

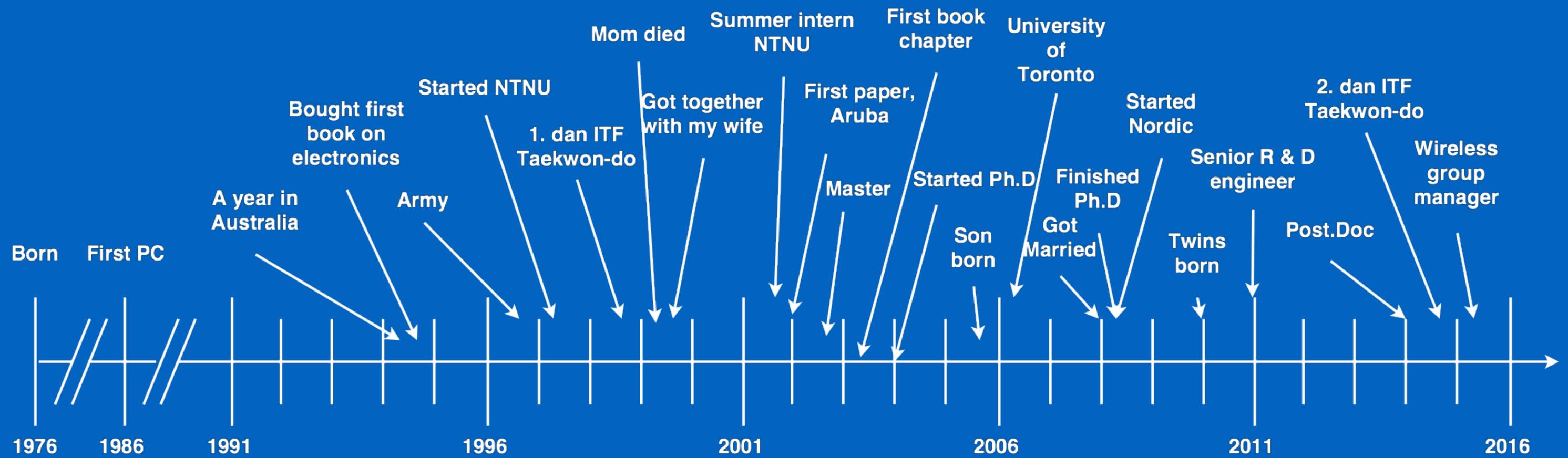


NORDIC
SEMICONDUCTOR

Smarter Things

Why I work with electronics, and why is it so complex?

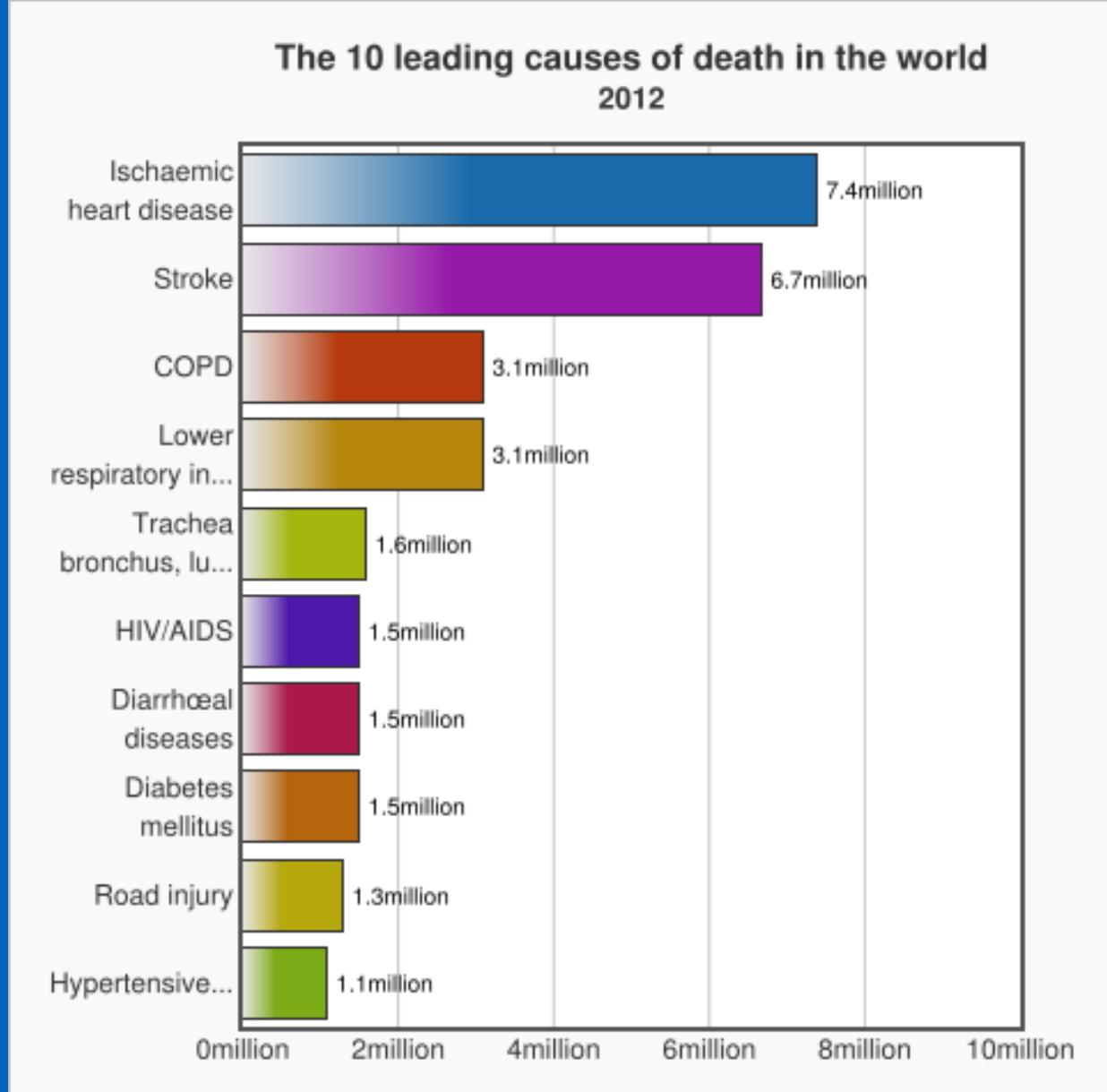
Carsten Wulff, Wireless Group Manager



I want to make the world better!

Wavy





... cardiovascular diseases killed **17.5 million** people in 2012, that is 3 in every 10 deaths ... WHO

APPLICATION: HEALTH & WELLNESS

Controlled study proves activity monitor and motivational website increase children's physical activity and improve health by making exercise fun



Zamzee uses Nordic Semiconductor technology to encourage children to exercise

The 'Zamzee' activity monitor, which includes a new Bluetooth Smart wireless version that employs Nordic Semiconductor wireless technology, encourages sedentary children to start enjoying the health and wellness benefits of physical activity by measuring performance and rewarding effort with virtual badges, "pointz", and virtual currency called "Zamz" which can be redeemed for prizes like toys and gift cards

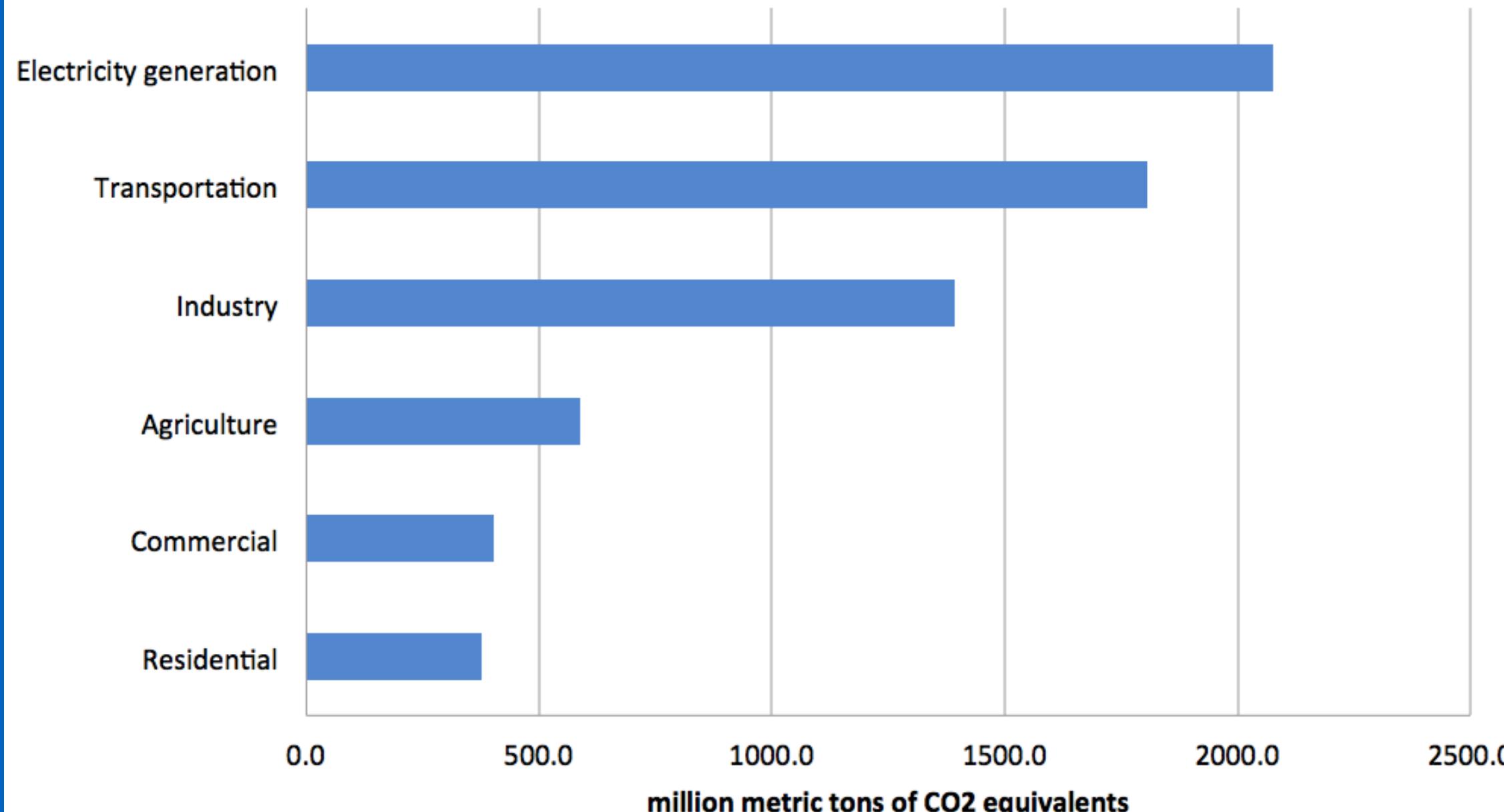
Oslo, Norway | 2014/08/26

Ultra low power (ULP) RF specialist Nordic Semiconductor ASA (OSE: NOD) today announces that U.S.-based non-profit research organization, HopeLab, has specified Nordic nRF8001 Connectivity ICs to provide the Bluetooth Smart® (previously known as Bluetooth low energy) wireless link in the latest wireless version of its 'Zamzee' activity monitor for children.

