Nordic and ICs

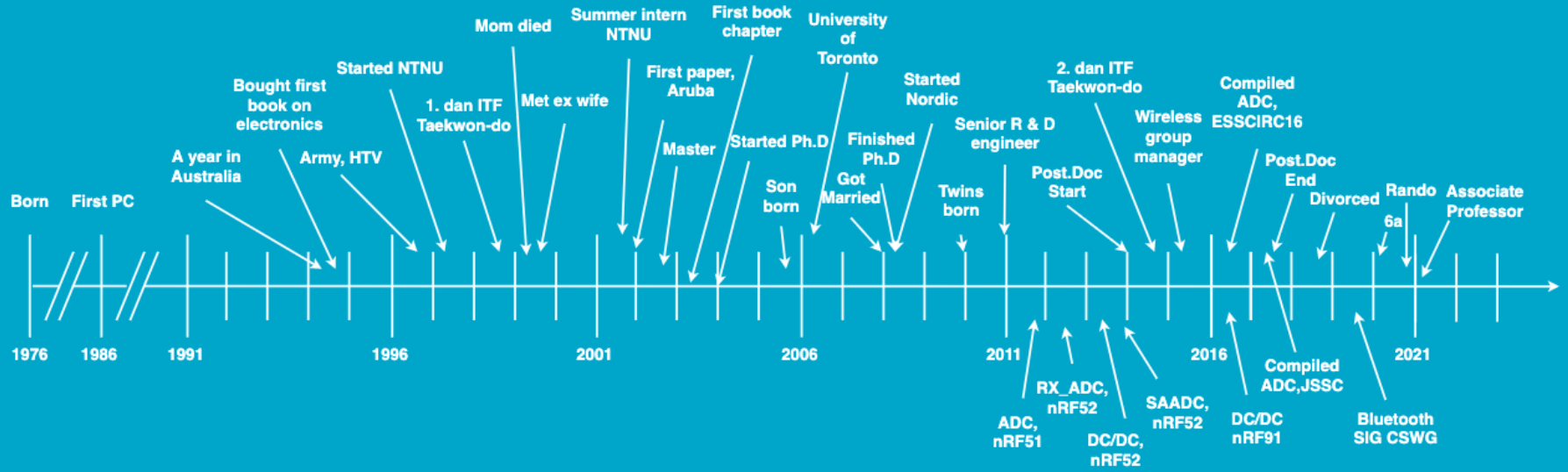
Specifically; who are we, why, what, and how ICs are made

NORDIC
SEMICONDUCTOR

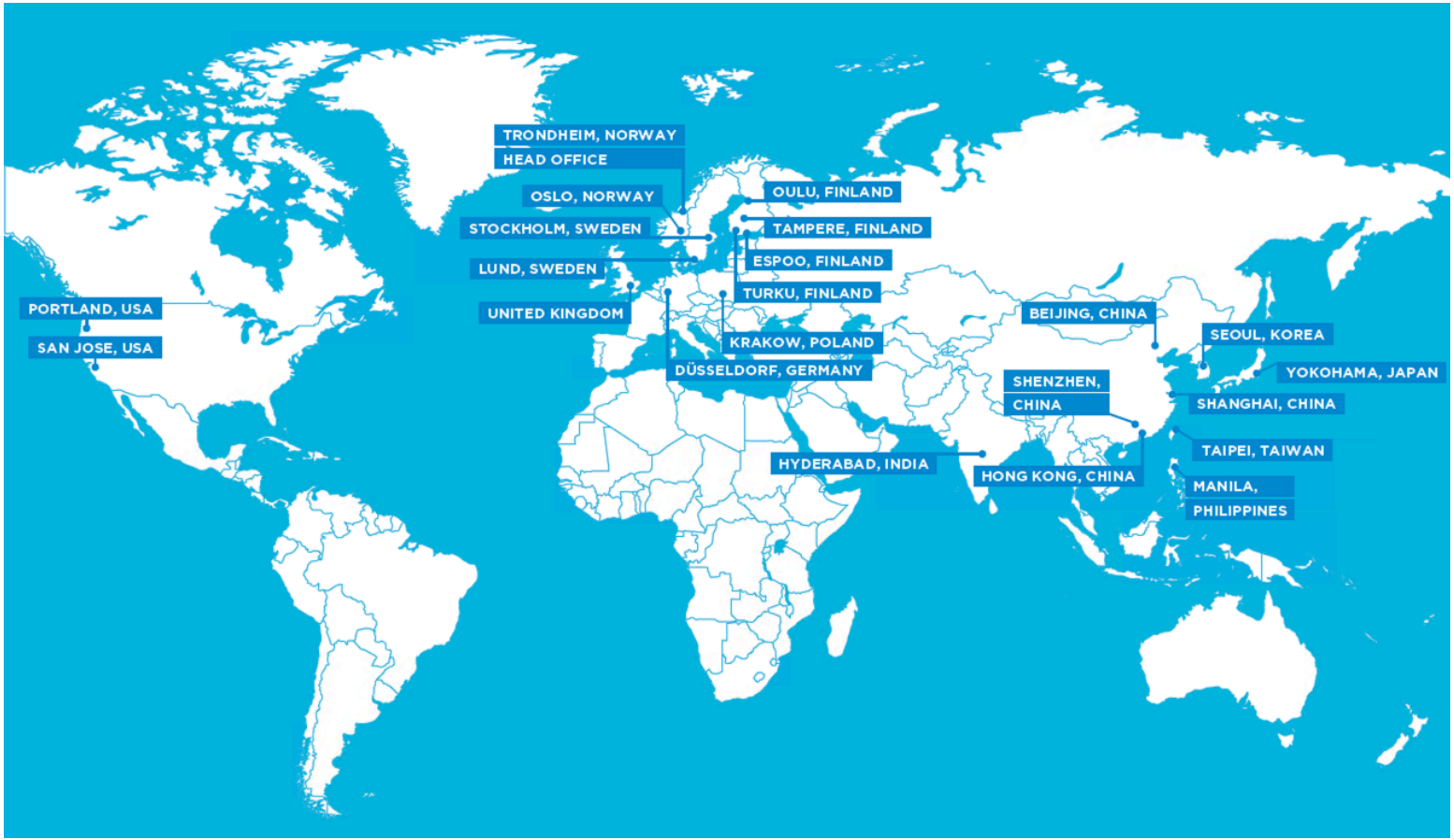
Smarter Things

Carsten Wulff, 2021-03-02

Carsten Wulff



Who



Svenn-Tore Larsen (CEO)

