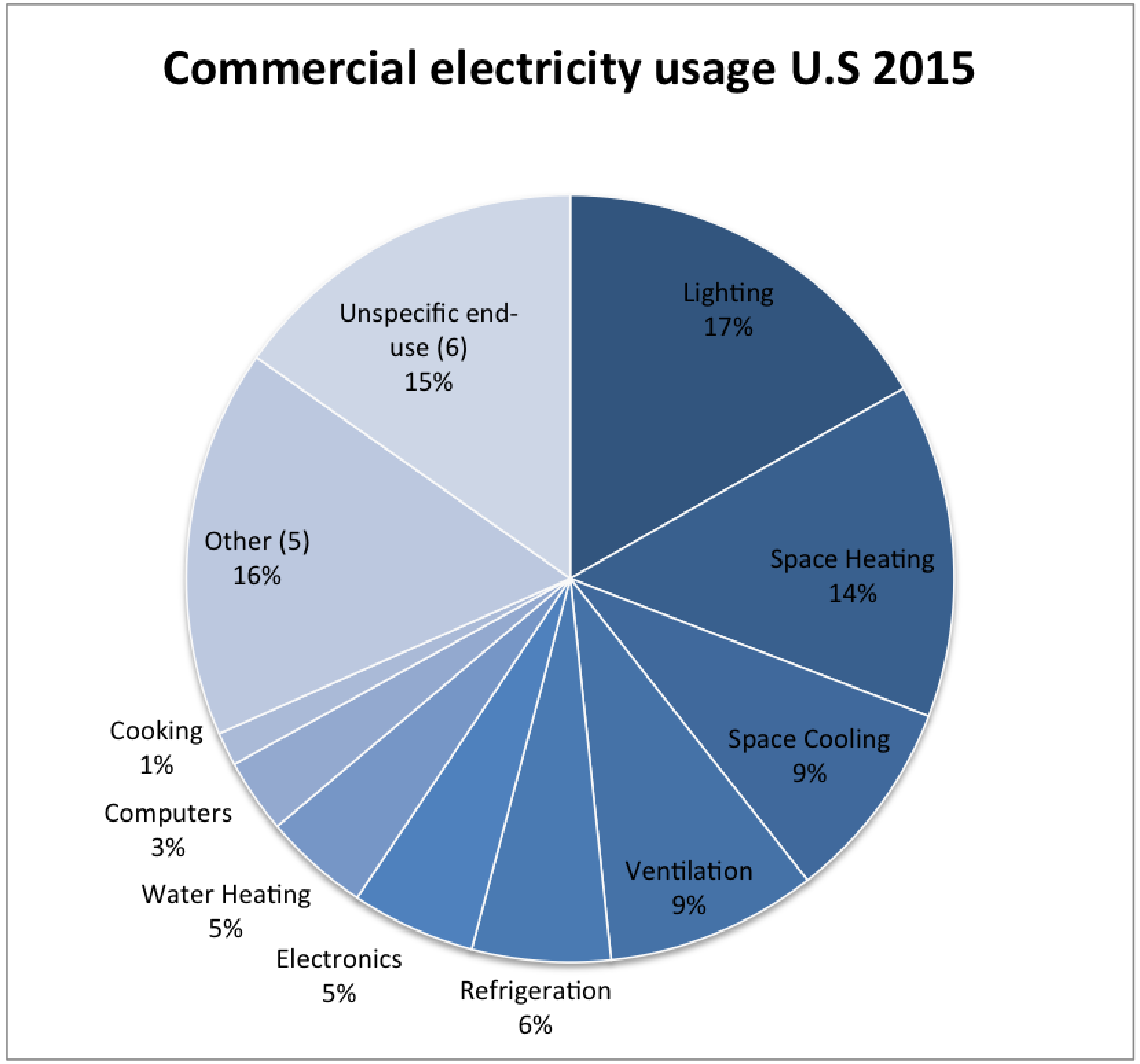
https://www.ncbi.nlm.nih.gov/pubmed/23139642


N52832
QFAAB0
1614AH
#51S

Challenge Number 2


CO2 emissions by source US
Electricity generation
Transportation
Industry
Agriculture
Commercial
Residential
0.0
500.0
1000.0
1500.0
2000.0
2500.0
million metric tons of CO2 equivalents


Residential electricity usage U.S. 2015
Space Heating (4)
28%
Water Heating
14%
Space Cooling
15%
Lighting
7%
Refrigeration (5)
6%
Electronics (6)
5%
Wet Cleaning
(7)
5%
Cooking
3%
Computers
3%
Other (8)
14%


Commercial electricity usage U.S 2015
Lighting
17%
Space Heating
14%
Space Cooling
9%
Ventilation
9%
Refrigeration
6%
Electronics
5%
Water Heating
5%
Computers
3%
Cooking
1%
Other (5)
16%
Unspecific end-
use (6)
15%

The primary way that IoT can help battle climate change is by reducing global energy consumpton, which will in turn reduce carbon emissions.

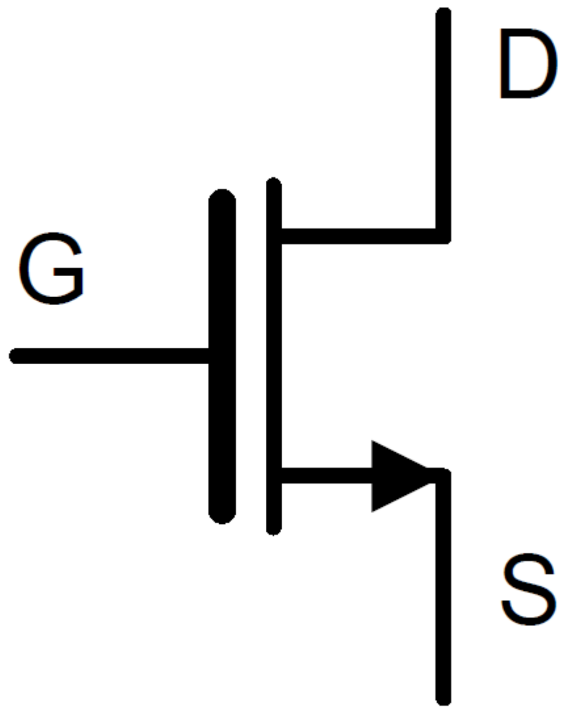
— *Michael Miller, The Internet of Things: How Smart TVs, Smart Cars, Smart Homes, and Smart Cites Are Changing the World*

How

Transistor

Transistor

- The most important device in an integrated circuit.
- An extremely complicated device
- Need computer models to describe the behavior accurately.
- BSIM model published in 1987, 17 parameters to describe a transistor. This is similar what you find in textbooks. Applies to 1um transistor lengths.



558 IEEE JOURNAL OF SOLID-STATE CIRCUITS, VOL. SC-22, NO. 4, AUGUST 1987

BSIM: Berkeley Short-Channel IGFET Model for MOS Transistors

BING J. SHEU, MEMBER, IEEE, DONALD L. SCHARFETTER, FELLOW, IEEE, PING-KEUNG KO, MEMBER, IEEE, AND MIN-CHIE JENG

Abstract —The Berkeley Short-channel IGFET Model (BSIM), an accurate and computationally efficient MOS transistor model, and its associated characterization facility for advanced integrated-circuit design are described. Both the strong-inversion and weak-inversion components of the drain-current expression are included. In order to speed up the circuit-simulation execution time, the dependence of the drain current on the substrate bias has been modeled with a numerical approximation. This approximation also simplifies the transistor terminal charge expressions. The charge model was derived from its drain-current counterpart to

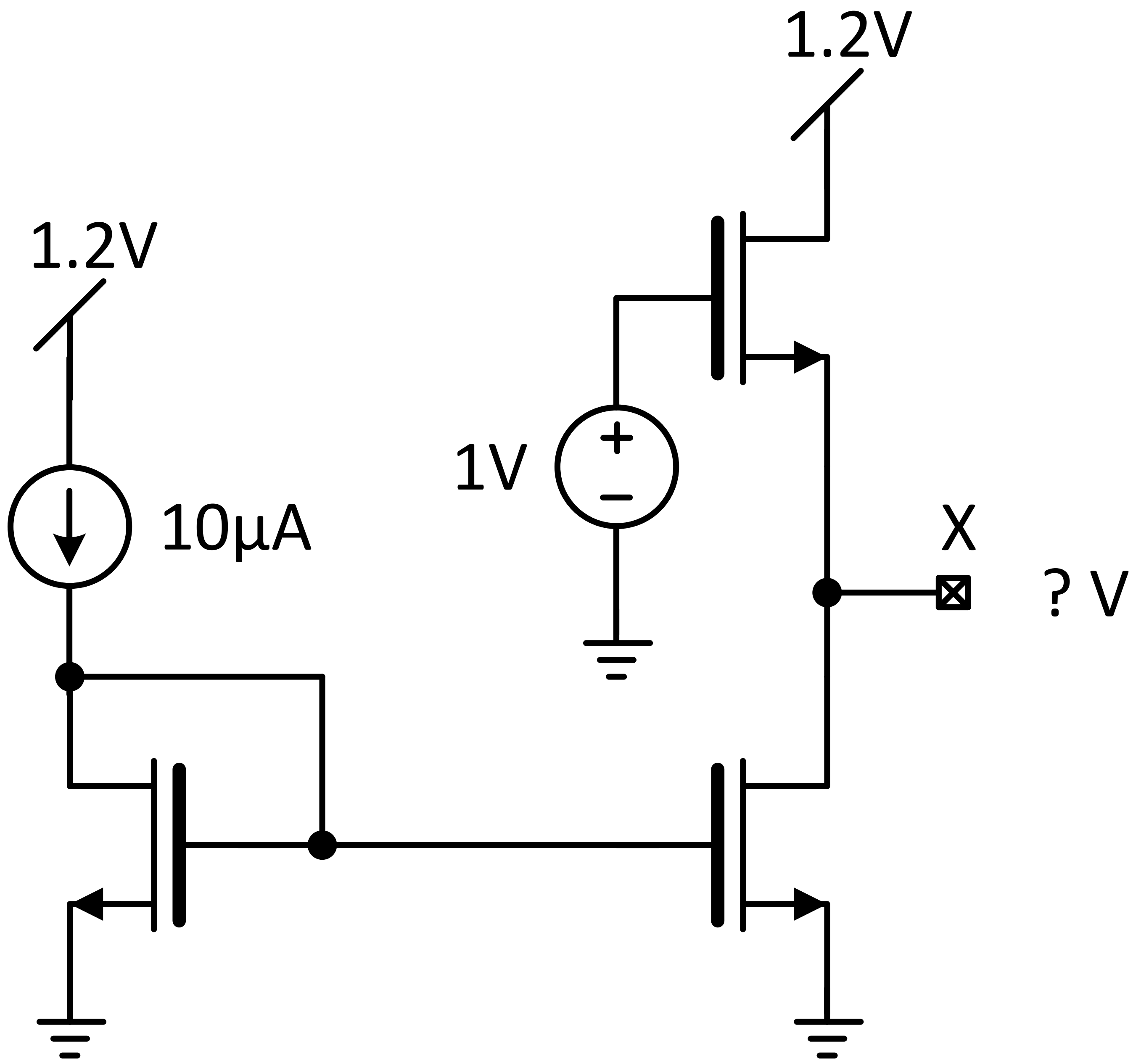
only as accurate as the models used. In the past, the SPICE2 program has provided three built-in MOS transistor models [6]. The Level-1 model, which contains fairly simple expressions, is most suitable for preliminary analysis. The Level-2 model, which contains expressions from detailed device physics, does not work well for small-geometry transistors. The Level-3 model represents an attempt to pursue the semi-empirical modeling approach