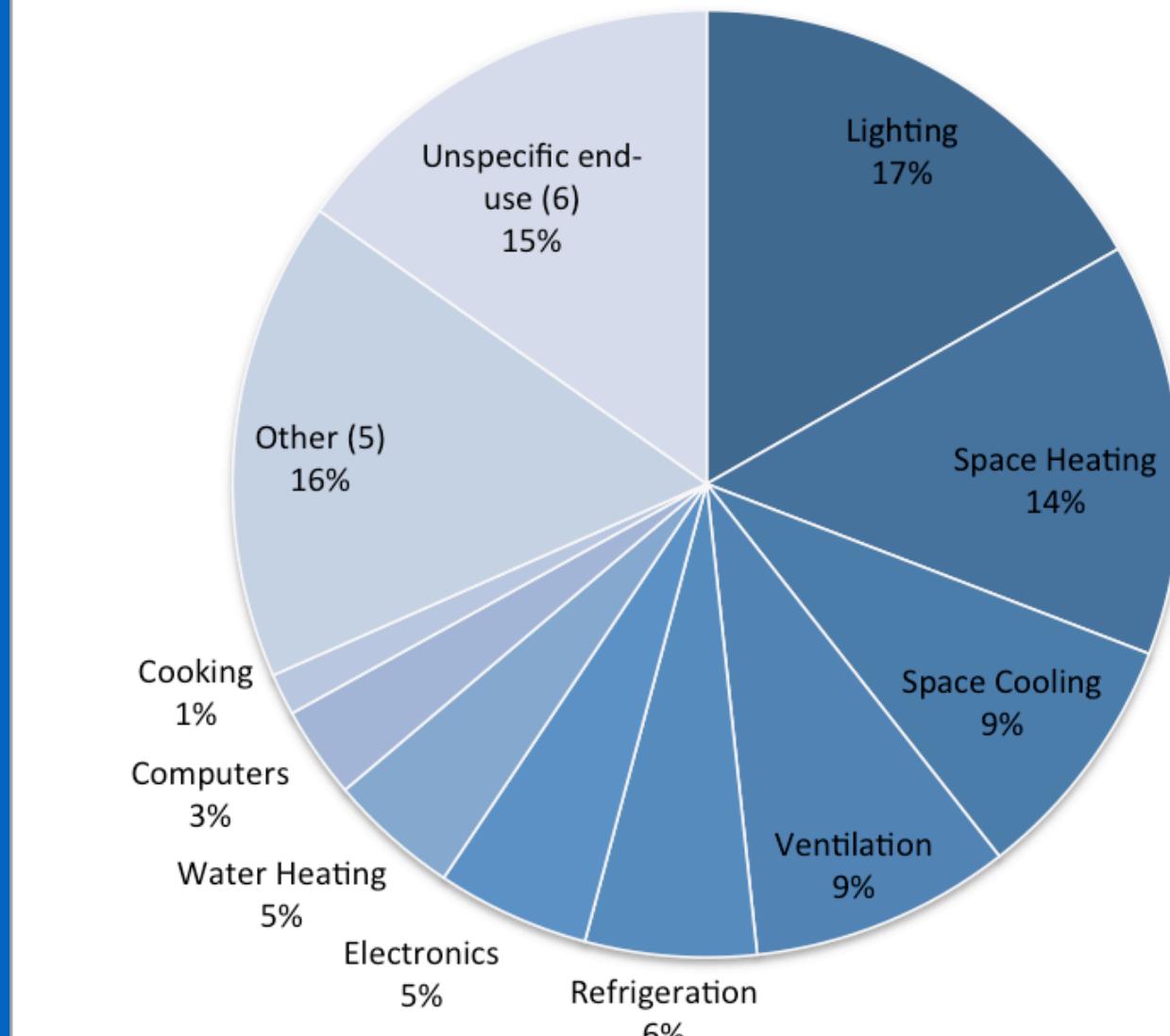
In a six-month randomized controlled trial of 448 subjects aged 11 to 14, Zamzee was proven to increase the weekly moderate-to-vigorous physical activity (MPVA) in children by 59 percent (equating to 45 additional minutes of MPVA per week) compared to a control group. (See "A