Svein-Egil Nielsen (CTO)

IC Norway

Wireless

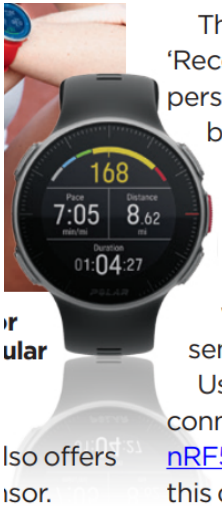
Why

My personal why 1 : Exercise

2011

2020

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



lso offers
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Polar's
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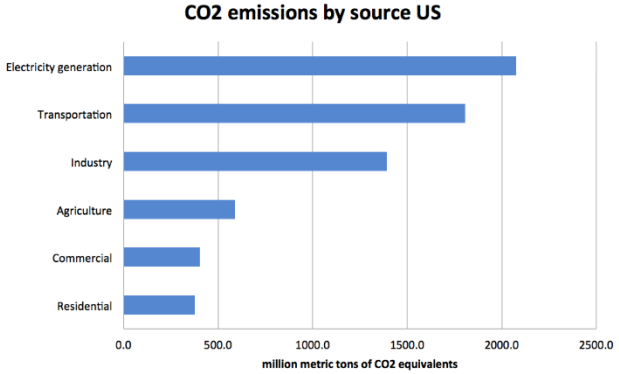
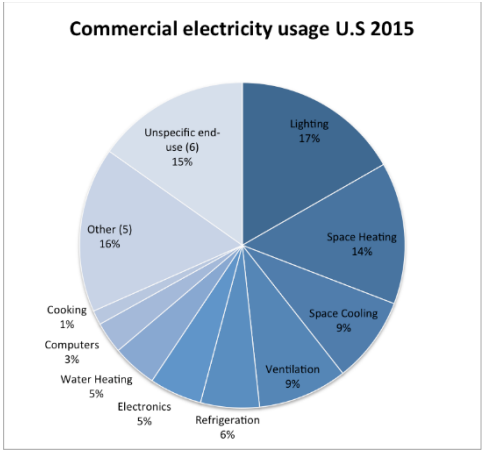
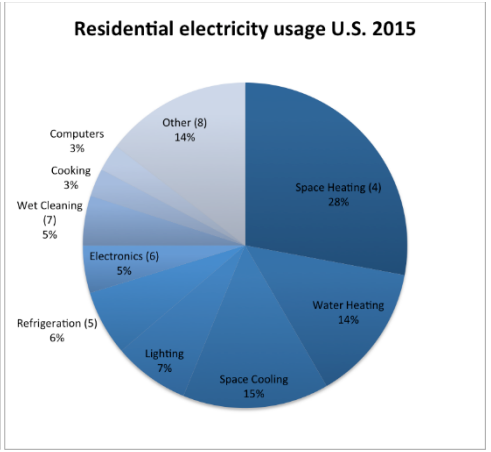
The Polar Vantage V also offers 'Recovery Pro' which offers personalized training guidance based on analysis of heart rate variability (HRV) orthostatic results to help recovery and avoid injury, as well as calculating running power without the need for external sensors.

Using Bluetooth Low Energy connectivity provided by Nordic's nRF52832 System-on-Chip (SoC), this data is synced to the user's Bluetooth 4.0 (and later) smartphone, where they can view detailed training statistics via the iOS- and Android-compatible Polar Flow app.

My personal why 2: Energy consumption



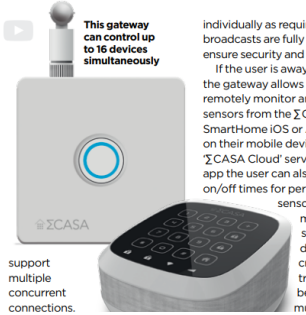




Bluetooth LE gateway powers 16 smart-home devices at once

IoT solutions company, Dexatek Technology, has released its '∑CASA' smart-home ecosystem based on Nordic Semiconductor's Bluetooth Low Energy wireless technology. The ∑CASA system comprises the '∑Central gateway' and a range of peripheral sensors to monitor smoke, shock, motion, door access, and environmental conditions, as well as devices to remotely control appliances and lighting in the home.

The ∑Central gateway employs Nordic's nRF52832 System-on-Chip (SoC) to provide wireless connectivity between the gateway and the ∑CASA peripherals, as well as the user's



This gateway can control up to 16 devices simultaneously

support multiple concurrent connections.

individually as required. The broadcasts are fully encrypte ensure security and privacy.

If the user is away from hor the gateway allows the user t remotely monitor and contro sensors from the ∑CASA-SmartHome iOS or Android a on their mobile device via the '∑CASA Cloud' server. From t app the user can also schedu on/off times for peripheral sensors, contro multiple sensors, sh devices, ar create ever triggers between multiple

Fixture-integrated sensor enables mesh-networked lighting installations

Murata has released its 'Fixture-Integrated Sensor' for the professional lighting sector, enabling manufacturers to develop Bluetooth mesh-based networked lighting products. The sensor employs Nordic's nRF52832 System-on-Chip (SoC) to provide the wireless mesh networking between individual sensors as well as Bluetooth 4.0 (and later) smartphones and tablets which offer a single point from where the sensors can be commissioned, configured, and controlled.

The device combines occupancy sensing, daylight harvesting, and 0-10 V dimming control in a compact form factor, and can be integrated into a wide range of new or existing luminaires. This is said to enable lighting manufacturers to deliver wirelessly-controllable and sensor-equipped lighting fixtures with minimal RF engineering

This fixture combines occupancy sensing, daylight harvesting, and dimming control

expertise. The sensor employs Bluetooth mesh software which enables users to instantly and simultaneously control up to hundreds of Bluetooth mesh-equipped lights from smartphones or tablets.

Once installed, the luminaires just need to be connected to mains power and can then be provisioned, configured, and controlled directly from a mobile device using either smart-light maker Silvair's iOS Platform or Nordic's iOS and Android nRF Mesh intuitive apps. The nRF Mesh app, for example, enables a range of management features for use in Bluetooth mesh networks, allowing simple provision and configuration of Bluetooth mesh networks and devices. Either app allows the user to create lighting zones, enable and disable sensors, pair with switches, as well as set desired lighting levels.

Bluetooth mesh allows devices within a Bluetooth LE network to communicate directly with companion devices without recourse to a central hub device. The topology extends range, flexibility, and reliability.