3. *Saturation Region* [$V_{GS} > V_{th}$ and $V_{DS} \geqslant V_{D\,SAT}$]:

$$I_{DS} = \frac{\mu_0}{[1+U_0(V_{GS}-V_{th})]} \cdot \frac{C_{ox}\frac{W}{L}(V_{GS}-V_{th})^2}{2aK}$$

BSIM 4.5 = 284 parameters

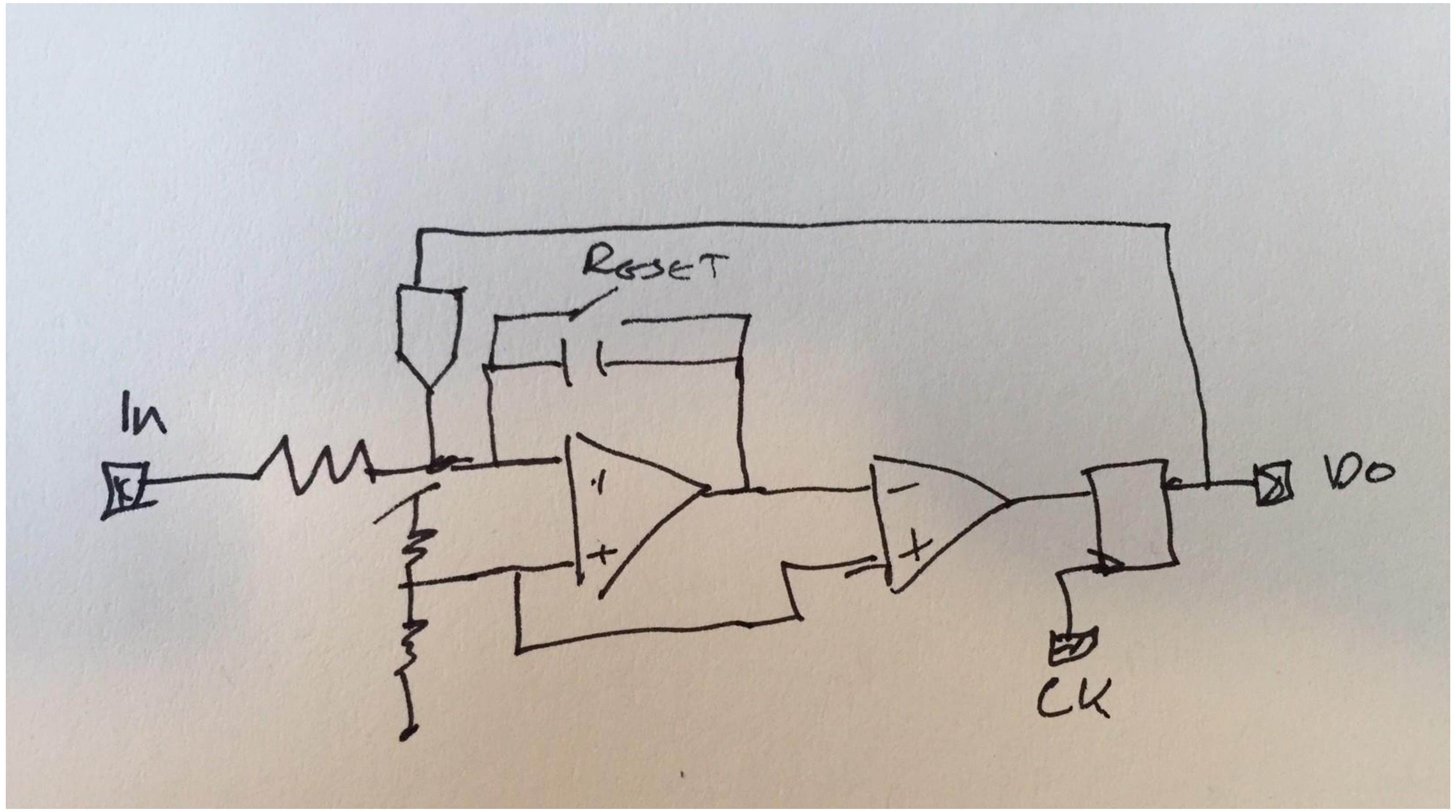
.MODEL N1 NMOS LEVEL=14 VERSION=4.5.0 BINUNIT=1 PARAMCHK=1 MOBMOD=0 CAPMOD=2 IGCMOD=1 IGBMOD=1 GEOMOD=1 DIOMOD=1 RDSMOD=0 RBODYMOD=0 RGATEMOD=3 PERMOD=1 ACNQSMOD=0 TRNQSMOD=0 TEMPMOD=0 TNOM=27 **TOXE=1.8E-009** TOXP=10E-010 TOXM=1.8E-009 DTOX=8E-10 EPSROX=3.9 WINT=5E-009 LINT=1E-009 LL=0 WL=0 LLN=1 WLN=1 LW=0 WW=0 LWN=1 WWN=1 LWL=0 WWL=0 XPART=0 TOXREF=1.4E-009 SAREF=5E-6 SBREF=5E-6 WLOD=2E-6 KU0=-4E-6 KVSAT=0.2 KVTH0=-2E-8 TKU0=0.0 LLODKU0=1.1 WLODKU0=1.1 LLODVTH=1.0 WLODVTH=1.0 LKU0=1E-6 WKU0=1E-6 PKU0=0.0 LKVTH0=1.1E-6 WKVTH0=1.1E-6 PKVTH0=0.0 STK2=0.0 LODK2=1.0 STETA0=0.0 LODETA0=1.0 LAMBDA=4E-10 VSAT=1.1E 005 VTL=2.0E5 XN=6.0 LC=5E-9 RNOIA=0.577 RNOIB=0.37 LINTNOI=1E-009 WPEMOD=0 WEB=0.0 WEC=0.0 KVTH0WE=1.0 K2WE=1.0 KU0WE=1.0 SCREF=5.0E-6 TVOFF=0.0 TVFBSDOFF=0.0 **VTH0=0.25** K1=0.35 K2=0.05 K3=0 K3B=0 W0=2.5E-006 DVT0=1.8 DVT1=0.52 DVT2=-0.032 DVT0W=0 DVT1W=0 DVT2W=0 DSUB=2 MINV=0.05 VOFFL=0 DVTP0=1E-007 DVTP1=0.05 LPE0=5.75E-008 LPEB=2.3E-010 XJ=2E-008 NGATE=5E 020 NDEP=2.8E 018 NSD=1E 020 PHIN=0 CDSC=0.0002 CDSCB=0 CDSCD=0 CIT=0 VOFF=-0.15 NFACTOR=1.2 ETA0=0.05 ETAB=0 UC=-3E-011 VFB=-0.55 **U0=0.032** UA=5.0E-011 UB=3.5E-018 A0=2 AGS=1E-020 A1=0 A2=1 B0=-1E-020 B1=0 KETA=0.04 DWG=0 DWB=0 PCLM=0.08 PDIBLC1=0.028 PDIBLC2=0.022 PDIBLCB=-0.005 DROUT=0.45 PVAG=1E-020 DELTA=0.01 PSCBE1=8.14E 008 PSCBE2=5E-008 RSH=0 RDSW=0 RSW=0 RDW=0 FPROUT=0.2 PDITS=0.2 PDITSD=0.23 PDITSL=2.3E 006 RSH=0 RDSW=50 RSW=150 RDW=150 RDSWMIN=0 RDWMIN=0 RSWMIN=0 PRWG=0 PRWB=6.8E-011 WR=1 ALPHA0=0.074 ALPHA1=0.005 BETA0=30 AGIDL=0.0002 BGIDL=2.1E 009 CGIDL=0.0002 EGIDL=0.8 AIGBACC=0.012 BIGBACC=0.0028 CIGBACC=0.002 NIGBACC=1 AIGBINV=0.014 BIGBINV=0.004 CIGBINV=0.004 EIGBINV=1.1 NIGBINV=3 AIGC=0.012 BIGC=0.0028 CIGC=0.002 AIGSD=0.012 BIGSD=0.0028 CIGSD=0.002 NIGC=1 POXEDGE=1 PIGCD=1 NTOX=1 VFBSDOFF=0.0 XRCRG1=12 XRCRG2=5 CGSO=6.238E-010 CGDO=6.238E-010 CGBO=2.56E-011 CGDL=2.495E-10 CGSL=2.495E-10 CKAPPAS=0.03 CKAPPAD=0.03 ACDE=1 MOIN=15 NOFF=0.9 VOFFCV=0.02 KT1=-0.37 KT1L=0.0 KT2=-0.042 UTE=-1.5 UA1=1E-009 UB1=-3.5E-019 UC1=0 PRT=0 AT=53000 FNOIMOD=1 TNOIMOD=0 JSS=0.0001 JSWS=1E-011 JSWGS=1E-010 NJS=1 IJTHSFWD=0.01 IJTHSREV=0.001 BVS=10 XJBVS=1 JSD=0.0001 JSWD=1E-011 JSWGD=1E-010 NJD=1 IJTHDFWD=0.01 IJTHDREV=0.001 BVD=10 XJBVD=1 PBS=1 CJS=0.0005 MJS=0.5 PBSWS=1 CJSWS=5E-010 MJSWS=0.33 PBSWGS=1 CJSWGS=3E-010 MJSWGS=0.33 PBD=1 CJD=0.0005 MJD=0.5 PBSWD=1 CJSWD=5E-010 MJSWD=0.33 PBSWGD=1 CJSWGD=5E-010 MJSWGD=0.33 TPB=0.005 TCJ=0.001 TPBSW=0.005 TCJSW=0.001 TPBSWG=0.005 TCJSWG=0.001 XTIS=3 XTID=3 DMCG=0E-006 DMCI=0E-006 DMDG=0E-006 DMCGT=0E-007 DWJ=0.0E-008 XGW=0E-007 XGL=0E-008 RSHG=0.4 GBMIN=1E-010 RBPB=5 RBPD=15 RBPS=15 RBDB=15 RBSB=15 NGCON=1 JTSS=1E-4 JTSD=1E-4 JTSSWS=1E-10 JTSSWD=1E-10 JTSSWGS=1E-7 JTSSWGD=1E-7 NJTS=20.0 NJTSSW=20 NJTSSWG=6 VTSS=10 VTSD=10 VTSSWS=10 VTSSWD=10 VTSSWGS=2 VTSSWGD=2 XTSS=0.02 XTSD=0.02 XTSSWS=0.02 XTSSWD=0.02 XTSSWGS=0.02 XTSSWGD=0.02