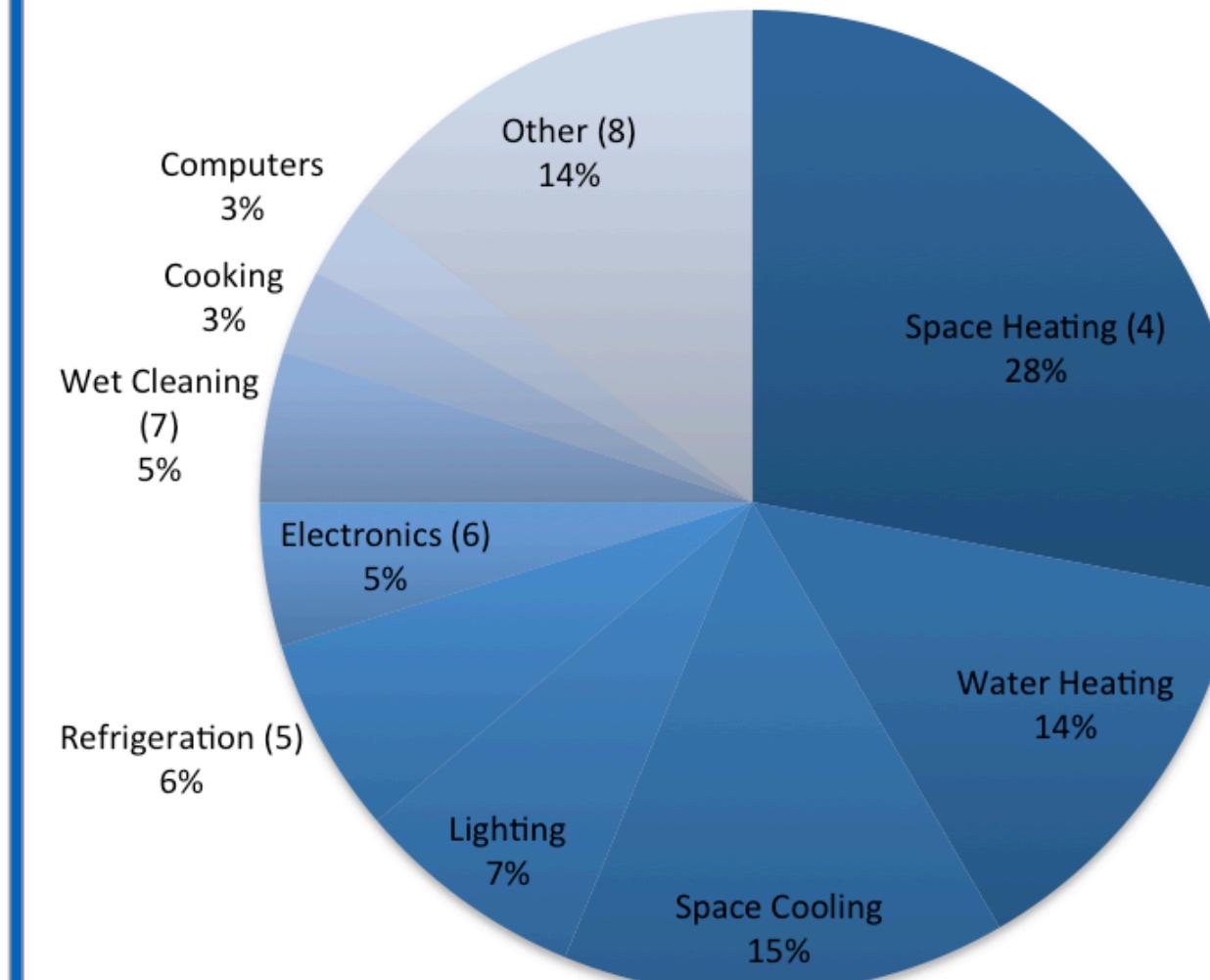
CO2 emissions by source US



Commercial electricity usage U.S 2015



Residential electricity usage U.S. 2015

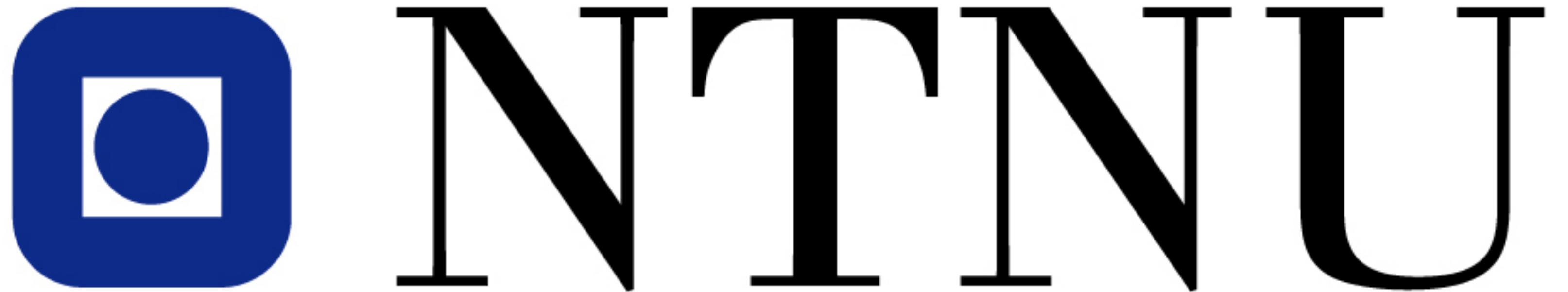


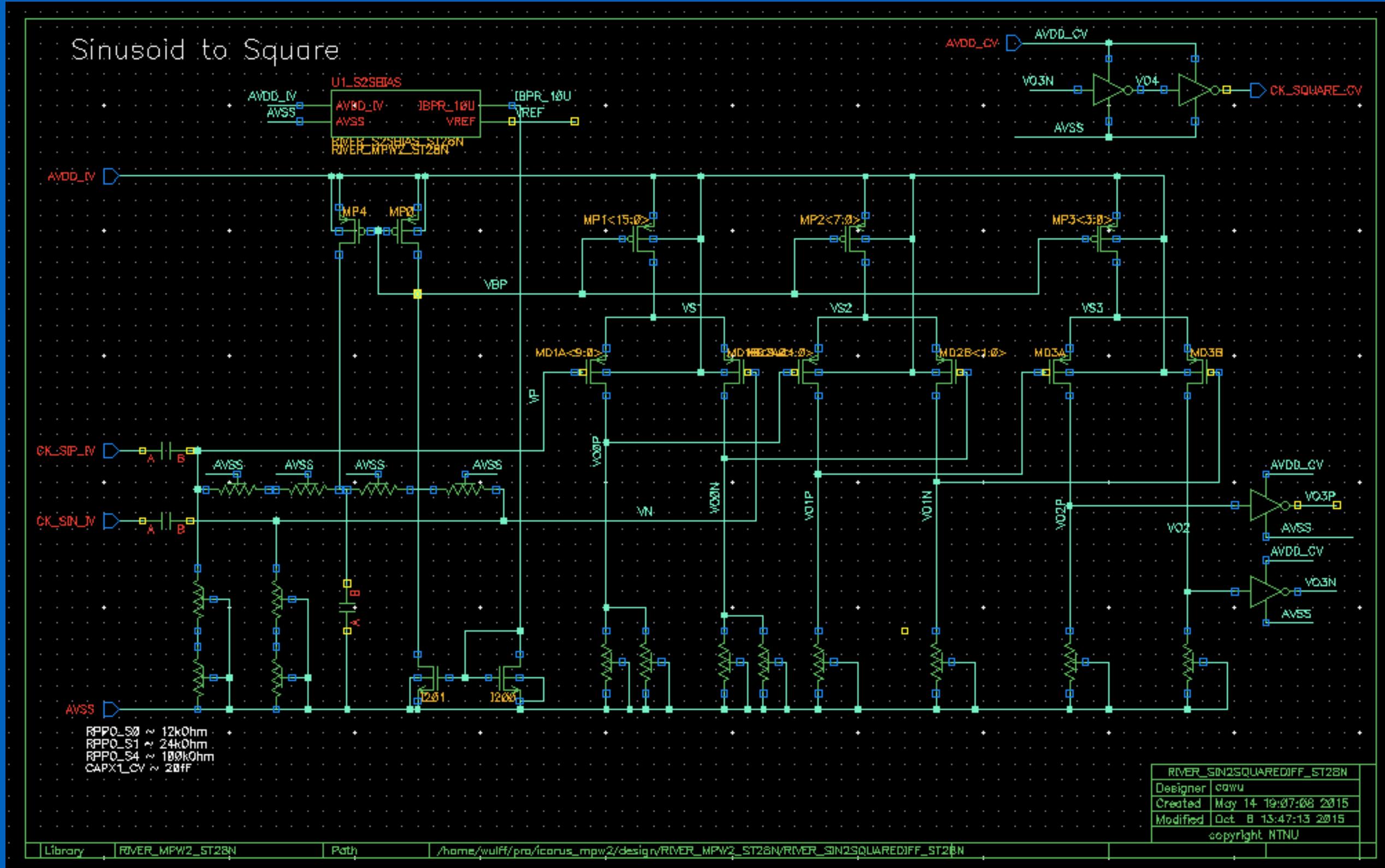
The primary way that IoT can help battle climate change is by reducing global energy consumption, which will in turn reduce carbon emissions.

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









adexl TB_RIVER_SIN2SQUAREDIFF_ST28N TB_RIVER_MPW2_ST28N

Launch File Create Tools Options Run EAD Parasitics/LDE Window Calibre Help

cadence

No Parasitics/LDE Single Run, Sweeps and Corners Reference:

Data View Outputs Setup Run Preview Results Diagnostics

Detail Replace

Parameter	typical	etc_0	etc_1	etc_2	etc_3	etc_4	etc_5	etc_6	etc_7	etc_8	etc_9	etc_10	etc_11
st28n_cap.scs	Ct	Ch	Cl	Cl	Cl	Cl							
st28n_comm...	Gt												
st28n_mos.scs	Mtt	Mff	Mss	Msf	Mfs	Mff	Mss	Msf	Mff	Mss	Msf	Mfs	
st28n_res.scs	Rt	Rh	Rh	Rh	Rl	Rl	Rl	Rl	Rh	Rh	Rh	Rh	
st28n_suppl...	Vt	Vh											
st28n_tempe...	Tt	Th											
temperature	st_temp												

Test	Output	Spec	Weight	Pass/Fail	Min	Max	typical	etc_0	etc_1	etc_2	etc_3	etc_4	etc_5	etc_6	etc_7	etc_8	etc_9	etc_10	etc_11
tran	vref				639.6m	703.7m	669.8m	658.1m	663.3m	641m	679.4m	683.6m	684.7m	665m	703.7m	658.1m	663.3m	641m	679.4m