My personal why 3: COVID-19

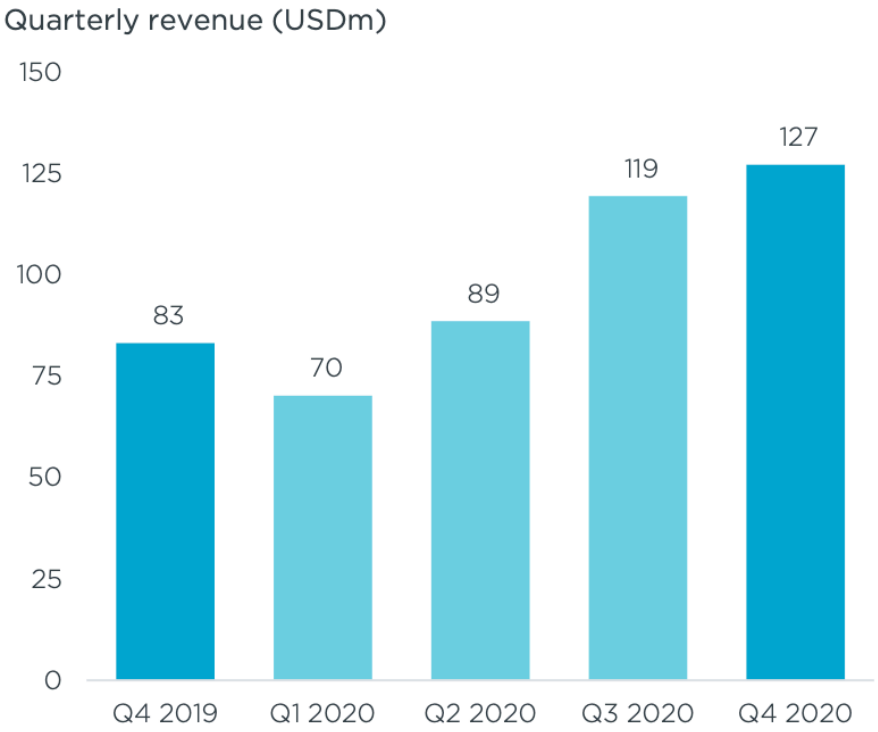
- Corona virus disease 2019 has exposed a need in the market for
  - Assistance with personal distancing
  - Exposure notification (Google/Apple + Bluetooth)
  - Home medical

Nordic inside COVID-19 home tester

- Nordic's nRF52810 Bluetooth LE SoC powers new COVID-19 Home Test kit from Ellume
  - Authorized by the FDA under an emergency use authorization, easy-to-use 15 minutes test for SARS-CoV-2 infection
  - Automatically transmitting results via Smartphone to secure cloud connection
  - Available over-the-counter
- Ellume expects demand in tens of millions

Money

Revenue growth of 53% in Q4



405 Million USD in 2020

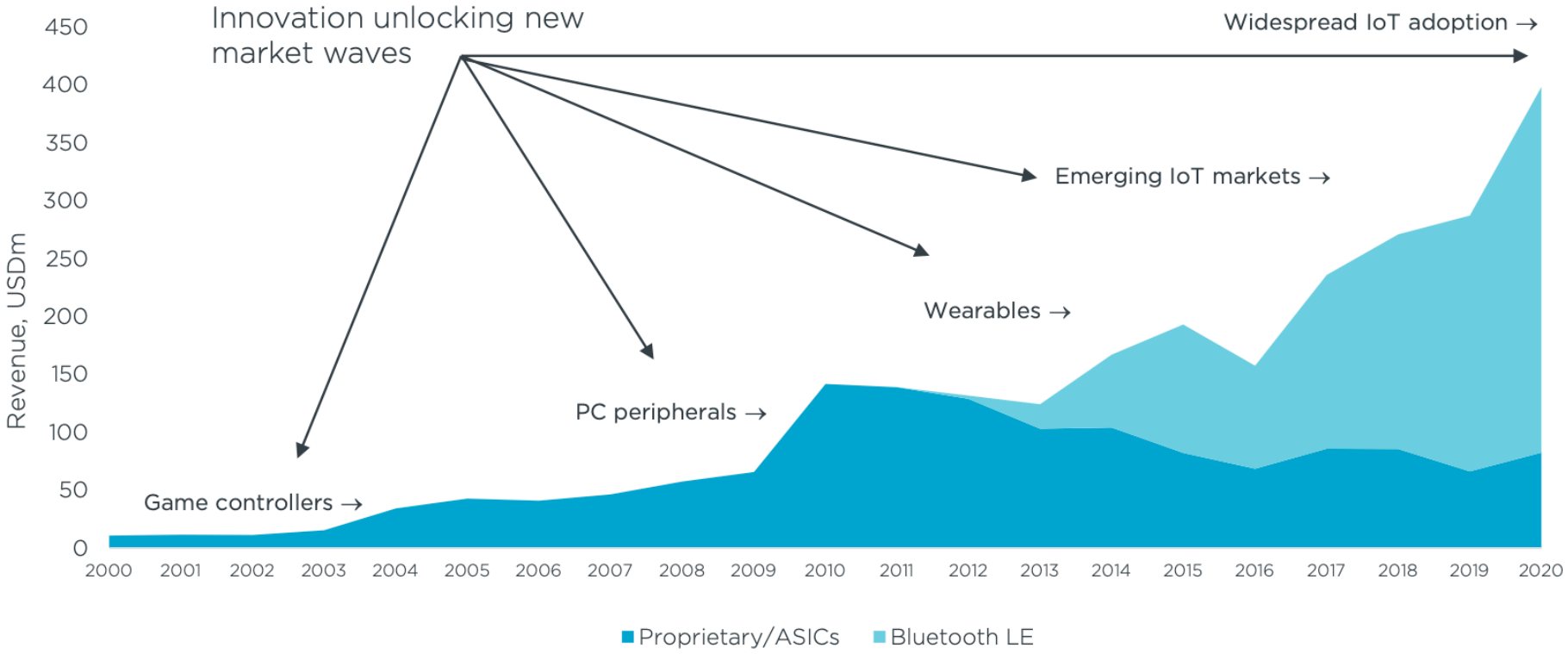
- Growth in all technologies in Q4...
  - Bluetooth accounting for 77% total revenue, after increasing 49% y-o-y to USD 97.6 million
  - Proprietary +55% to USD 25.3 million
  - Cellular IoT USD 2.7 million (USD 0.2 million)
- ...and for the full year 2020
  - Bluetooth +43% to USD 316.0 million
  - Proprietary +27% to USD 76.1 million
  - Cellular IoT +524% to USD 6.5 million