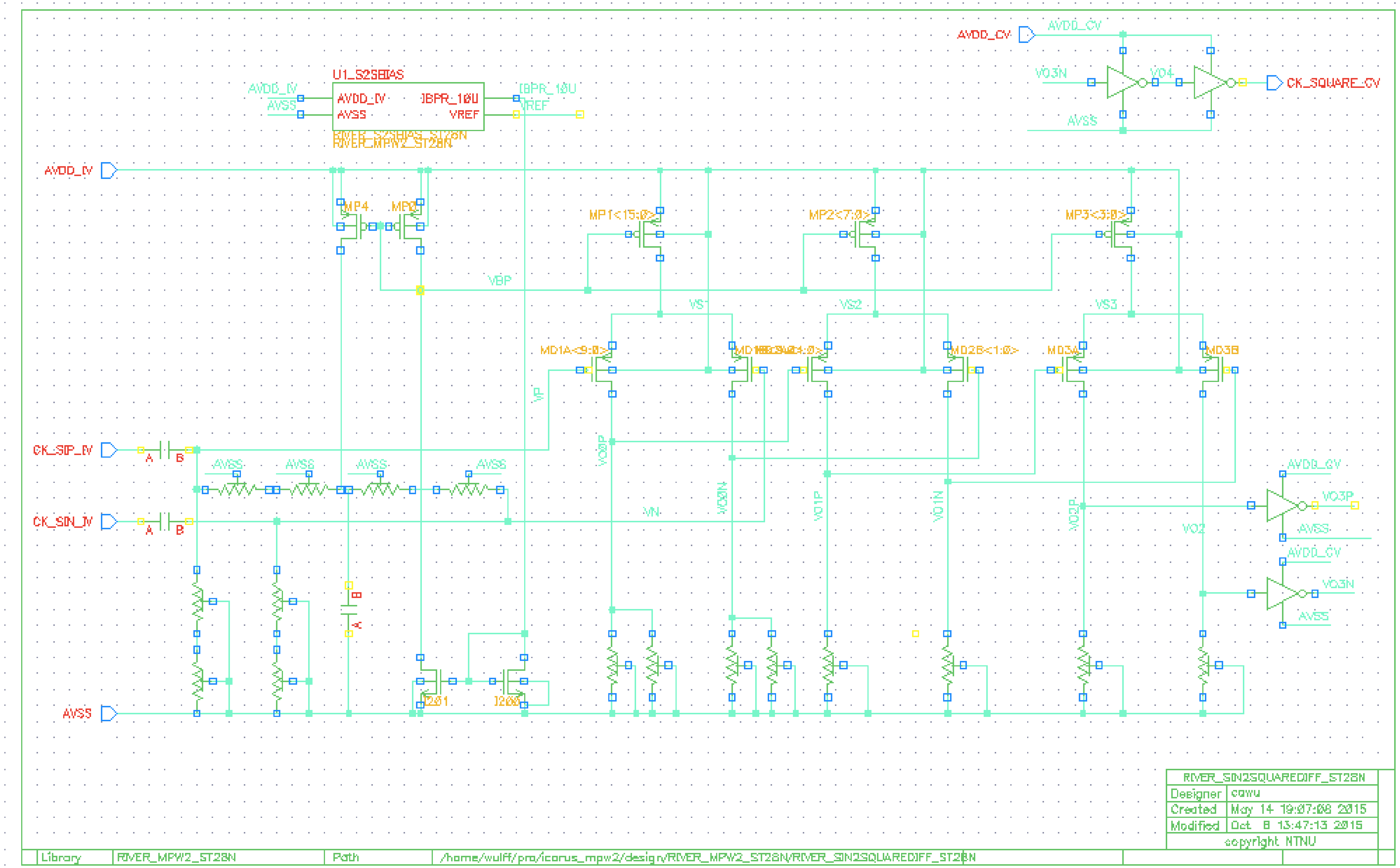
What is the voltage at node X?

Analog Schematic Design

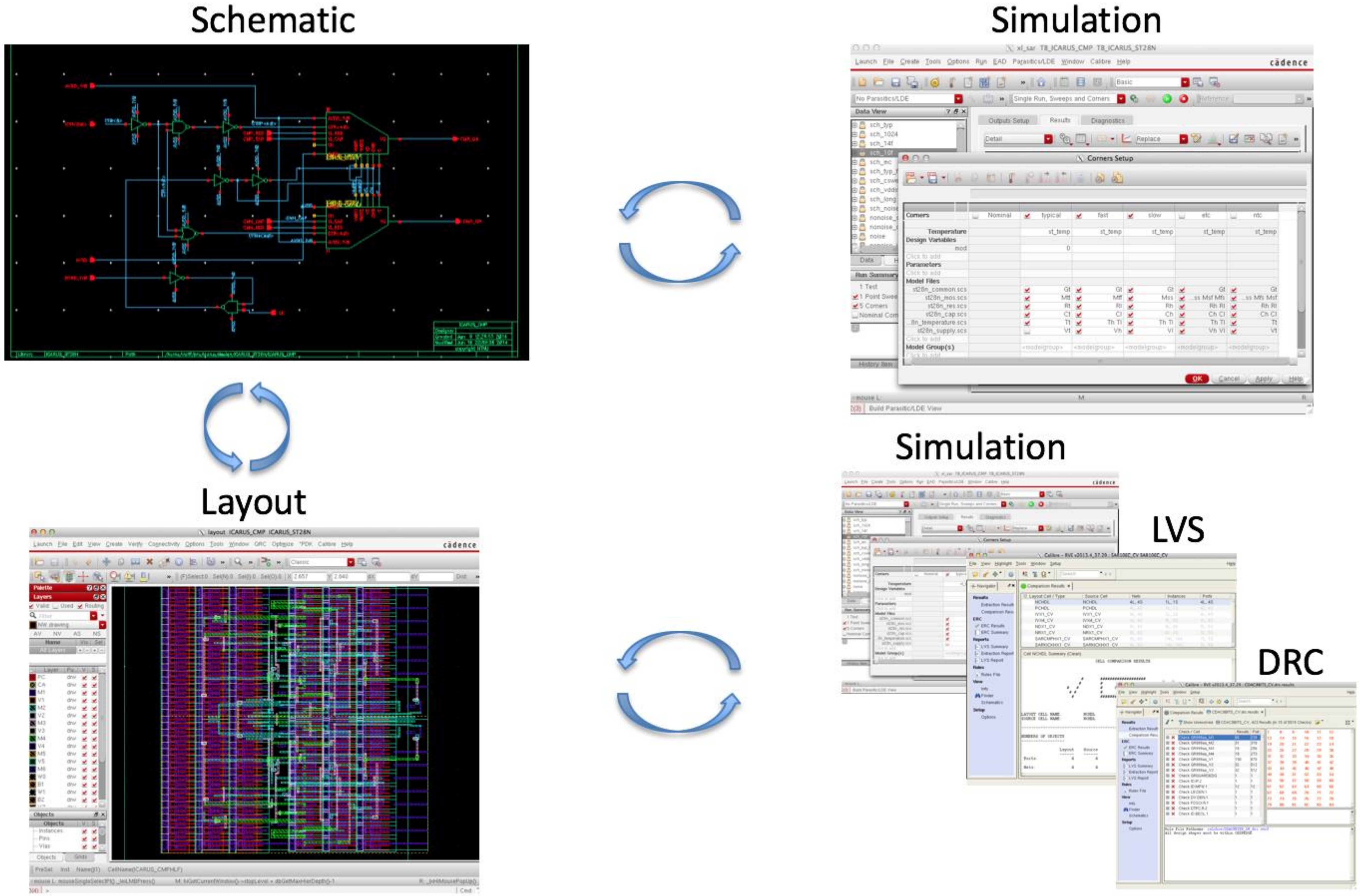
Typical start of design: paper and a pencil