Corners Setup

CSV CSV

Corners Nominal typical fast slow etc ntc

Temperature st_temp st_temp st_temp st_temp st_temp

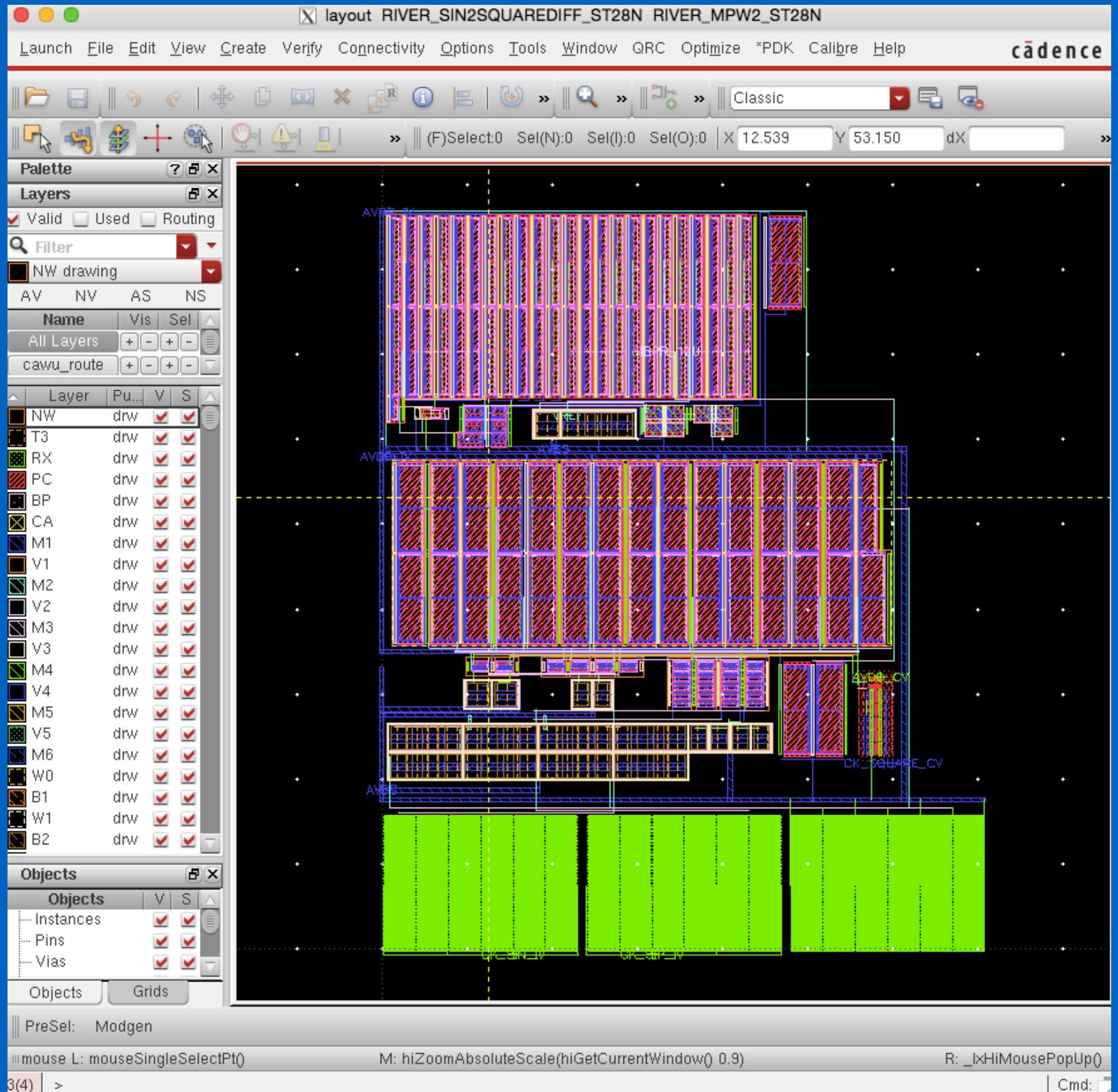
Design Variables Click to add

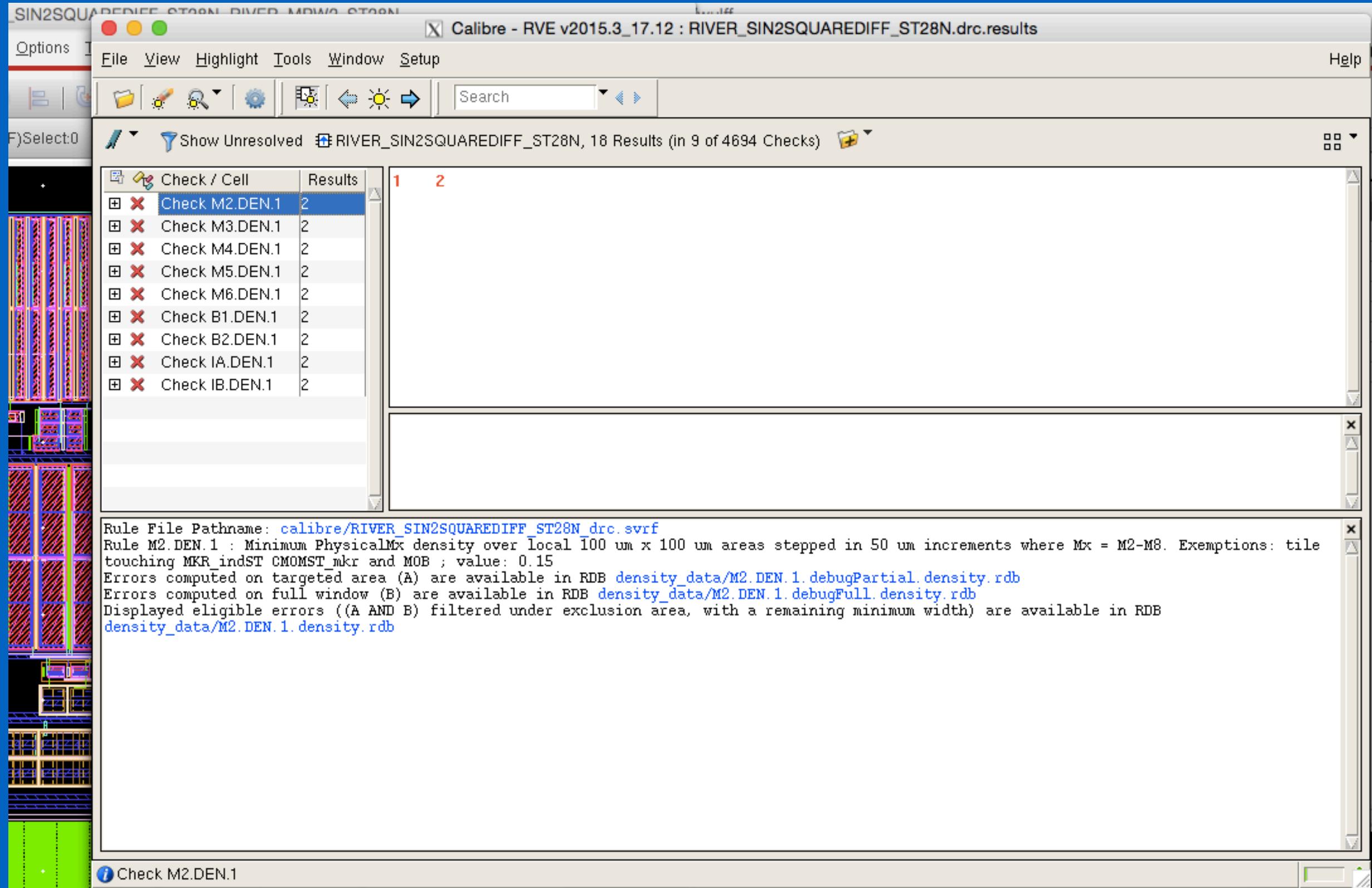
Parameters Click to add

Model Files

st28n_common.scs	<input checked="" type="checkbox"/>	Gt	<input checked="" type="checkbox"/>	Gt	<input checked="" type="checkbox"/>	Gt													
st28n_mos.scs	<input checked="" type="checkbox"/>	Mtt	<input checked="" type="checkbox"/>	Mff	<input checked="" type="checkbox"/>	Mss	<input checked="" type="checkbox"/>	...ss	<input checked="" type="checkbox"/>	Mfs	<input checked="" type="checkbox"/>	...ss	Mfs	<input checked="" type="checkbox"/>	Msf	<input checked="" type="checkbox"/>	Mfs	<input checked="" type="checkbox"/>	Mfs
st28n_res.scs	<input checked="" type="checkbox"/>	Rt	<input checked="" type="checkbox"/>	Rl	<input checked="" type="checkbox"/>	Rh	<input checked="" type="checkbox"/>	Rh	<input checked="" type="checkbox"/>	Rl	<input checked="" type="checkbox"/>	Rh	Rl	<input checked="" type="checkbox"/>	Rh	Rl	<input checked="" type="checkbox"/>	Rh	Rl
st28n_cap.scs	<input checked="" type="checkbox"/>	Ct	<input checked="" type="checkbox"/>	Cl	<input checked="" type="checkbox"/>	Ch	<input checked="" type="checkbox"/>	Ch	<input checked="" type="checkbox"/>	Cl	<input checked="" type="checkbox"/>	Ch	Cl	<input checked="" type="checkbox"/>	Ch	Cl	<input checked="" type="checkbox"/>	Ch	Cl
st28n_temperature.scs	<input checked="" type="checkbox"/>	Tt	<input checked="" type="checkbox"/>	Th	<input checked="" type="checkbox"/>	Th	<input checked="" type="checkbox"/>	Th	<input checked="" type="checkbox"/>	Th	<input checked="" type="checkbox"/>	Th	Tt	<input checked="" type="checkbox"/>	Tt	<input checked="" type="checkbox"/>	Tt	<input checked="" type="checkbox"/>	Tt
st28n_supply.scs	<input checked="" type="checkbox"/>	Vt	<input checked="" type="checkbox"/>	Vh	<input checked="" type="checkbox"/>	Vi	<input checked="" type="checkbox"/>	Vh	<input checked="" type="checkbox"/>	Vi	<input checked="" type="checkbox"/>	Vh	Vi	<input checked="" type="checkbox"/>	Vh	Vi	<input checked="" type="checkbox"/>	Vh	Vi

OK Cancel Apply Help





Calibre - RVE v2015.3_17.12 : RIVER_SIN2SQUAREDIFF_ST28N RIVER_SIN2SQUAREDIFF_ST28N

File View Highlight Tools Window Setup Help

Navigator Info Comparison Results

Results

- Extraction Results
- Comparison Results

ERC

- ERC Results
- ERC Summary

Reports

- LVS Summary
- Extraction Report
- LVS Report

Rules

- Rules File

View

- Info
- Finder
- Schematics

Setup

- Options

RIVER_SIN2SQUAREDIFF_ST28N.drc.results Comparison Results

Layout Cell / Type	Source Cell	Nets	Instances	Ports
NCH_IO_12F_12C	NCH_IO_12F_12C	4L, 4S	1L, 1S	4L, 4S
NCH_IO_12F_16C	NCH_IO_12F_16C	4L, 4S	1L, 1S	4L, 4S
NCH_IO_160F_24C	NCH_IO_160F_24C	4L, 4S	1L, 1S	4L, 4S
NCH_LVT_IO_12F_12C	NCH_LVT_IO_12F_12C	4L, 4S	1L, 1S	4L, 4S
NCHDL	NCHDL	4L, 4S	1L, 1S	4L, 4S
PCH_IO_160F_24C	PCH_IO_160F_24C	4L, 4S	1L, 1S	4L, 4S
PCH_IO_160F_4C	PCH_IO_160F_4C	4L, 4S	1L, 1S	4L, 4S
PCH_IO_6F_14C	PCH_IO_6F_14C	4L, 4S	1L, 1S	4L, 4S

Cell NCH_IO_12F_12C Summary (Clean)

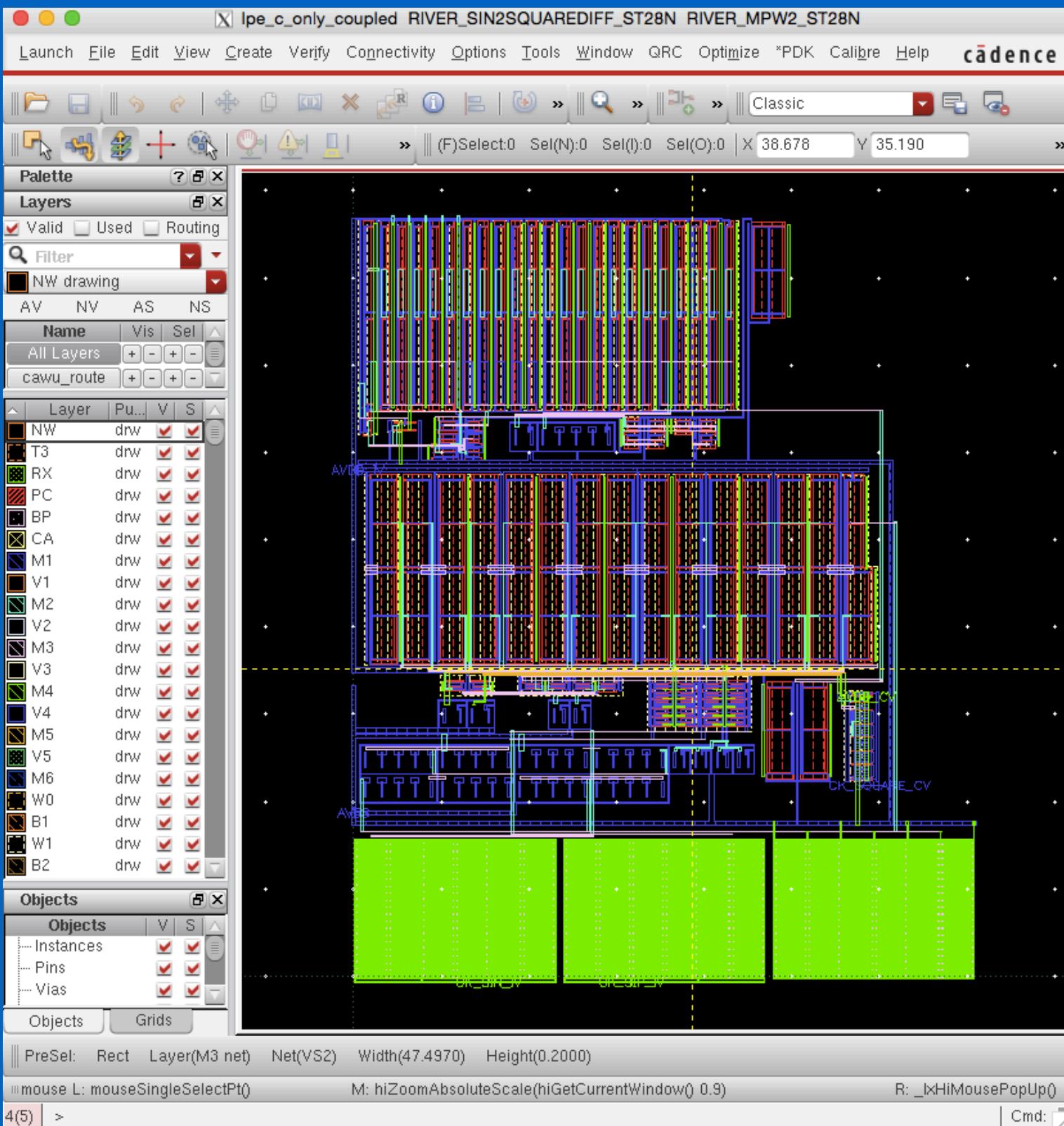
CELL COMPARISON RESULTS

CORRECT # #
#####

LAYOUT CELL NAME: NCH_IO_12F_12C
SOURCE CELL NAME: NCH_IO_12F_12C

INITIAL NUMBERS OF OBJECTS

	Layout	Source	Component Type
Ports:	4	4	
Nets:	4	4	
Instances:	2	1 *	MF (4 nines)



adexl TB_RIVER_SIN2SQUAREDIFF_ST28N TB_RIVER_MPW2_ST28N

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cadence

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Parameter	typical	etc_0	etc_1	etc_2	etc_3	etc_4	etc_5	etc_6	etc_7	etc_8	etc_9	etc_10	etc_11
st28n_cap.scs	Ct	Ch	Cl	Cl	Cl	Cl							
st28n_comm...	Gt												
st28n_mos.scs	Mtt	Mff	Mss	Msf	Mfs	Mff	Mss	Msf	Mff	Mss	Msf	Mfs	
st28n_res.scs	Rt	Rh	Rh	Rh	Rl	Rl	Rl	Rl	Rh	Rh	Rh	Rh	
st28n_suppl...	Vt	Vh											
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temperature	st_temp												

Test	Output	Spec	Weight	Pass/Fail	Min	Max	typical	etc_0	etc_1	etc_2	etc_3	etc_4	etc_5	etc_6	etc_7	etc_8	etc_9	etc_10	etc_11
tran	vref				639.6m	703.7m	669.8m	658.1m	663.3m	641m	679.4m	683.6m	684.7m	665m	703.7m	658.1m	663.3m	641m	679.4m