Revenue growth in all markets

Group	Consumer Electronics	Wearables	Building/ Retail	Healthcare	Others
USDm 127.1	USDm 53.7	USDm 18.1	USDm 27.0	USDm 10.6	USDm 13.5
+52.9% y-o-y +6.5% q-o-q	+59.0% y-o-y -3.0% q-o-q	+12.3% y-o-y -6.7% q-o-q	+62.3% y-o-y +17.8% q-o-q	+113.2% y-o-y +36.0% q-o-q	+30.3% y-o-y +26.6% q-o-q

- Year-on-year growth across the markets
- Strong but seasonally slower for Consumer Electronics and Wearables
- Building/Retail, Healthcare and modules securing growth from Q3 to Q4

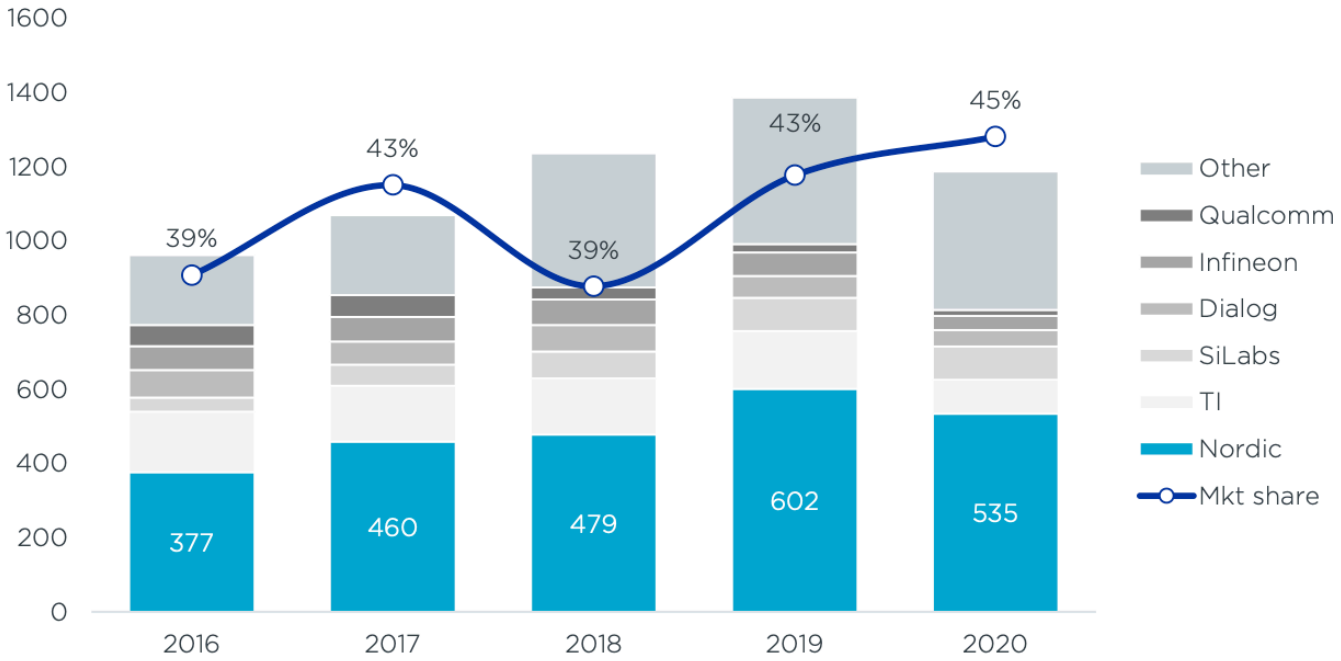
Nordic is on a long-lasting growth journey