Draw schematic



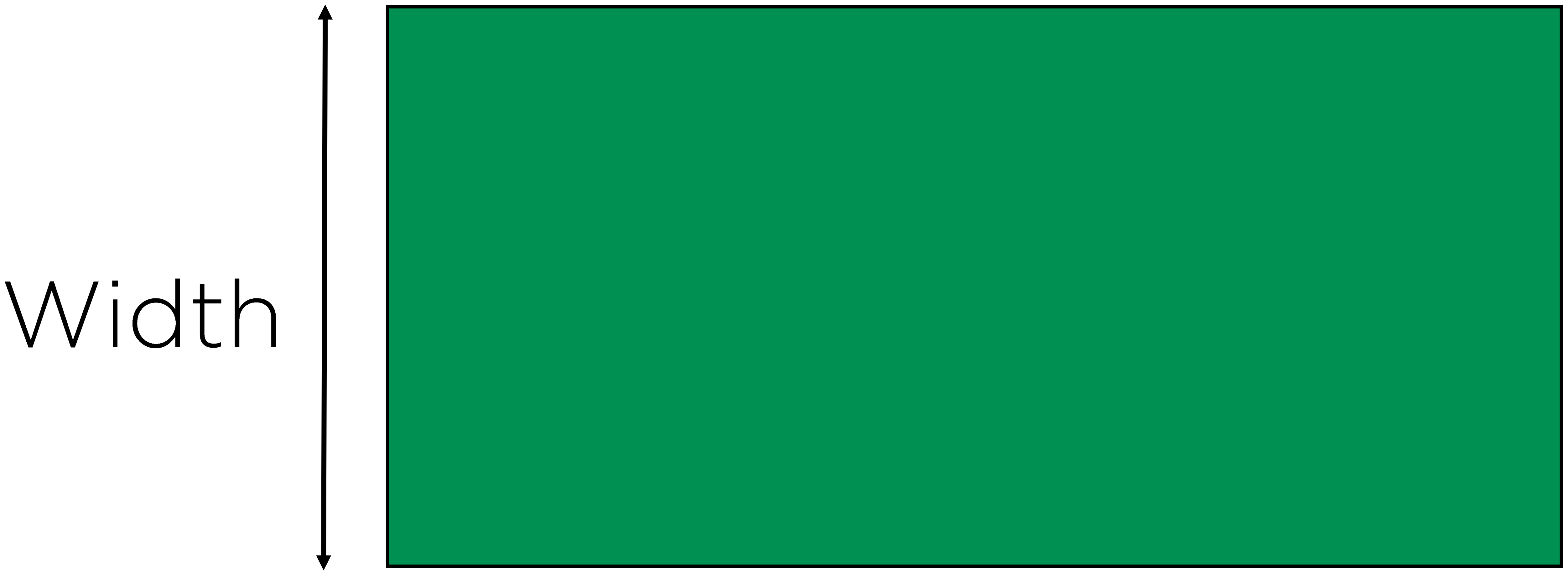
Analog Design



Analog Layout Design

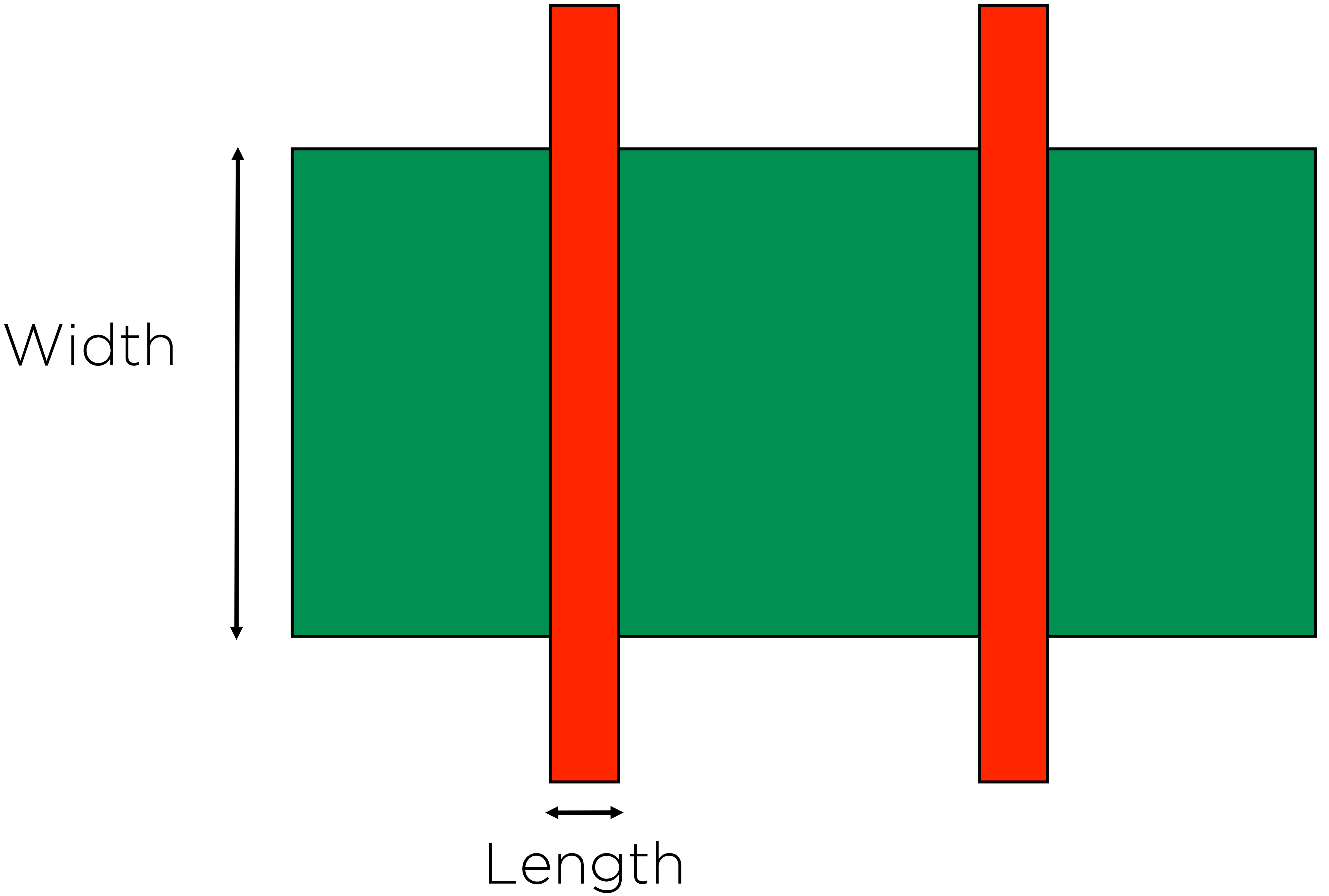
Making a GDSII file that can be sent to the foundry