Corners Setup

CSV CSV Nominal typical fast slow etc ntc

Temperature st_temp st_temp st_temp st_temp st_temp

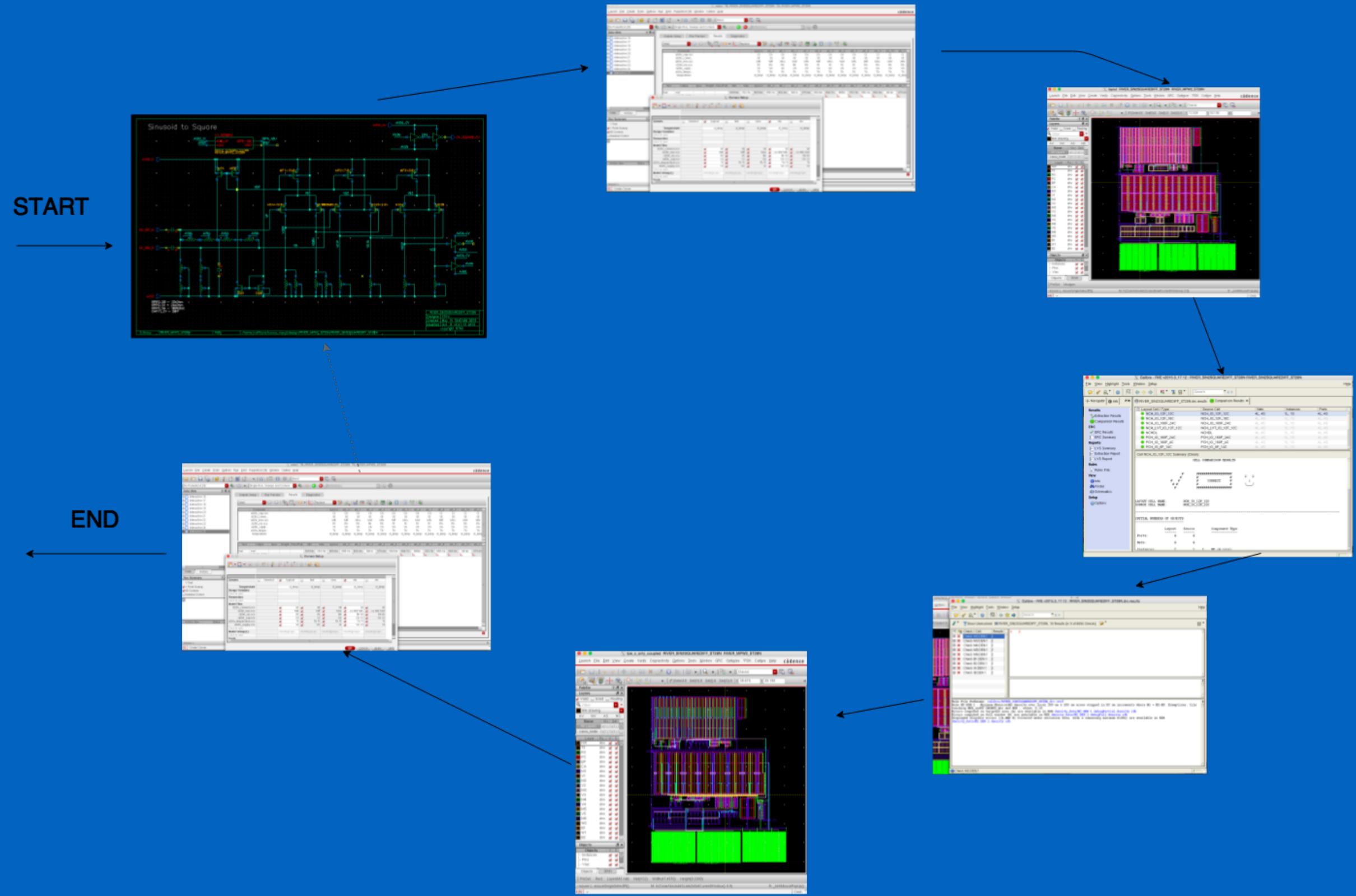
Design Variables Click to add

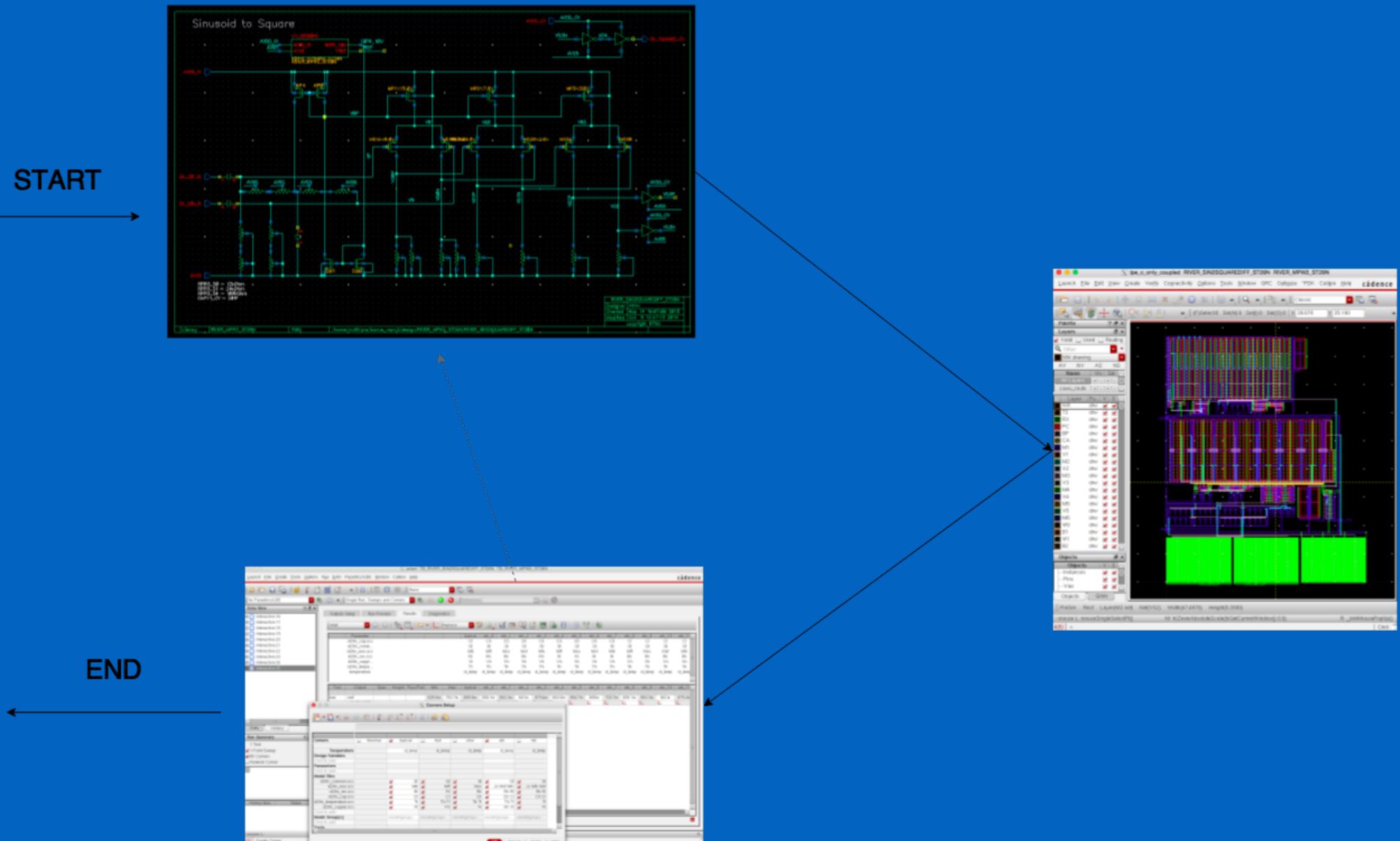
Parameters Click to add

Model Files

st28n_common.scs	<input checked="" type="checkbox"/>	Gt	<input checked="" type="checkbox"/>	Gt									
st28n_mos.scs	<input checked="" type="checkbox"/>	Mtt	<input checked="" type="checkbox"/>	Mff	<input checked="" type="checkbox"/>	Mss	<input checked="" type="checkbox"/>	...ss	<input checked="" type="checkbox"/>	Mfs	<input checked="" type="checkbox"/>	...ss	Mfs
st28n_res.scs	<input checked="" type="checkbox"/>	Rt	<input checked="" type="checkbox"/>	RI	<input checked="" type="checkbox"/>	Rh	<input checked="" type="checkbox"/>	Rh	<input checked="" type="checkbox"/>	RI	<input checked="" type="checkbox"/>	Rh	RI
st28n_cap.scs	<input checked="" type="checkbox"/>	Ct	<input checked="" type="checkbox"/>	CI	<input checked="" type="checkbox"/>	Ch	<input checked="" type="checkbox"/>	Ch	<input checked="" type="checkbox"/>	CI	<input checked="" type="checkbox"/>	Ch	CI
st28n_temperature.scs	<input checked="" type="checkbox"/>	Tt	<input checked="" type="checkbox"/>	Th	<input checked="" type="checkbox"/>	TI	<input checked="" type="checkbox"/>	Th	<input checked="" type="checkbox"/>	TI	<input checked="" type="checkbox"/>	Th	Tt
st28n_supply.scs	<input checked="" type="checkbox"/>	Vt	<input checked="" type="checkbox"/>	Vh	<input checked="" type="checkbox"/>	VI	<input checked="" type="checkbox"/>	Vh	<input checked="" type="checkbox"/>	VI	<input checked="" type="checkbox"/>	Vh	VI

OK Cancel Apply Help

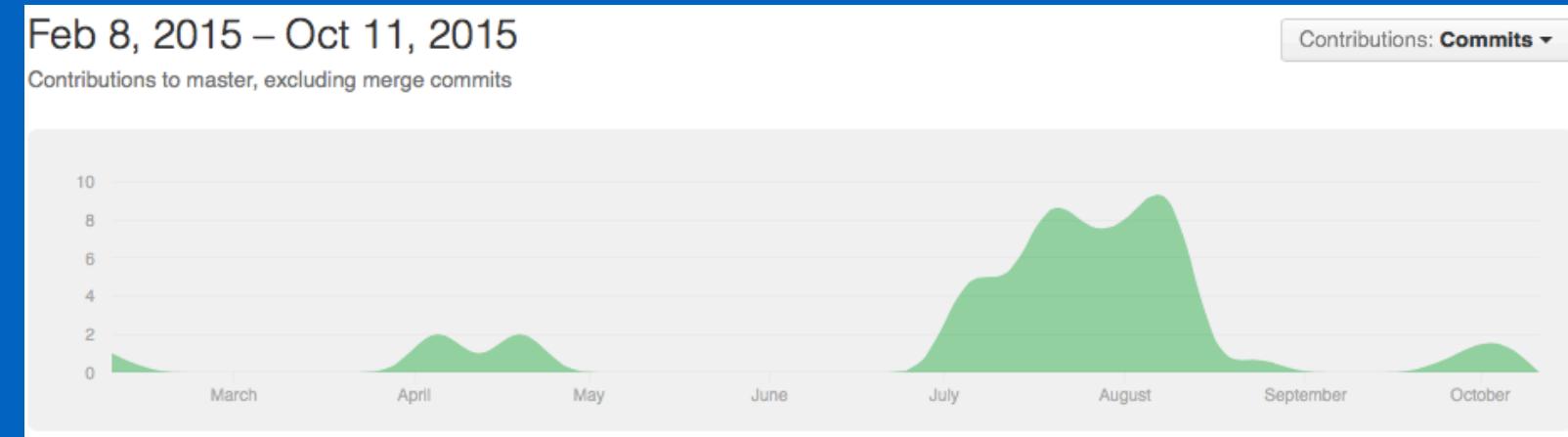




Do you want to help me?

If you have a *passion* for programming, and want bring about the *new dawn* of analog electronics design automation

<https://github.com/wulffern/ciccreator>



See **how** it works.