Fortifying the broad market leadership

Continued high certification market share

Bluetooth Low Energy end-product certifications



End-product certifications, Nordic Q4 20

141

45 % mkt share in Q4'20 isolated

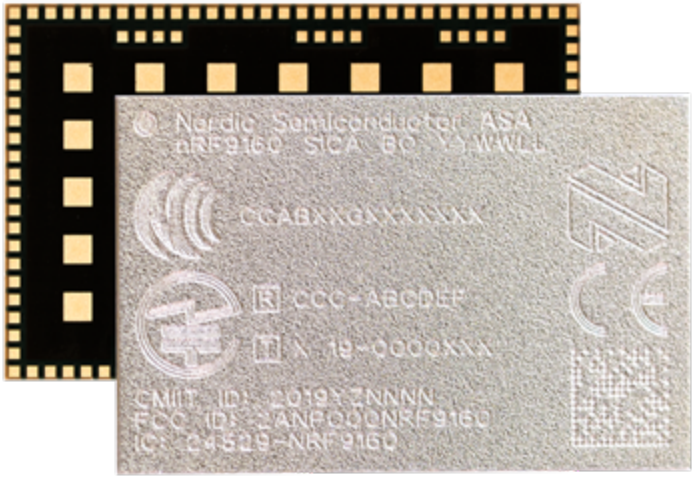
+1% y-o-y

+16% q-o-q

*Source: DNB Markets/FCC

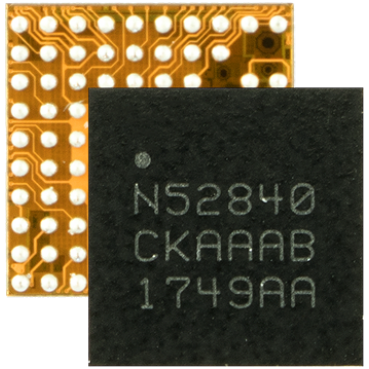
What

Long Range



LTE-M/NB-IoT + GPS

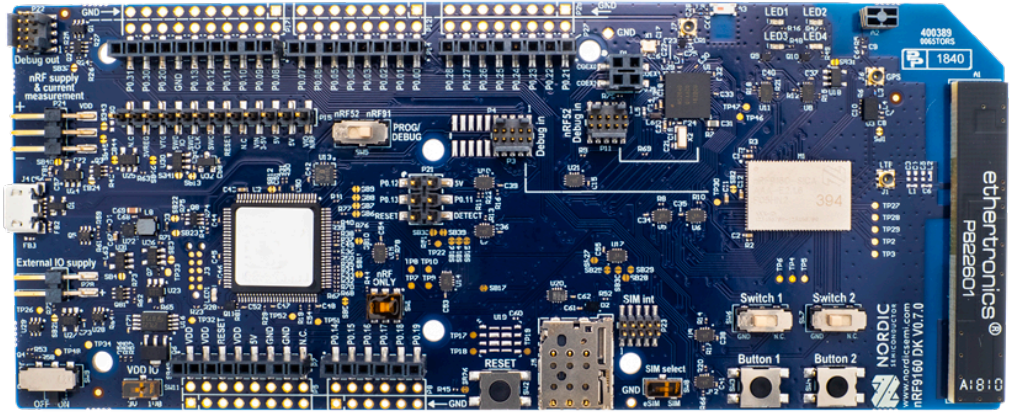
Short Range



Bluetooth 5, Bluetooth mesh, Thread, Zigbee, 802.15.4, ANT and proprietary

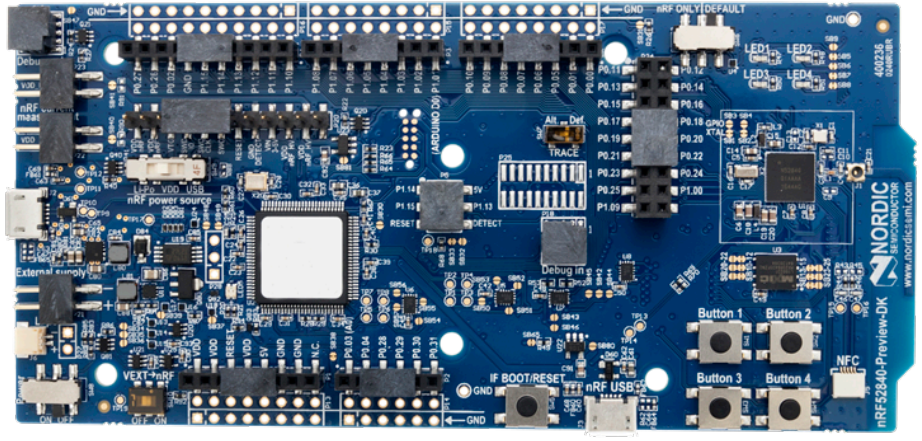
Professional developer

Long Range



nRF9160 DK

Short Range



nRF52840 DK

New product launches in Q4

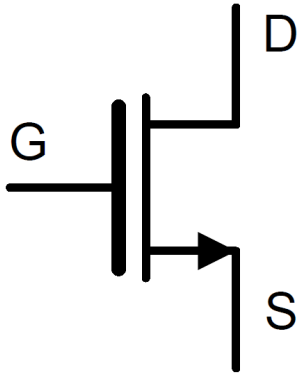
Tsingoal nRF52833	Shenzhen DO Intelligent Technology nRF52840	Eve Systems nRF52840	NousLogic nRF9160	tiptap nRF9160
Bluetooth LE & UWB Module	Smartwatch	Smart home products supporting both Bluetooth LE & Thread	Healthcare/medical realtime monitoring	Contactless payment terminal

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 1 µm transistor lengths.



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

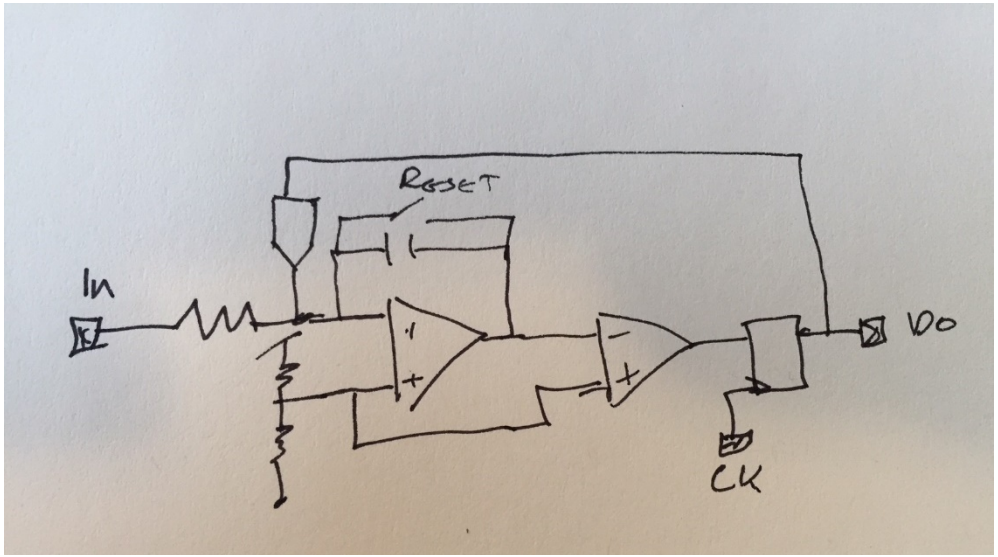
3. *Saturation Region* [$V_{GS} > V_{th}$ *and* $V_{DS} \geq V_{D\,SAT}$]:

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

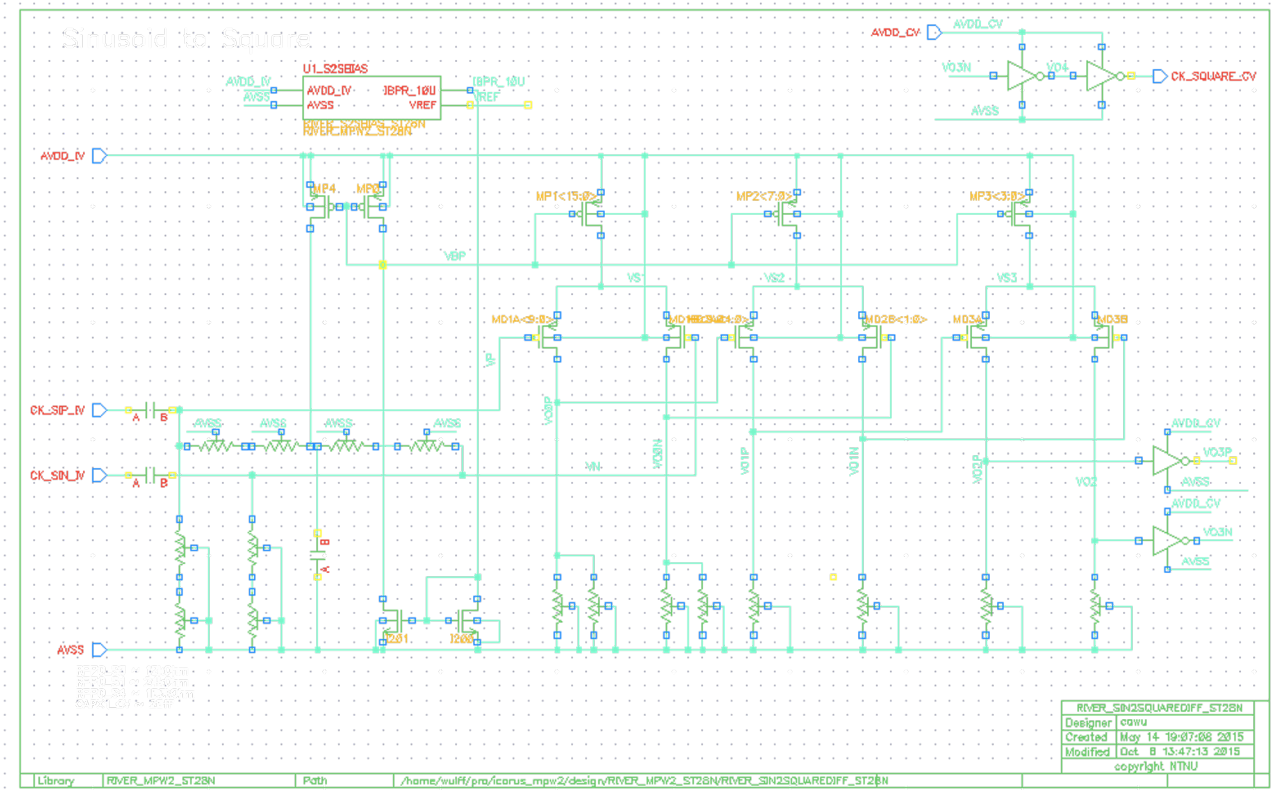
BSIM 4.5 = 284 parameters

.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

Typical start of design: paper and a pencil

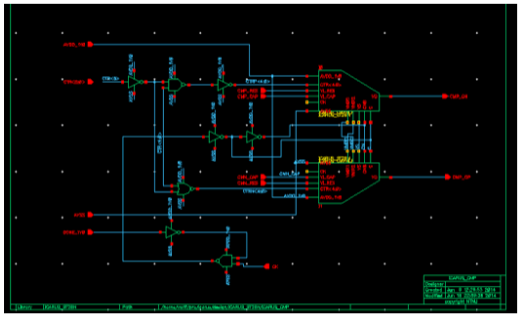


Draw schematic

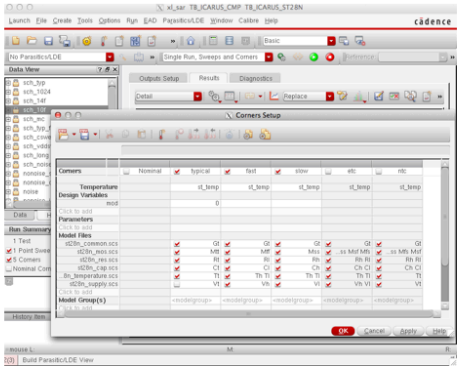


Analog Design

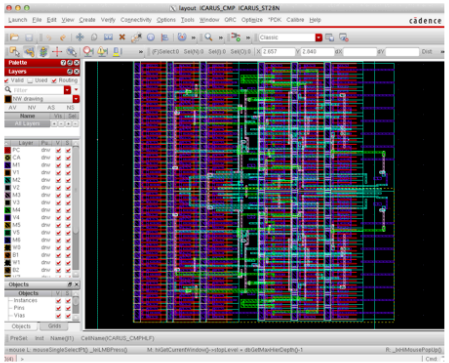
Schematic



Simulation



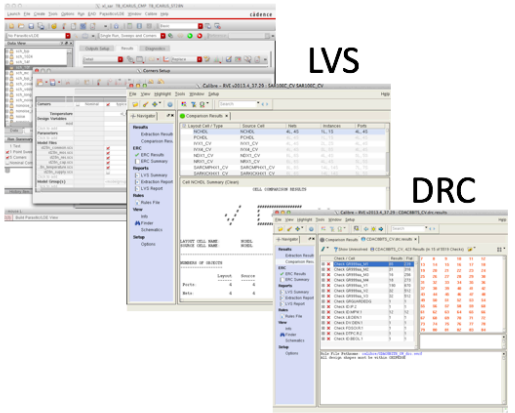
Layout

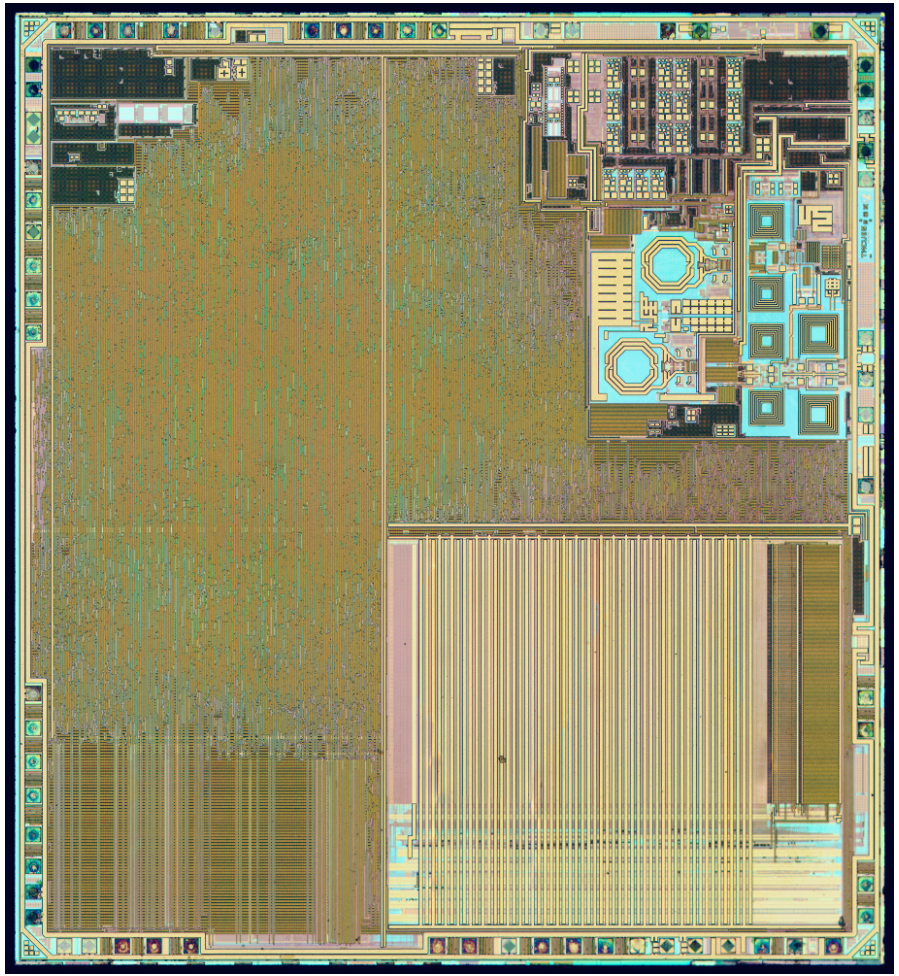


Simulation

LVS

DRC





Manufacturing ICs

Extremely expensive

NORDIC SEMICONDUCTOR

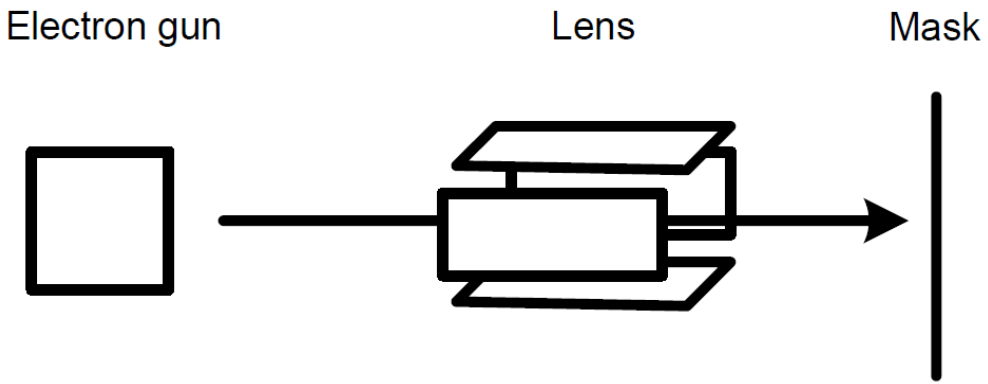
Smarter Things

Fabless IC design

IC foundry: 46,968 (2016)