Transistor layout - Diffusion

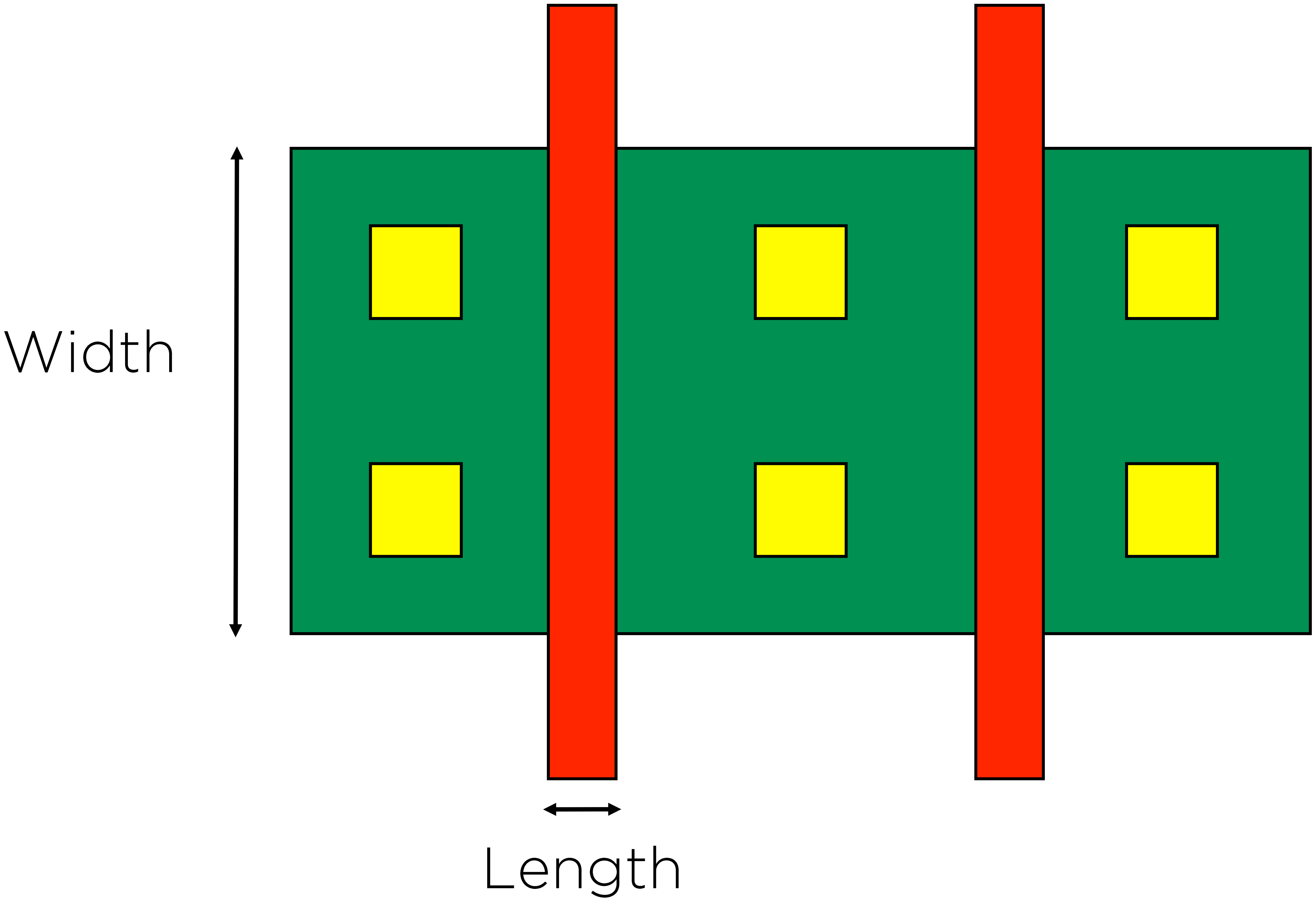


Marks the boundary of a transistor

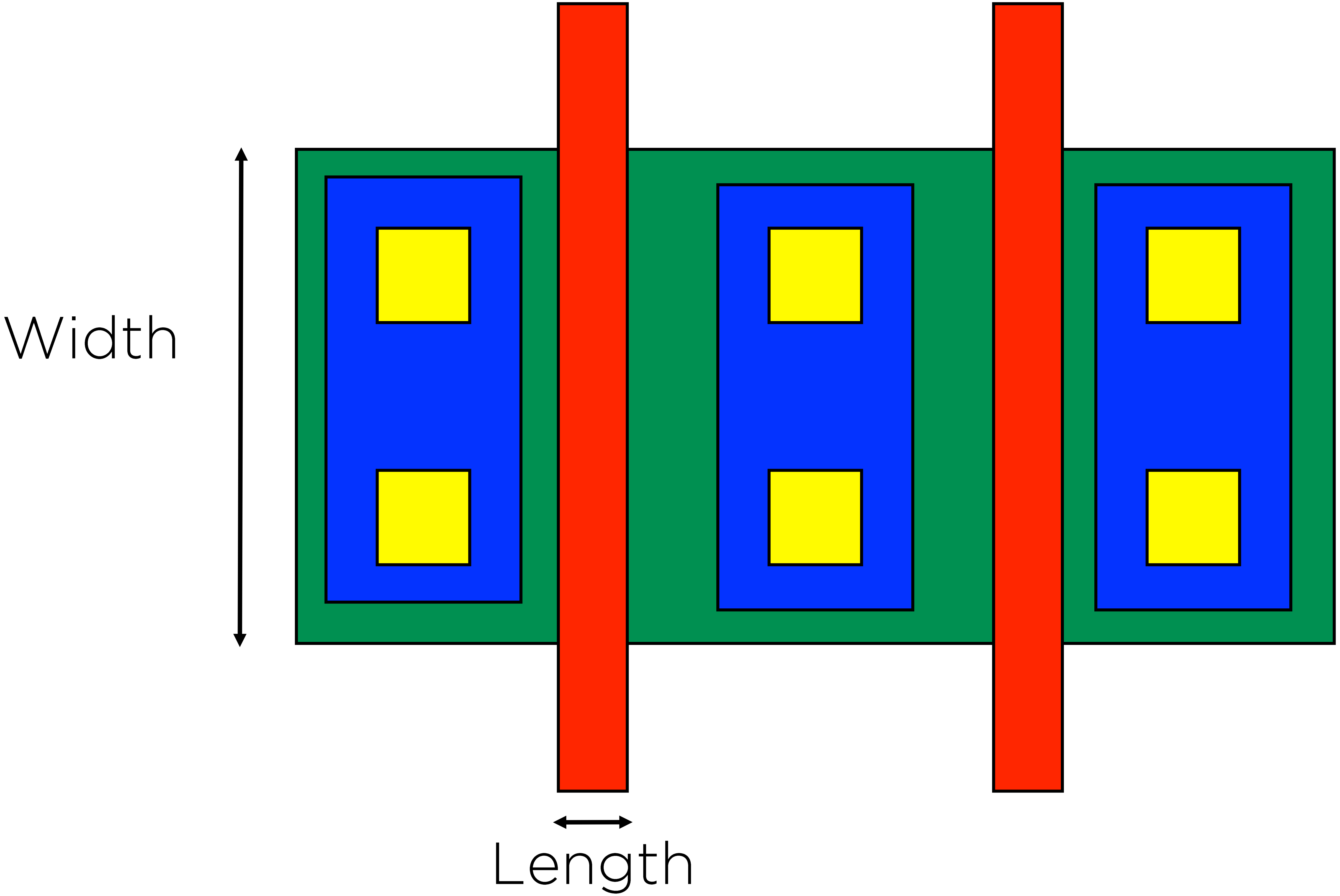
Transistor layout - Gate



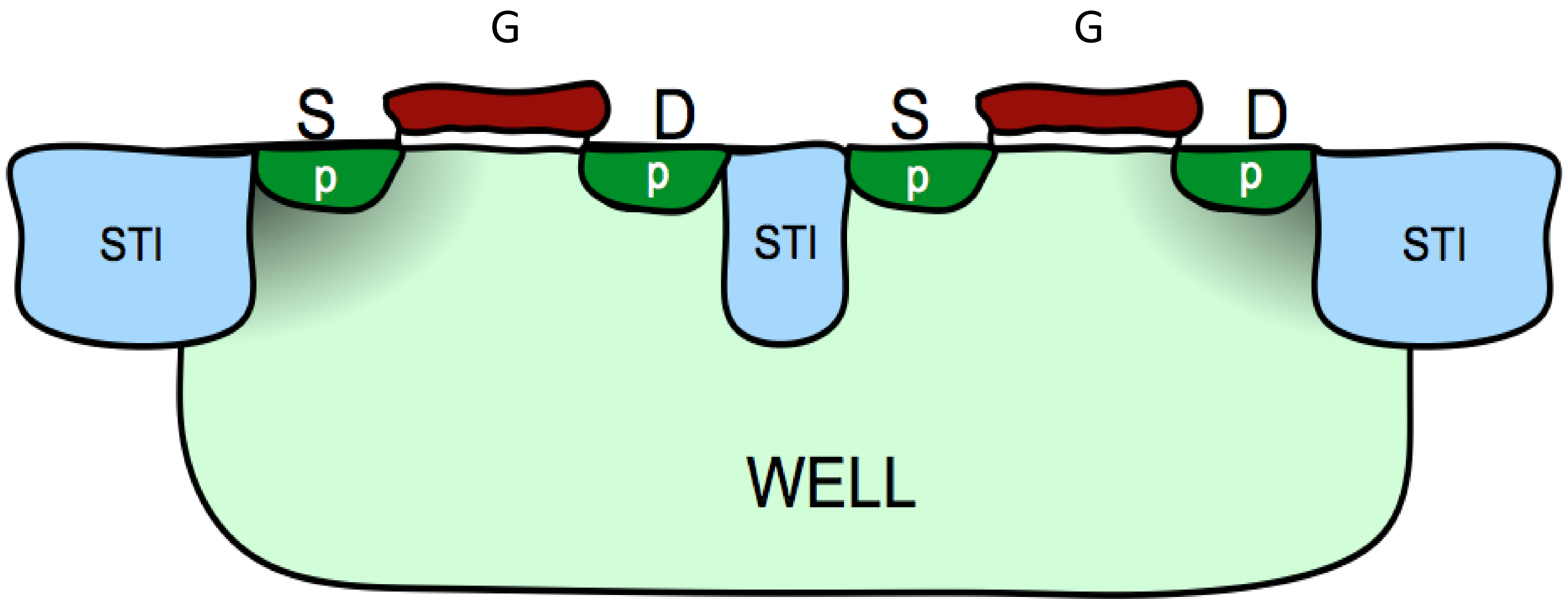
Transistor layout - Contacts



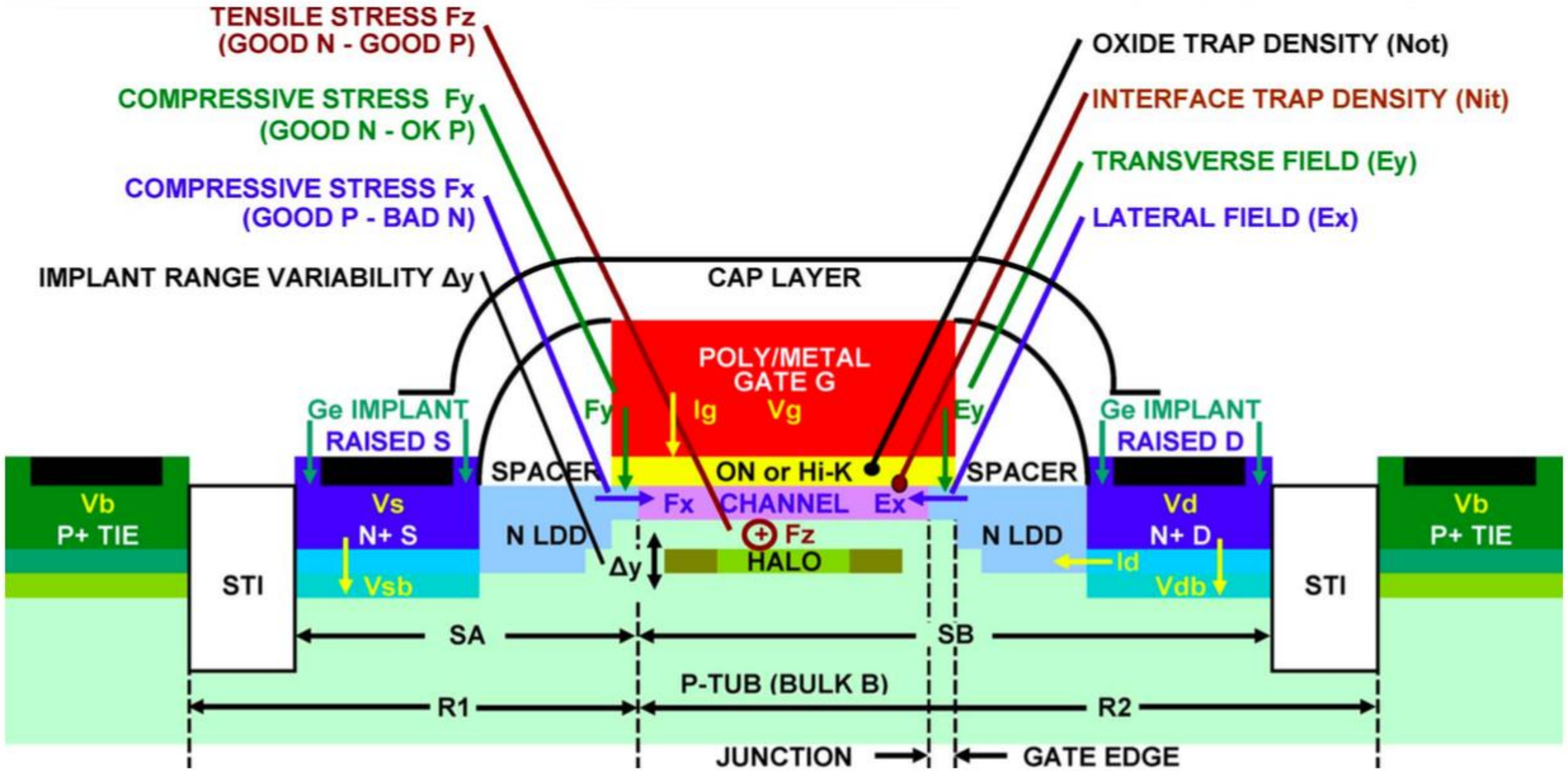
Transistor layout - Metal 1



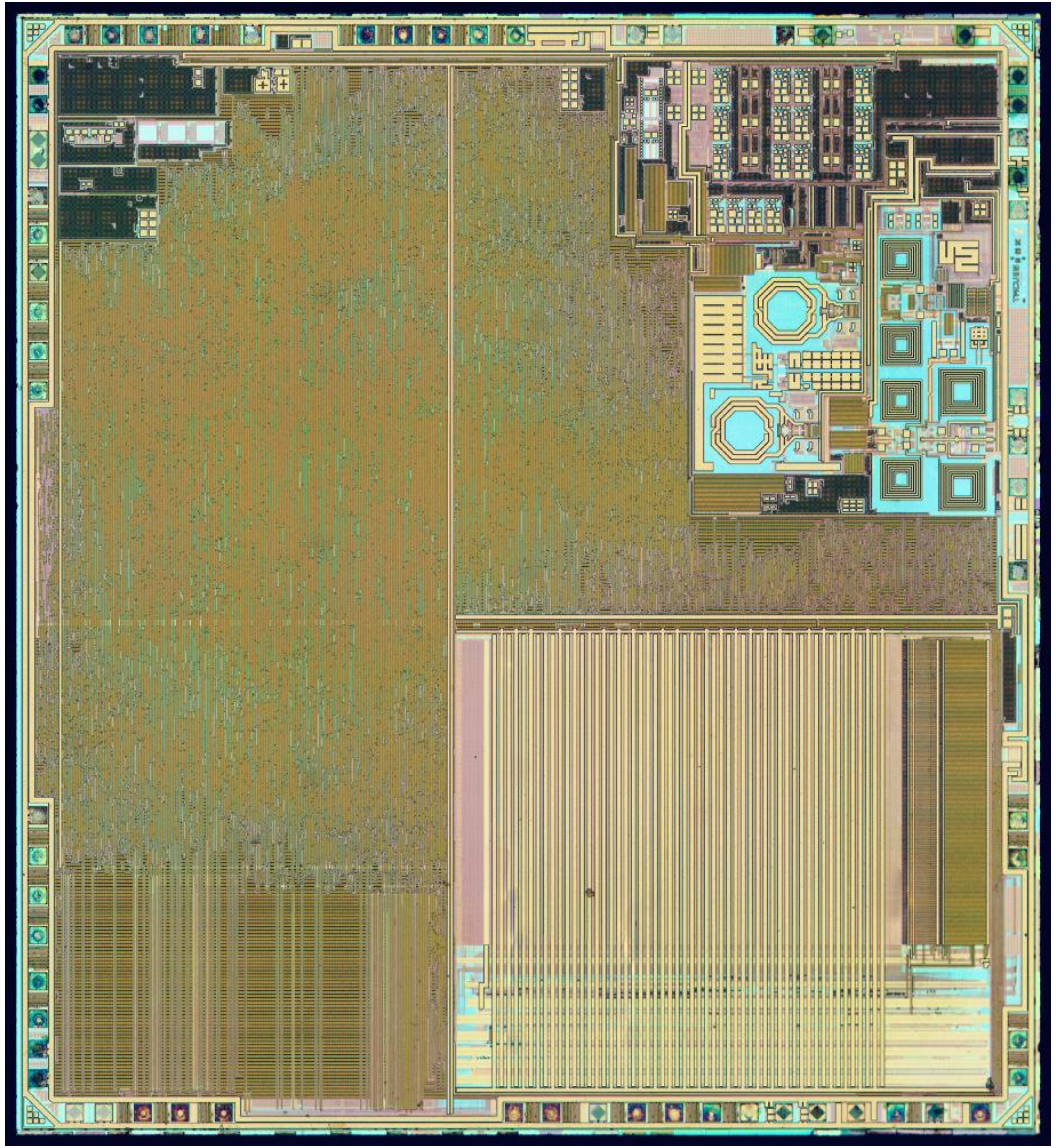
Transistor cross section



Real transistor cross section



Lewyn, 2009, Proceedings of IEEE



Algorithm

Range in Wireless systems

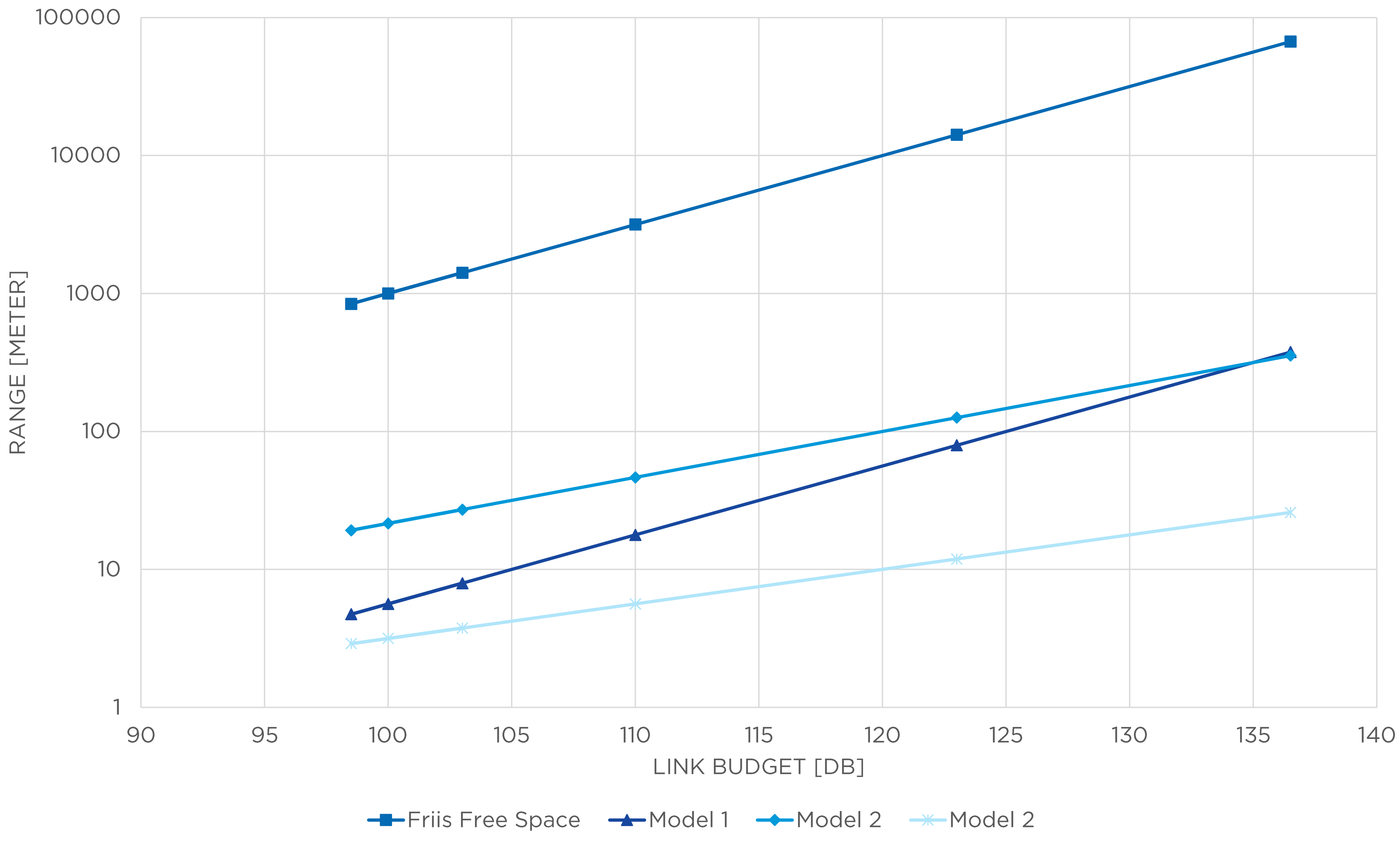
- Assume antennas that transmit in a uniform fashion (isotropic) and without gain.
- Assume free space
- Friis Transmission Formula

$$FSPL\ [dB] = 20log(Distance) + 20log(frequency) - 20log\left(\frac{4\pi}{c}\right)$$

$$\boldsymbol{Distance\ at\ 2.4\ GHz \sim 10^{\frac{FSPL\ [dB]\ -\ 40\ dB}{20}}}$$