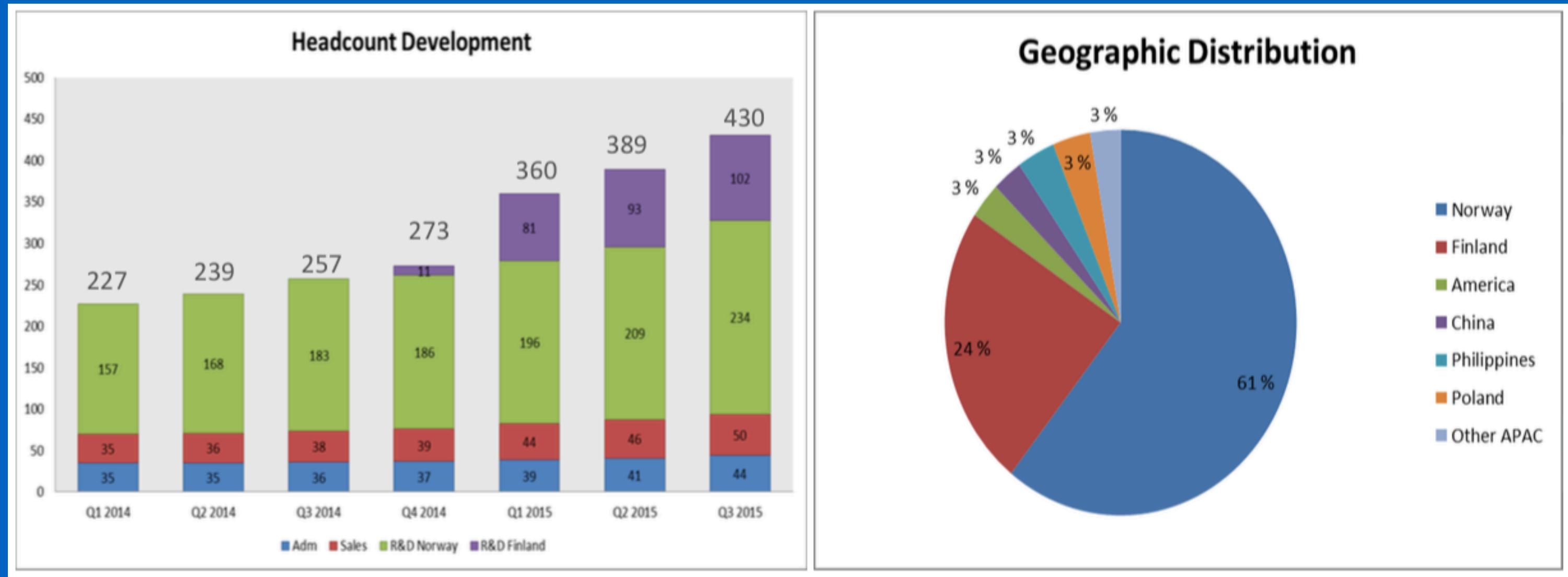


NORDIC
SEMICONDUCTOR

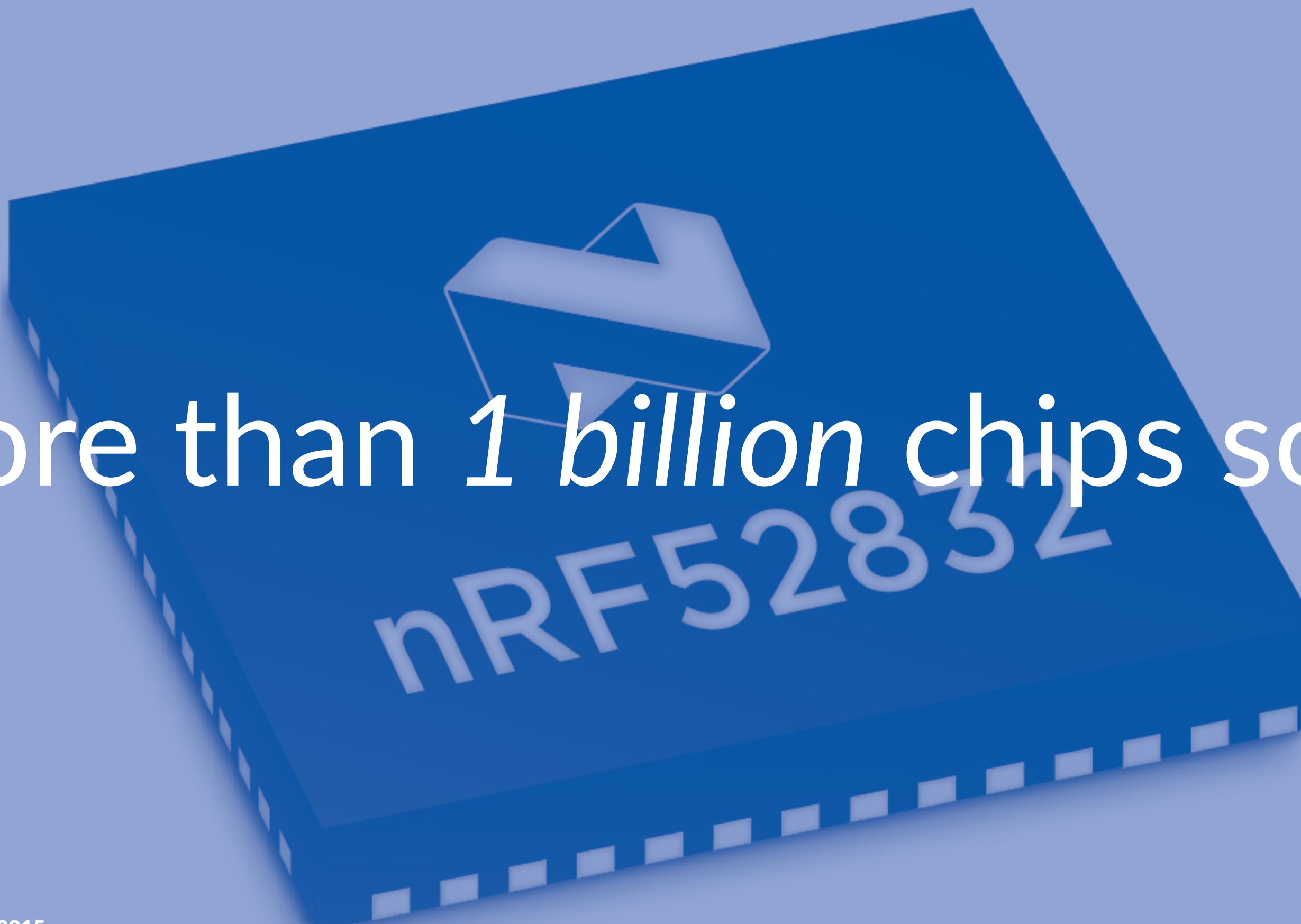
Smarter Things



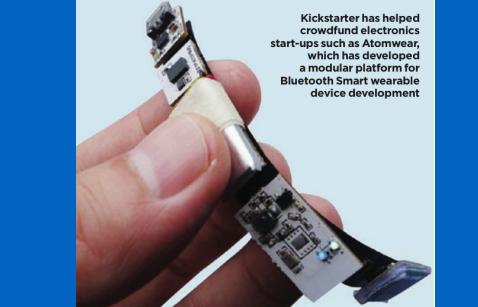
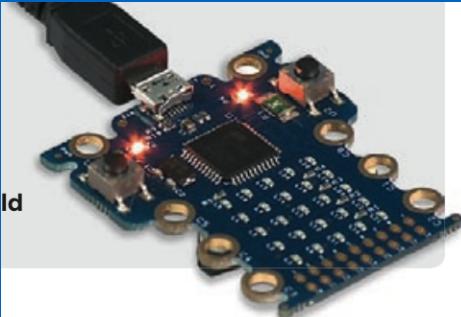
Passionately committed to ultra-low-power wireless technology that will benefit the lives of billions worldwide