Packaging and test: 65,695

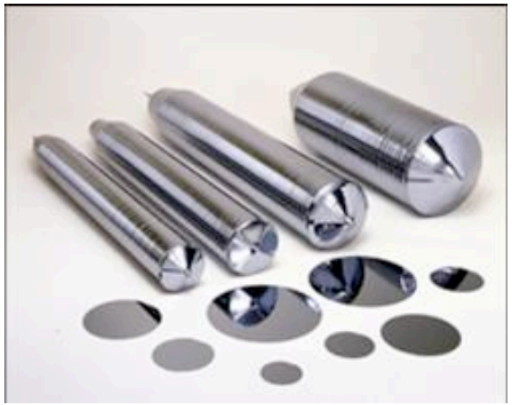
Mask making



- Mask making is extremely expensive, on the order of 1 MUSD – 10 MUSD per design
- A normal chip has around 30 - 40 masks.

Search terms: Czochralski process, dicing

The wafer – the fundamental building block



http://www.tomshardware.com/reviews/semiconductor-production-101,1590-3.html

- Ingot = An ultra pure, single crystal of silicon
- Wafer = A very thin slice of an ingot, used as the first layer in processing

Lithography

Today, for most products: 193nm argon fluoride excimer laser

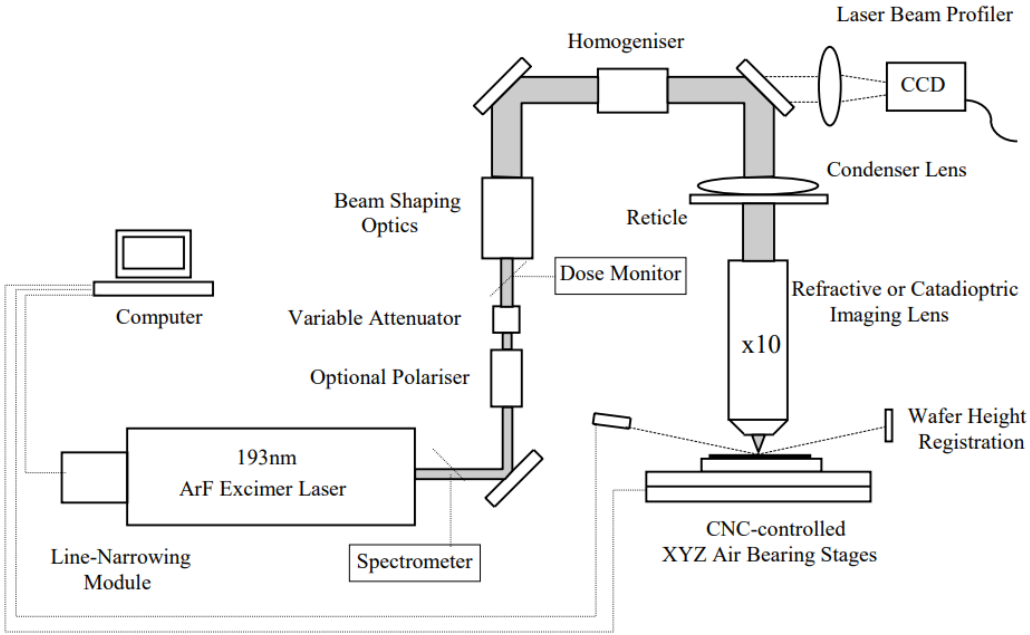
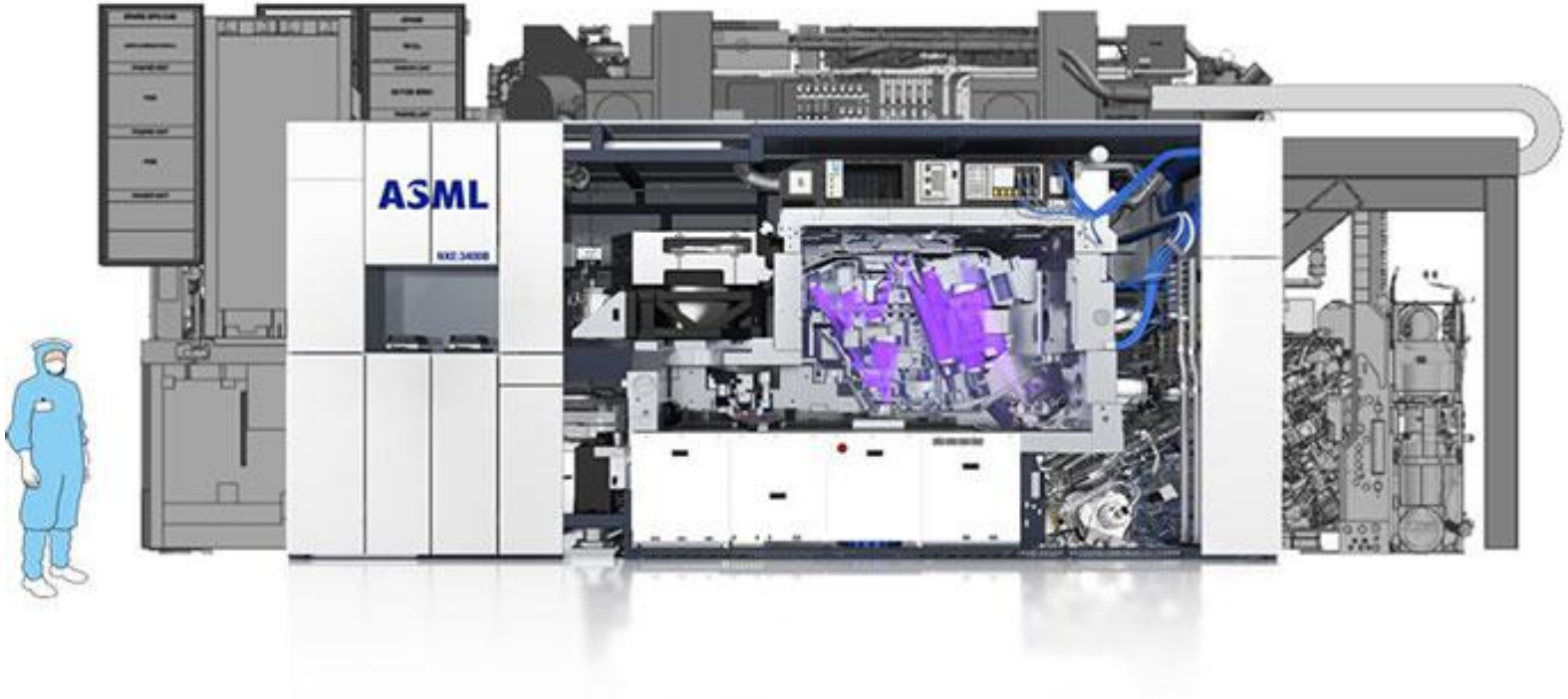