$$\boldsymbol{Distance\ at\ 0.9\ GHz \sim 10^{\frac{FSPL\ [dB]\ -31\ dB}{20}}}$$

Link Budget


100000
10000
1000
100
10
1
RANGE [METER]
90
95
100
105
110
115
120
125
130
135
140
LINK BUDGET [DB]
Friis Free Space
Model 1
Model 2
Model 2

Link budget = TX power – RX sensitivity

RX sensitivity = -174 dBm + 10 x log(datarate) + Noise Figure (NF) + Energy per bit/Noise (Eb/N0)

Thermal noise

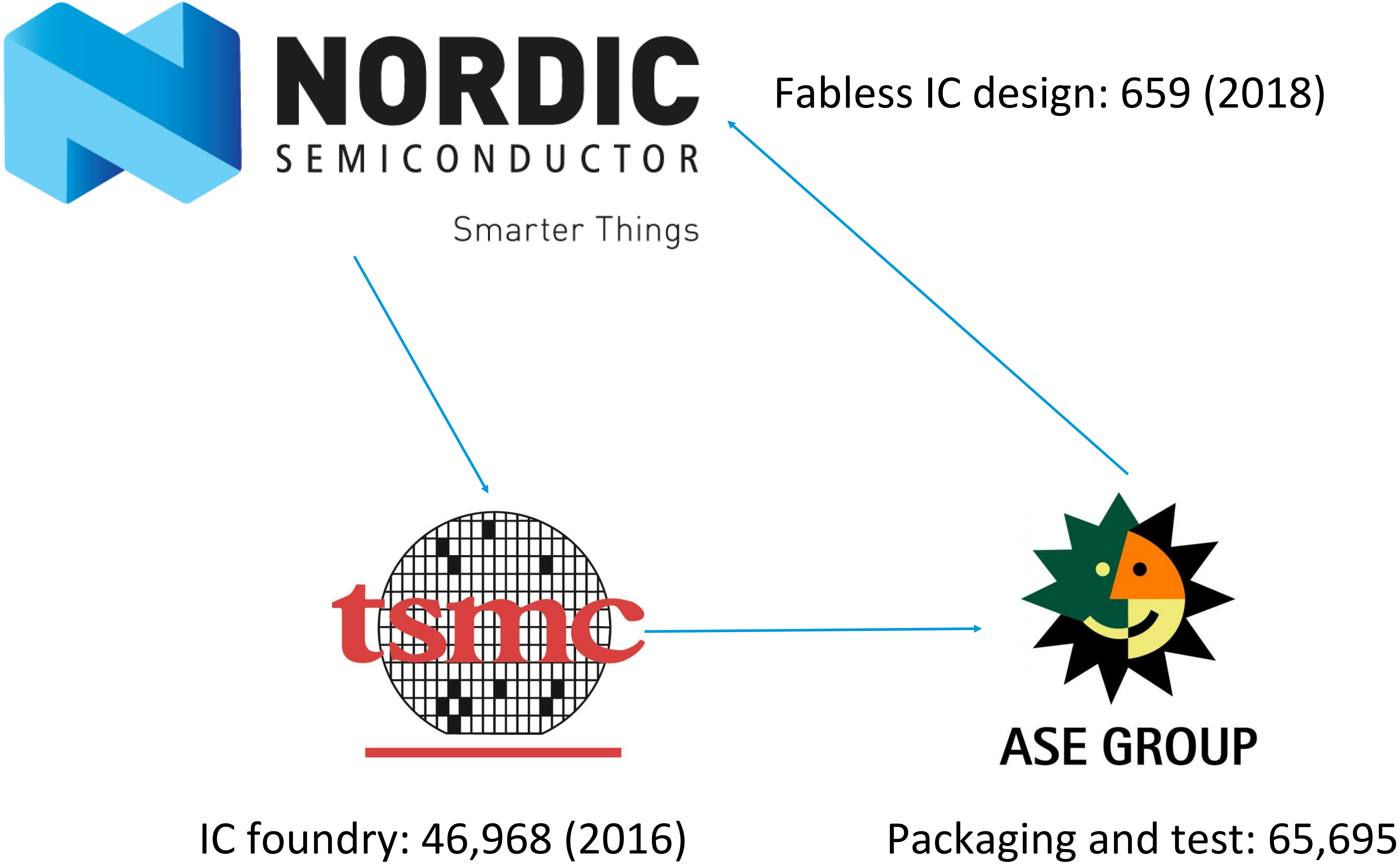
Bits per second

Analog Radio receiver

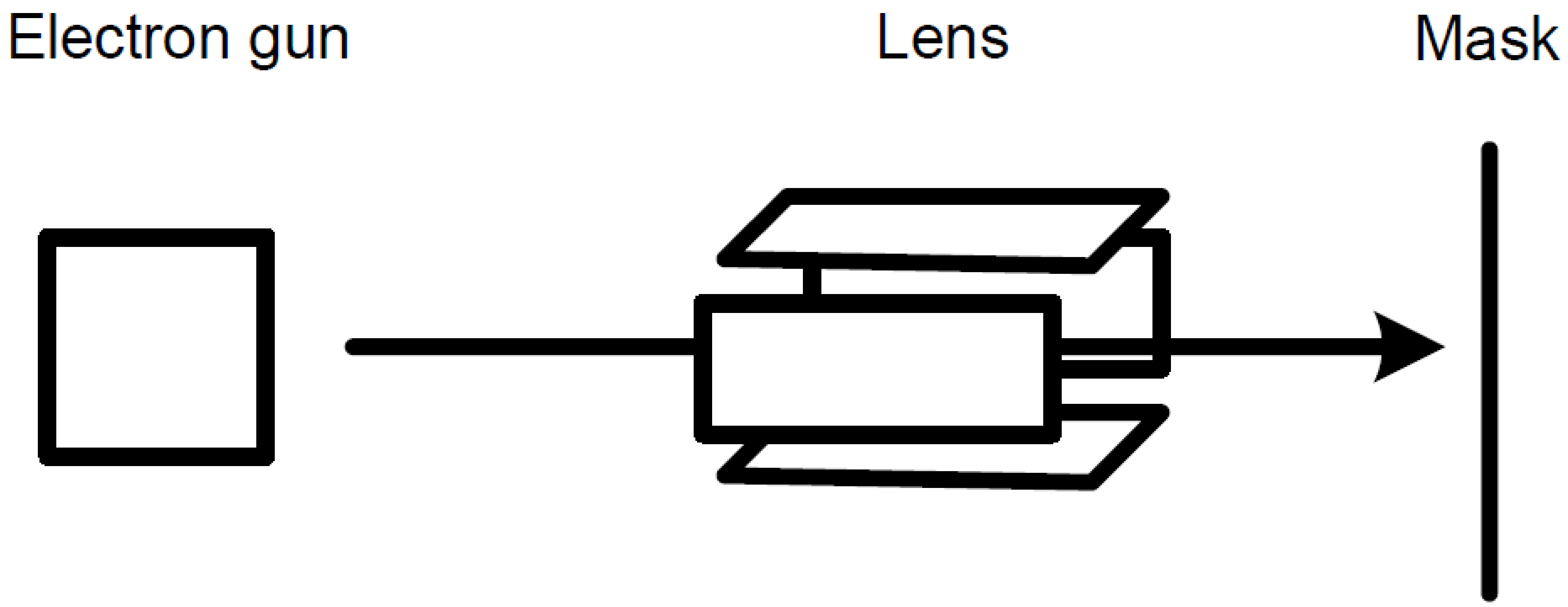
Algorithm team

Manufacturing ICs

Extremely expensive


NORDIC
SEMICONDUCTOR
Smarter Things
Fabless IC design: 659 (2018)
tsmc
ASE GROUP
IC foundry: 46,968 (2016)
Packaging and test: 65,695

Mask making



- Mask making is extremely expensive
- A normal chip has around 30 - 40 masks.