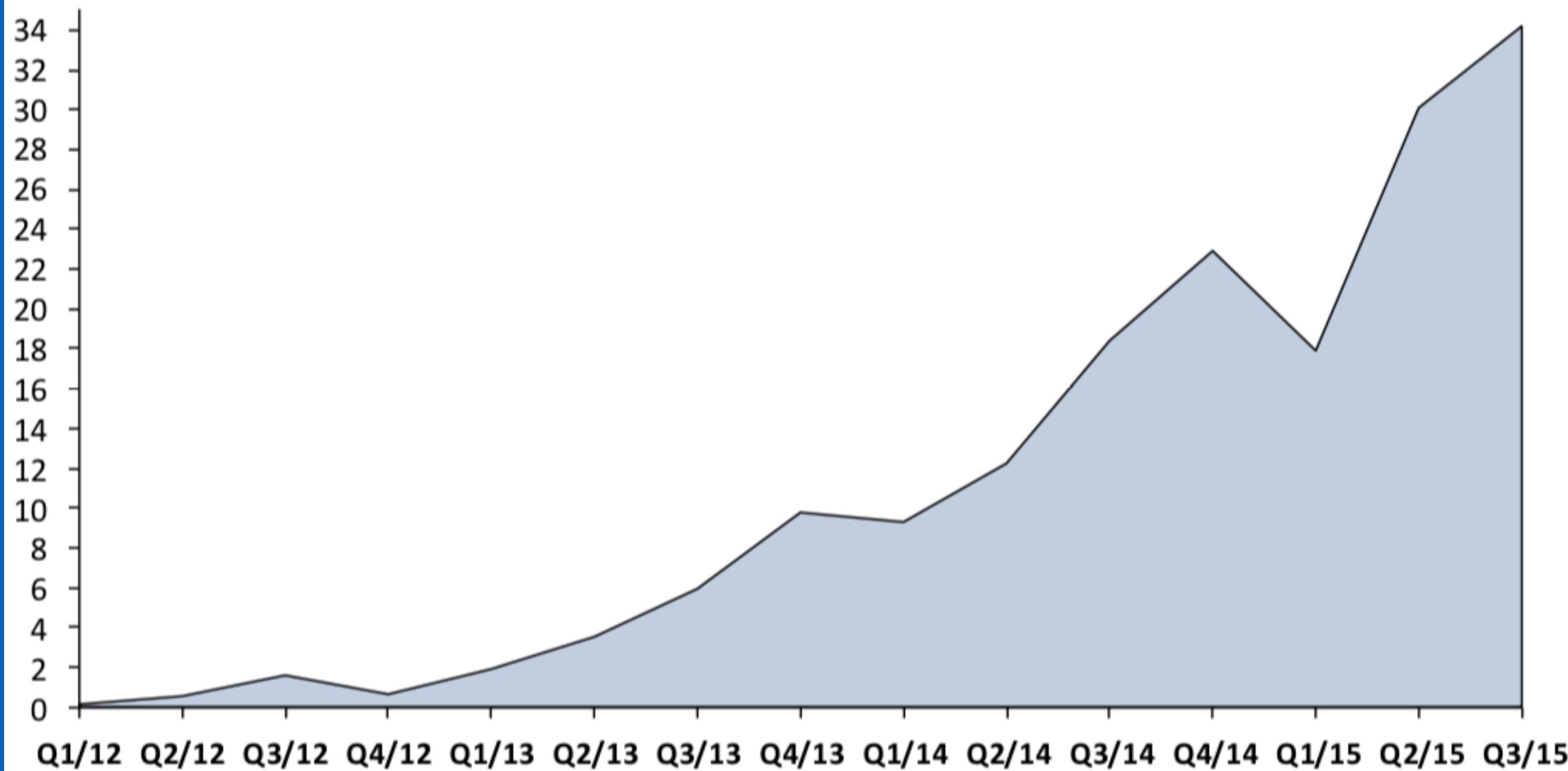
Währt



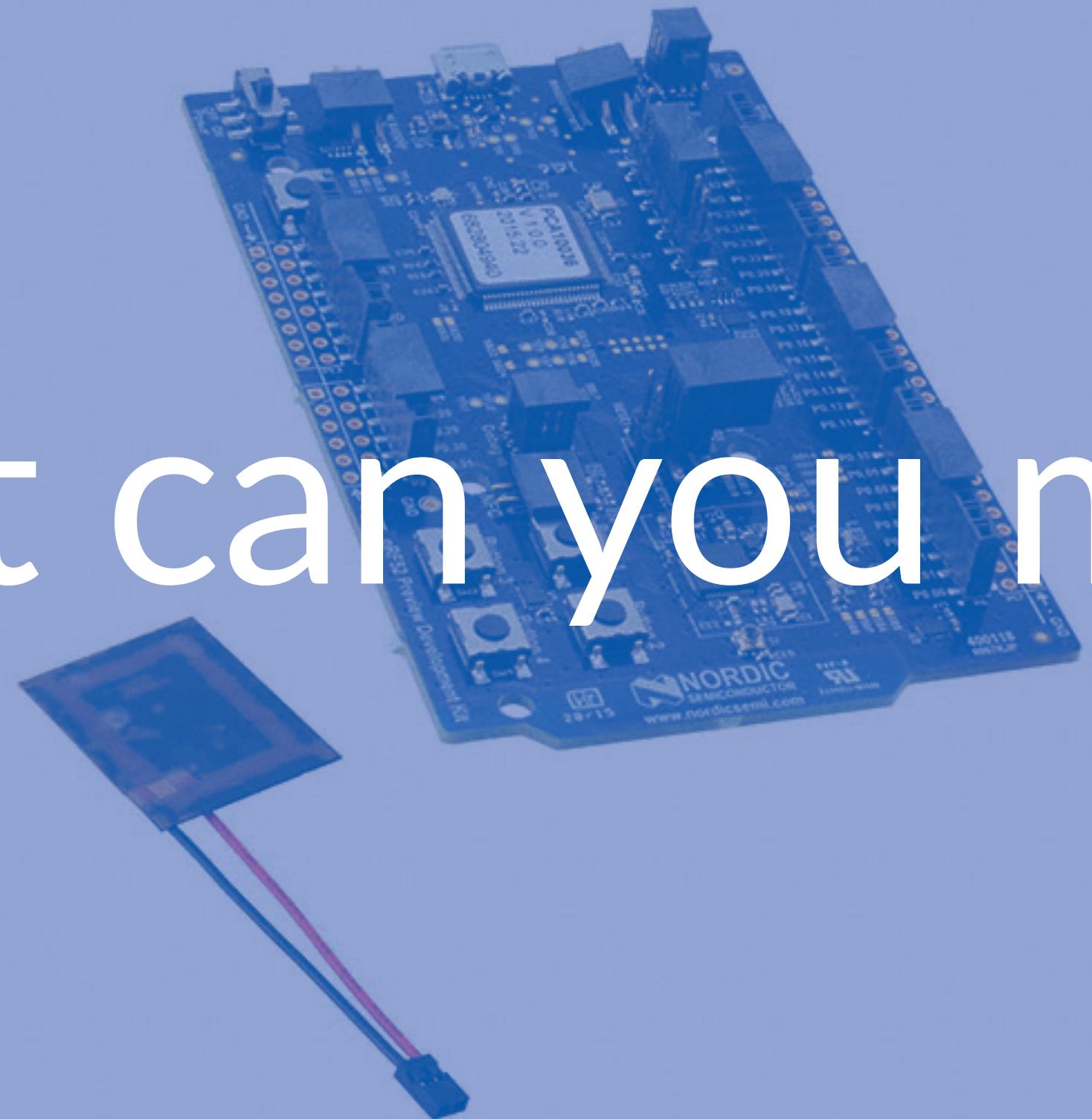
more than 1 billion chips sold



Total Nordic revenue from Bluetooth Smart, 2012 – Q3 2015 (MUSD)

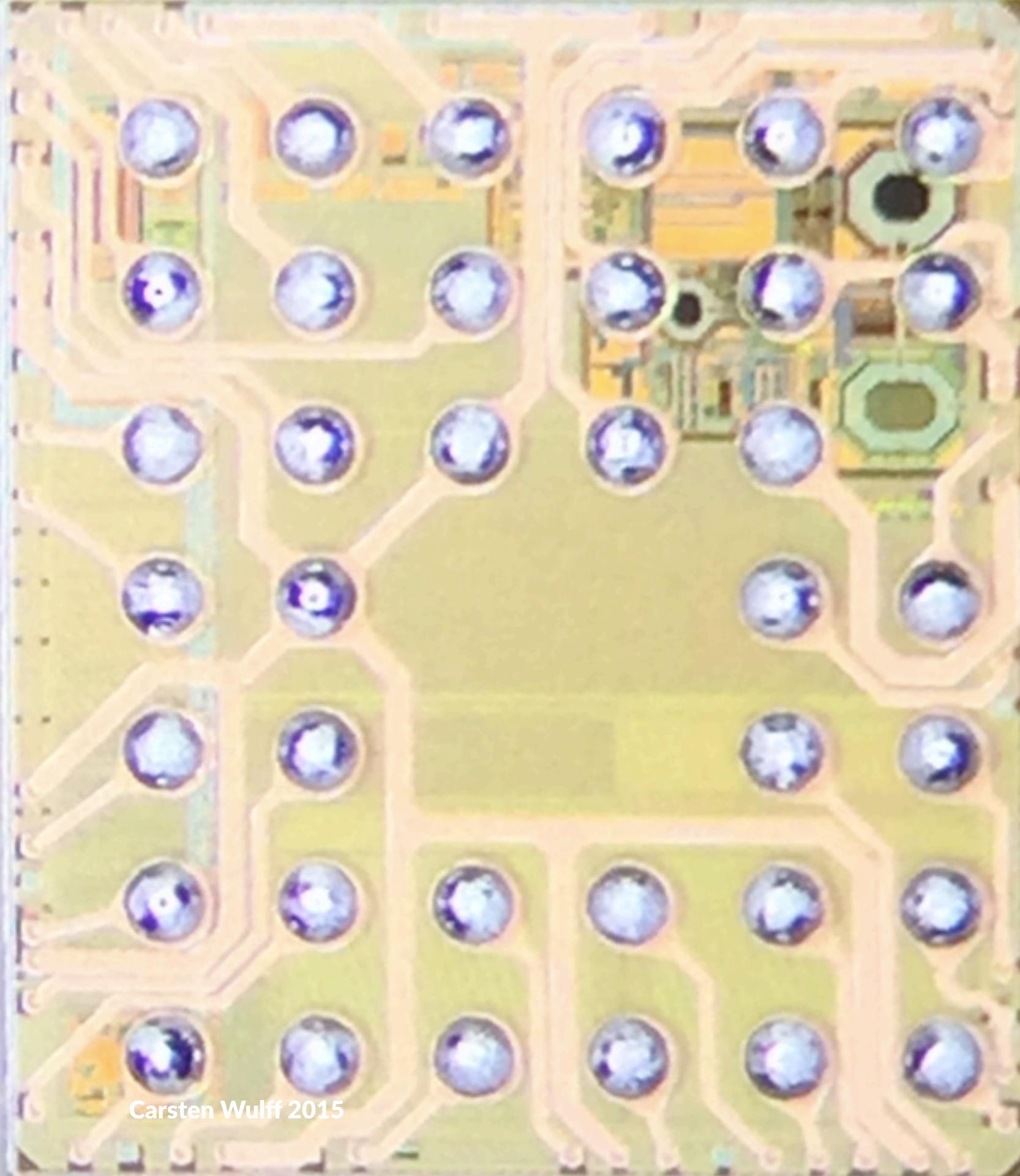


What can you make?



nRF52832

3.0mm x 3.2mm
~ 13 million transistors
thousands of capacitors
thousands of resistors
thousands of diodes
6 bipolar transistors
2 inductors
1 balun



analog/RF: oscillators, bandgaps, noise generators, temperature sensor, linear voltage regulators, switch-mode voltage regulators, pad drivers, ADC, comparator, NFC, 2.4GHz radio

digital: CPU, memory, signal processing, I2S, crypto, RTC, timers, clocks, power control, SPI, TWI, UART, quadrature decoder, random number generator, pulse density modulator, event generators, pulse width modulators

software: MDK, SDK, build servers, ANT stack, BTLE stack, iOS apps, Android apps, developer tools, IPV6 SDK, HomeKit SDK, sniffer

applications: beacon, smart remote, keyboard, toys

nRF52832 objective product specification,
page 25/537

3 Block diagram

This block diagram illustrates the overall system. Arrows with white heads indicate signals that share physical pins with other signals.