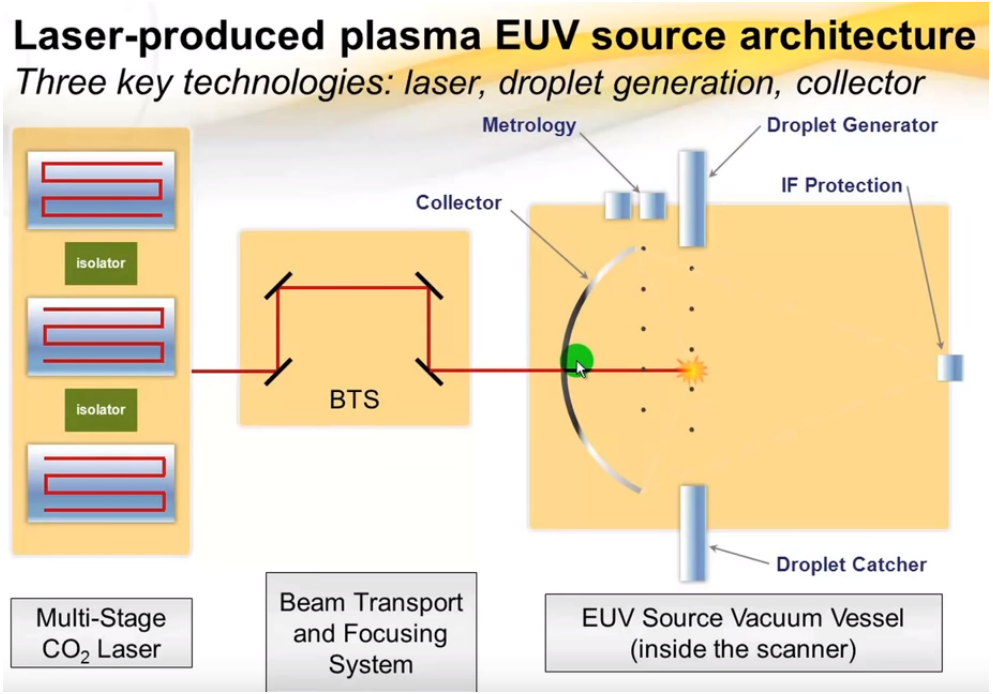
Figure 2. Schematic diagram of 193nm excimer laser lithography exposure system

Lithography machines (https://www.youtube.com/watch?v=ShYWUlJ2FZs)

Today at 7 nm: Extreme ultra violet

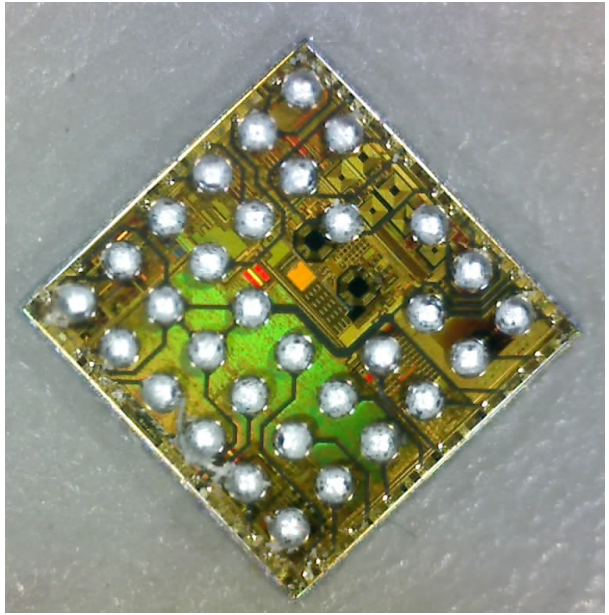


Today at 7 nm: Extreme ultra violet



[EUV light source (https://www.youtube.com/watch?v=5yTARacBxHI)]

Research & development takes time



Software design
Acoustics
Signal processing
Computer design
Radio Systems
Circuit- and systems design
Electro-optics
Electronic Devices and Materials

Time to market

Months
Years
Decades

Thanks!

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