Lithography

Today: 193nm argon fluoride excimer laser

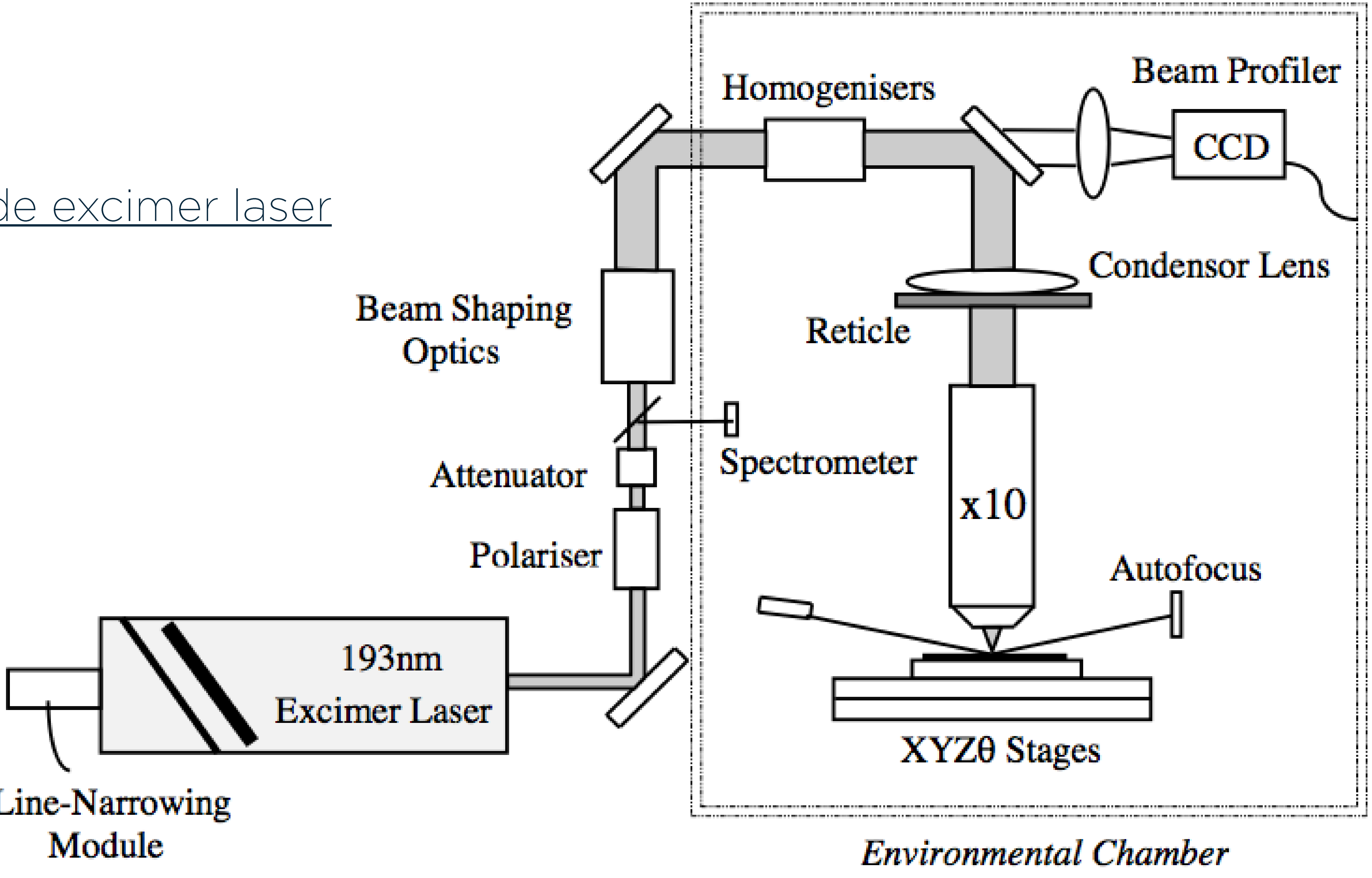
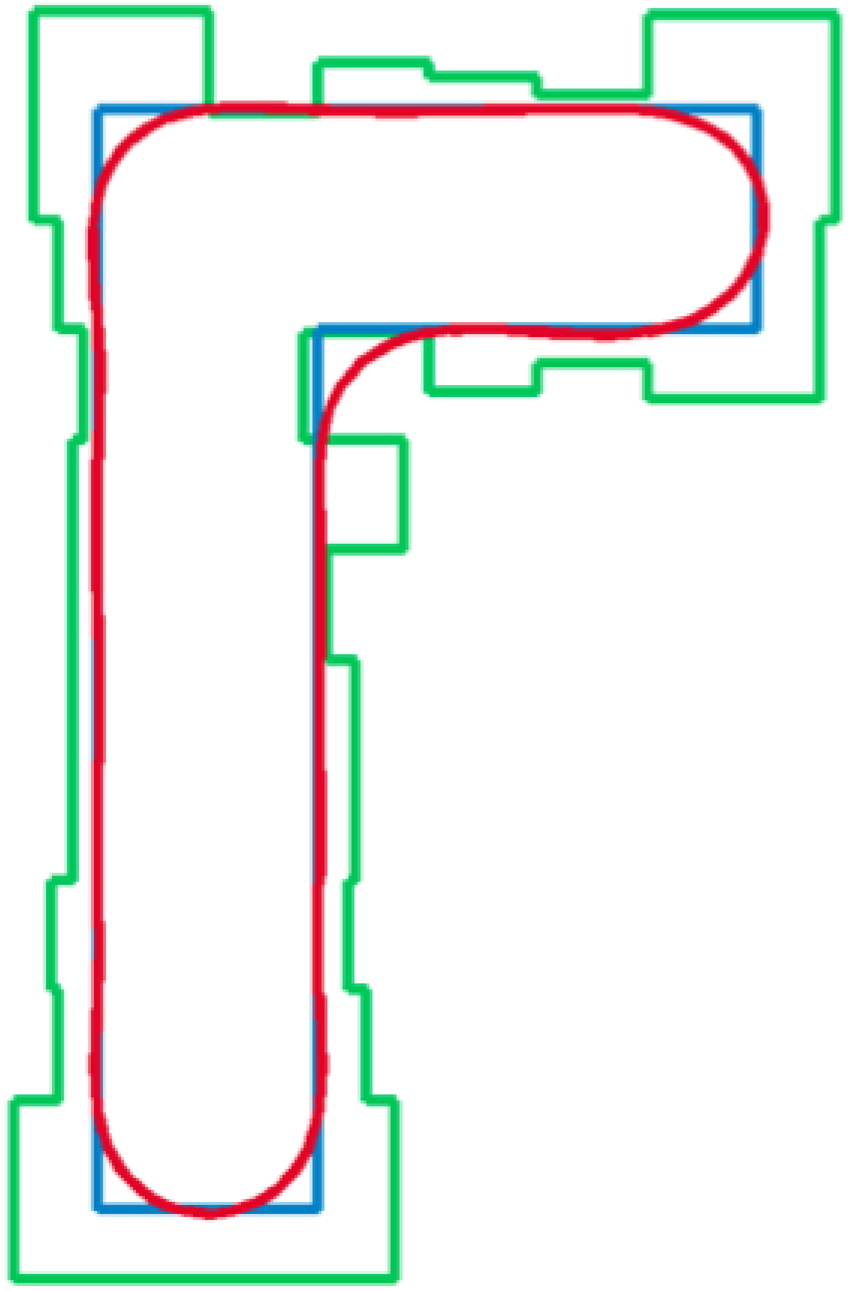


Figure 2. Schematic diagram of 193nm Microstepper

Lithography machines (https://www.youtube.com/watch?v=ShYWUIJ2FZs)

Optical proximity correction



- The wavelength of the developing light is larger than minimum features (193nm > 20nm)
- Diffraction patterns affect the light intensity on the photo-resist
- Extensive calculations need to calculate how the mask should look to compensate for diffraction and processing inaccuracies

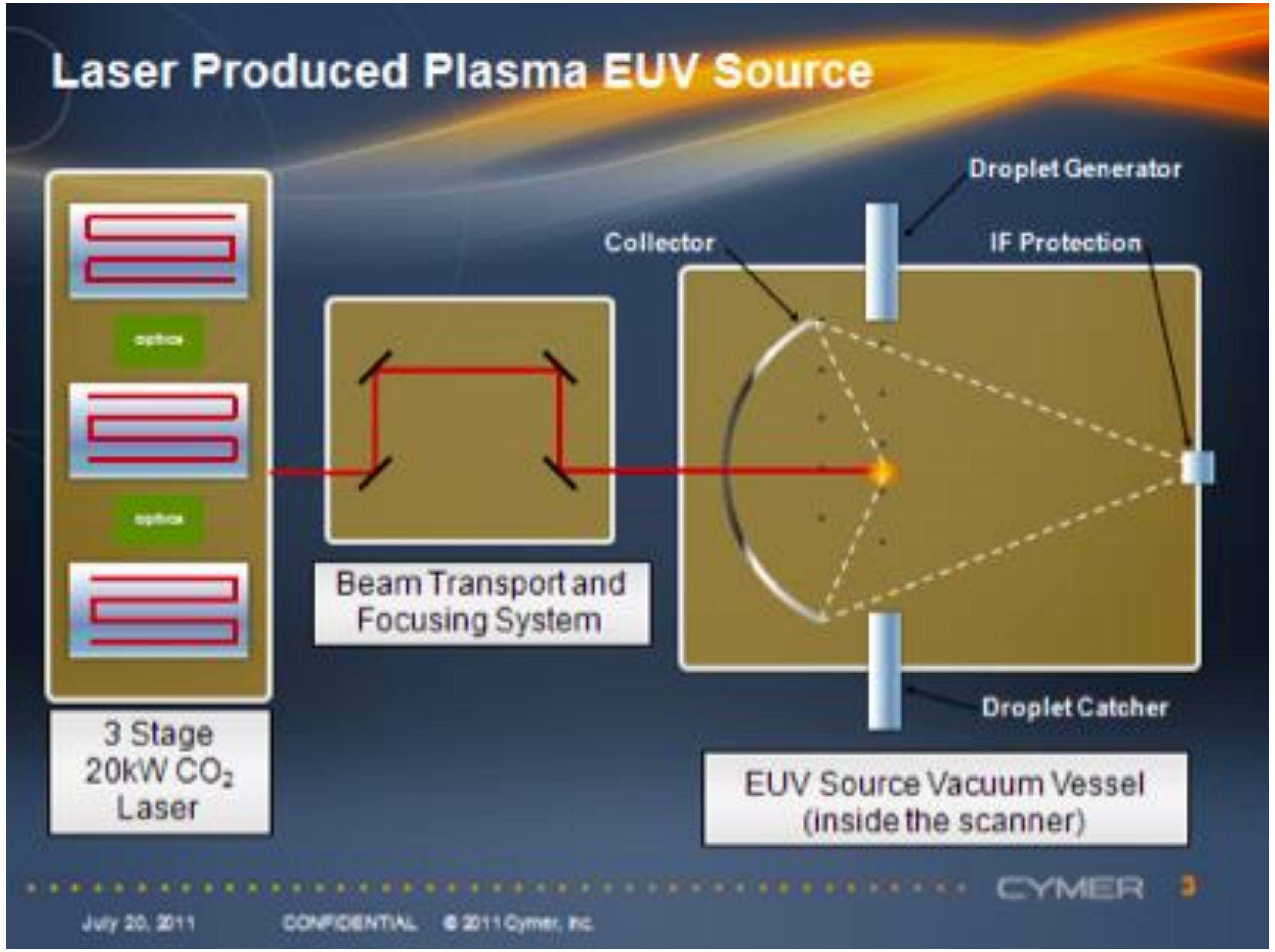
Blue = Pattern we draw in our CAD programs