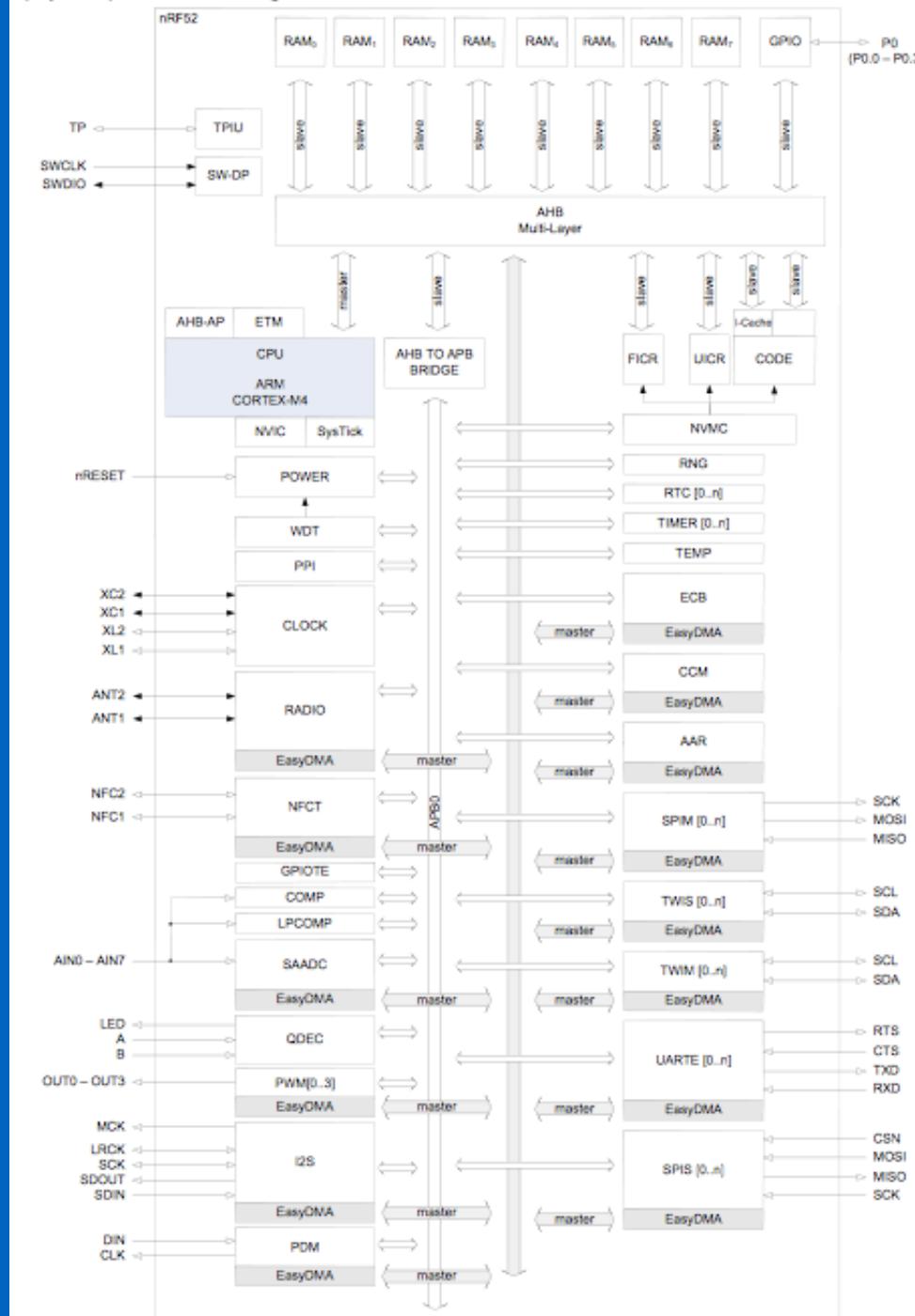
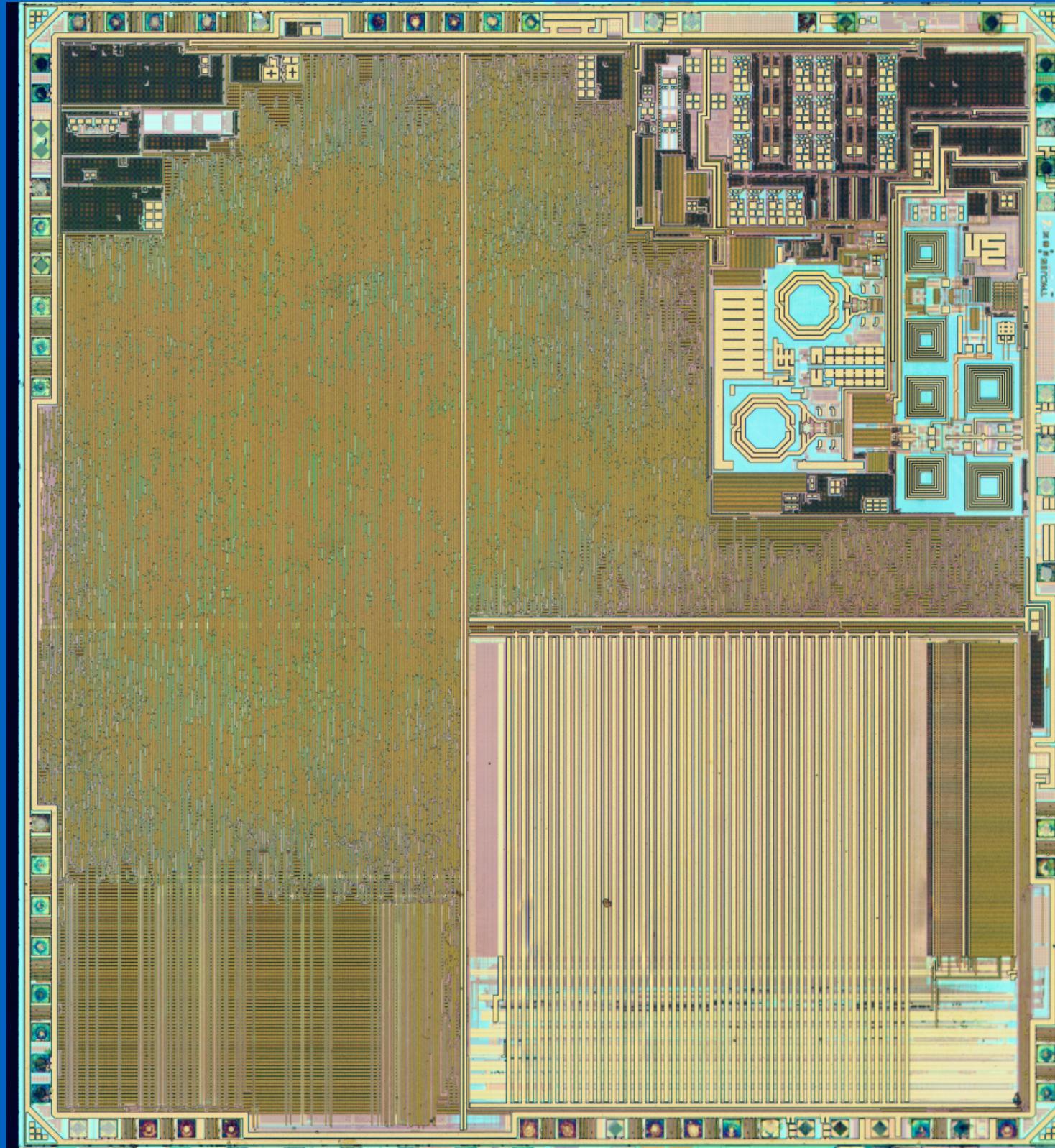
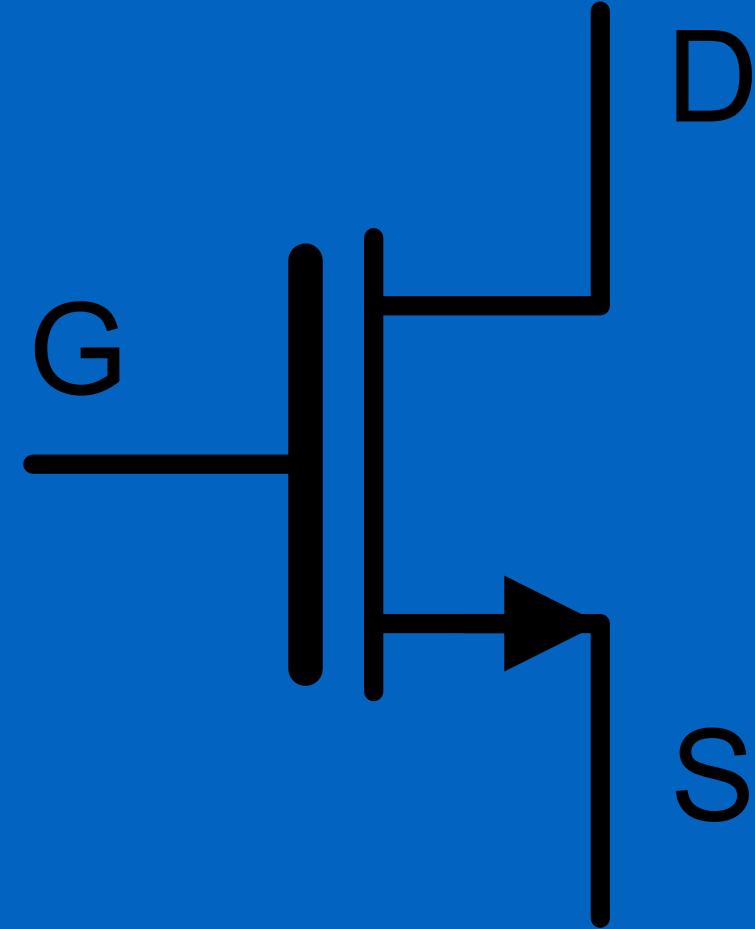


Figure 1: Block diagram





Simple model

$$I_D = \begin{cases} \text{high} & \text{if } V_{GS} > V_{TH} \\ 0 & \text{if } V_{GS} \leq V_{TH} \end{cases}$$

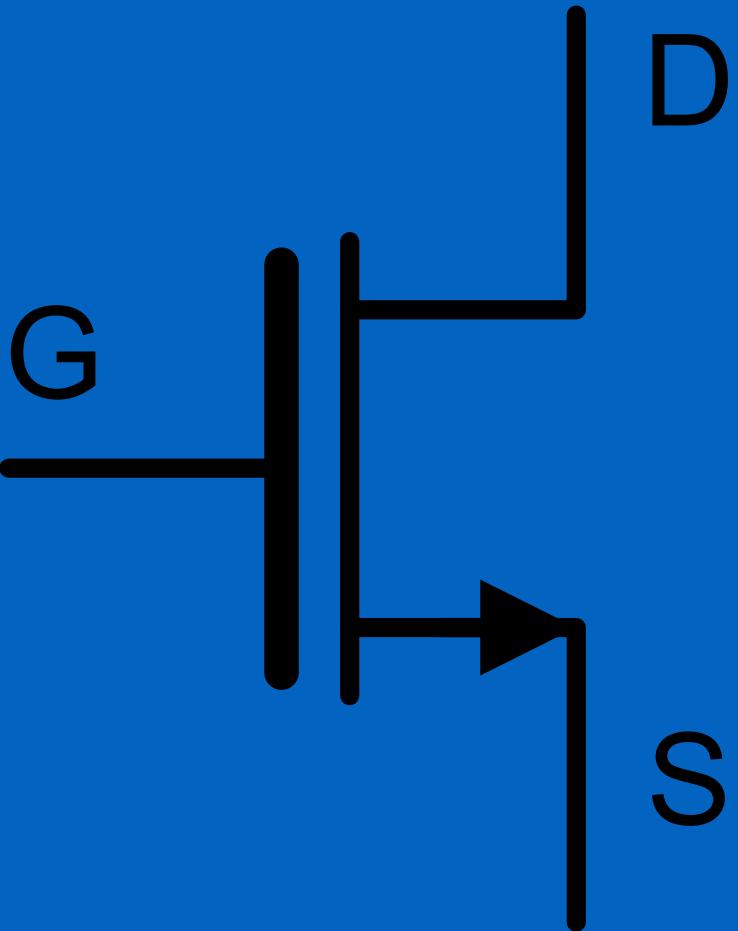
What you learn

$$I_D = \mu_n C_{ox} W/L (V_{GS} - V_{TH})^2$$

The truth

$$I_D = f(W, L, \mu_n, t_{ox}, sa, sb, sca, scb, scc, ad, as, pd, ps, \dots, V_{GS}, V_{DS})$$

284 parameters in BSIM 4.5



```
.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 NJSS=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
NJSSW=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
```

Don't panic!



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