Green = How the mask actually looks

Red = Pattern on chip

http://upload.wikimedia.org/wikipedia/en/6/65/Optical_proximity_correction.png

Tomorrow (probably): Extreme ultra violet



http://www.cymer.com/euv_light_sources/

[EUV lithography]()

What

Low power wireless product offering

Low power short-range IoT

Bluetooth, 802.15.4/Thread, Zigbee and 2.4GHz RF SoCs
Advanced multiprotocol solutions
MUSD 228 revenue in 2017

Low power cellular IoT

Multimode LTE-M / NB-IoT SiPs
Strategic investment since 2015
Sampling first lead customers now

Connectivity and application

Highly integrated wireless SoCs with on-chip MCU
Wireless protocol stacks and and application SDK

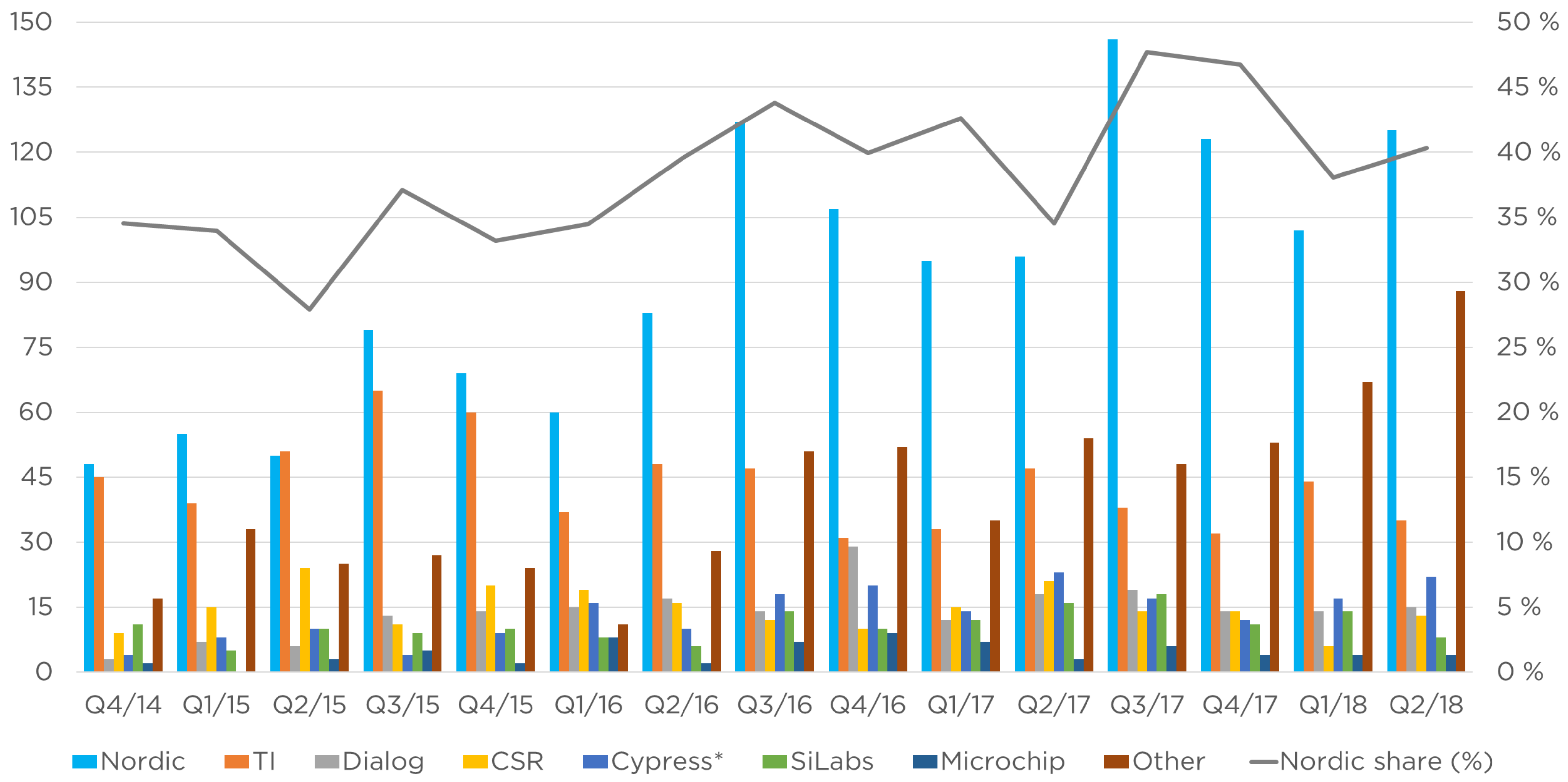
Integrated circuits (ICs)

Embedded software

Development tools

Leading and broad position in Bluetooth

Bluetooth low energy end-product certifications*



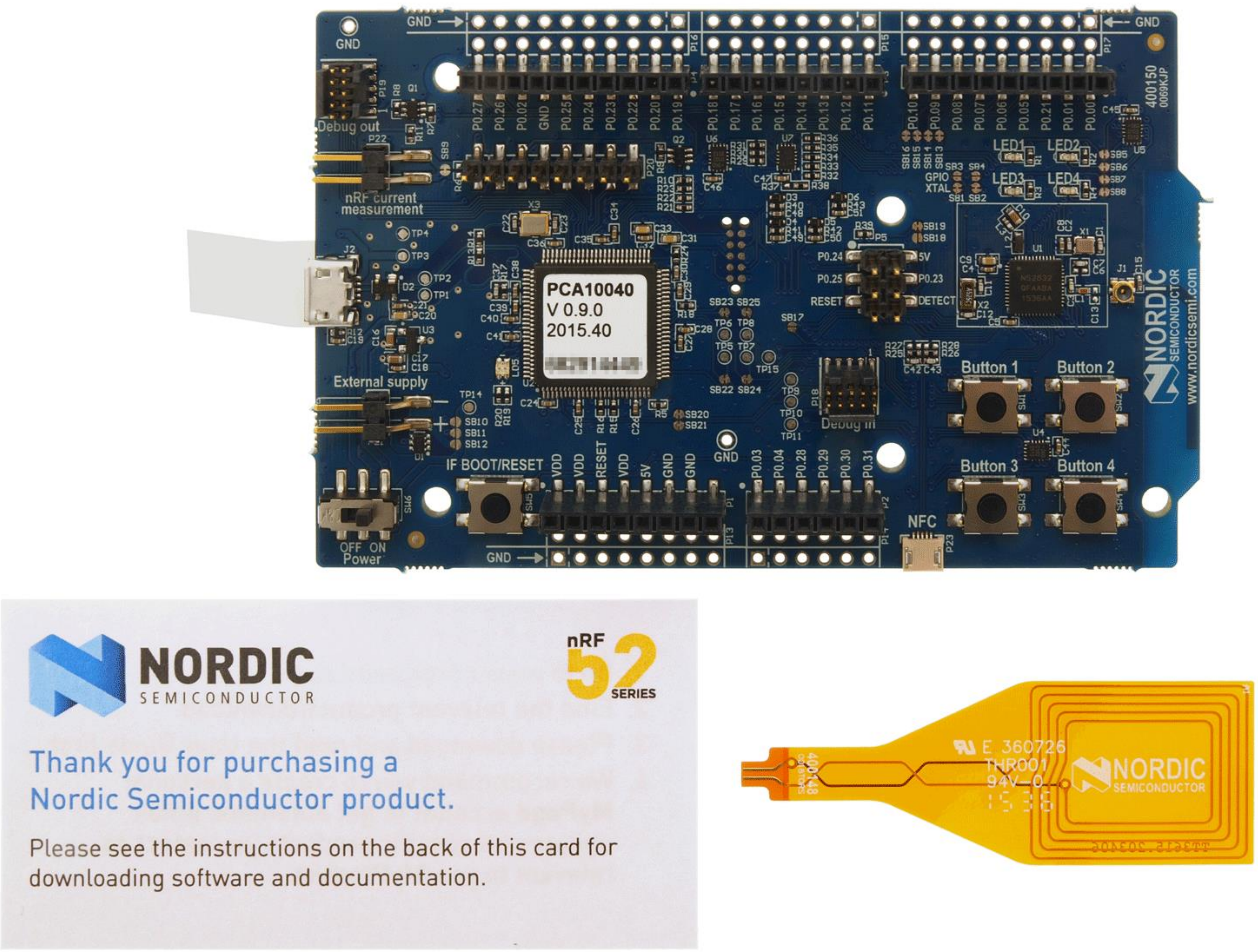
End-product certifications, Nordic Q2 18

125

+30% y-o-y

+23% q-o-q

*Source: DNB Markets


PCA10040
V 0.9.0
2015.40
nRF current measurement
External supply
Debug out
Debug in
IF BOOT/RESET
OFF ON
Power
Button 1
Button 2
Button 3
Button 4
NFC
NORDIC
SEMICONDUCTOR
www.nordicsemi.com
NORDIC
SEMICONDUCTOR
nRF
52
SERIES
Thank you for purchasing a
Nordic Semiconductor product.
Please see the instructions on the back of this card for
downloading software and documentation.
E 360726
NORDIC
SEMICONDUCTOR

NORDIC
SEMICONDUCTOR
Smarter Things

Want to help me make
a better world?

And have fun at the same time

http://www.nordicsemi.com

carsten.wulff@nordicsemi.no