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MASTER OF SCIENCE

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# Integrated Circuit Design



## At a Glance

- The best of German and Asian know-how in integrated electronics
- Nurturing innovators to take on the dynamic semiconductor industry
- Joint degree conferred by TUM and NTU
- Vast career prospects regionally and worldwide
- Apply online at [www.tum-asia.edu.sg](http://www.tum-asia.edu.sg)

# About TUM & NTU

## Technical University of Munich (TUM)

The Technical University of Munich (TUM) was founded in 1868 and is one of Europe's leading technical universities. Serving as an entrepreneurial university that promotes talents and creates value for society, TUM has produced 17 Nobel Prize winners since 1927, most notably Ernst Otto Fischer (Chemistry) and Rudolf Mößbauer (Physics). Its focus areas are engineering sciences, natural sciences, life sciences, medicine, management and political and social sciences.

TUM promotes talents with its network of strong partners in research and industry. It is represented worldwide with the TUM Asia campus in Singapore, as well as offices in Beijing, Brussels, Cairo, Mumbai, San Francisco and São Paulo.

In international rankings, TUM regularly places among the best universities in Germany and worldwide. It is the only university to have won recognition as a German 'Excellence University' in every round since 2006.

## Technical University of Munich (TUM) Asia

Technical University of Munich (TUM) Asia was set up in 2002 as the first academic venture abroad by a German university, blending German academic excellence with industry relevance in Asia. Its partnerships with top Asian universities and industry leaders combine German engineering with Asian relevance to equip talents for industry and research sectors in the world.

With the changing needs of the economy, the specialised Master programmes that are offered keep pace with industry needs through an Asian-European perspective. Lecturers and professors hail from as far as Germany to equip students with their rich knowledge and experience.

More than a thousand students have come through the doors of TUM Asia and now ply their trades in top research institutes and companies across the globe.

## Nanyang Technological University (NTU)

Inaugurated in 1991, Nanyang Technological University (NTU) has grown to become a full-fledged research university and has been ranked the world's best young university (under 50 years old) by Quacquarelli Symonds for the sixth consecutive year in 2019.

NTU's academic and research programmes, which bear strong real-world relevance, have garnered strong support from major corporations and industry leaders. As the main Science and Technology university in Singapore, NTU has made substantial contributions to Singapore's drive for research and innovation.

**NO. 1**  
university

TUM is ranked as the no. 1 University in Germany\*

**NO. 6**  
in employability

TUM ranked no. 6 in the Global Employability Survey<sup>^</sup>

**17**  
Nobel Prize recipients

17 scientists and alumni of TUM have received the Nobel Prize

**50**  
universities

TUM is ranked among the world's Top 50 Universities<sup>#</sup>

\* As rated by QS World Ranking 2015 -2019 and Academic Ranking of World Universities (Shanghai ranking) 2011 - 2013, 2016

<sup>^</sup> As ranked in the 2018 & 2019 Global University Employability Ranking by Times Higher Education (THE)

<sup>#</sup> As rated by Times Higher Education World University Rankings 2020, QS World Ranking 2018 and Academic Ranking of World Universities (Shanghai ranking) 2016 - 2018



# Programme Overview

Awarded by TUM and NTU, the **Master of Science in Integrated Circuit Design (MSc in ICD)** equips students with the academic proficiency and hands-on knowledge required in the design, development, and manufacture of integrated circuit and integrated electronic products.

## Programme Structure and Timeline



**14**  
modules

- 6 Core Technical Electives
- 4 Specialisation Technical Electives
- 2 Non-Technical Elective Modules
- 2 Lab Courses



**45**  
contact hours

for every Core and  
Specialisation Elective  
Module

**2 Years**

- Full-time programme
- Coursework in Singapore
- Internationally-recognised degree

July

Arrival in  
Singapore

Year 1

- Laboratory Modules
- Core Technical Elective Modules
- Specialisation Technical Elective Modules
- Non-Technical Elective Modules

Year 2

- Non-Technical Elective Modules
- Internship
- Master Thesis at a company, university or research institute (Supervised by an NTU or TUM professor)

Graduation

End of  
programme

**Note:** This outline is a general reference to the duration of study. A student's actual duration of study may or may not follow this general reference. This outline is subject to change during the course timetable.

# Programme Modules

## Compulsory Laboratory Modules

### Laboratory 1 Analog IC Design

Introduction to Cadence design tools; CMOS high speed analog circuits; HF characteristics of CMOS Transistors and more.

### Laboratory 2 Digital IC Design

Synchronous digital circuit concept; description of sequential and combinational logic cells; basic components of digital circuits; state machines; simulation; synthesis, static timing analysis; implementation and testing.

## Core Technical Elective Modules

(Choose 6 out of 7 modules)

### Analog IC Design

Review of fundamentals: Noise, Modeling, Analog Building Blocks, Components Layout, Switched Capacitor Circuits, Current Mode Circuits, Transconductors, Auto-tuning, Gm-C and MOSFET-C Filters, Continuous-Time Filters, Switch Current Circuits and Class D Amplifiers.

### Design Methodology & Automation

Computer-aided design of primarily digital integrated circuits; VLSI design flow; Overview of system level, algorithmic level, register transfer level, logic level, and circuit level VLSI design methods. Focus on: logic synthesis, digital simulation, testing. Techniques from discrete mathematics and computer science. Emphasis is placed on techniques that are applicable to very complex, industrially relevant circuits.

### Digital IC Design

Review of integrated circuit fundamentals: Layout and design issues, CMOS digital circuits, BiCMOS digital circuits, Sub-system design in digital circuits and Design methodologies.

### Digital Signal Processing

Introduction to Discrete Fourier transform (DFT) and fast Fourier transform (FFT). Z transform. Digital filters. Linear prediction and optimum linear filters. Power spectrum estimation.

### IC Packaging

Plastic Packaging Materials Manufacturing Processes for Plastic Encapsulated Microelectronics. State-of-the-art Packaging Techniques. Failure Mechanisms, Sites, and Modes. Qualification Process. Accelerated Testing for Packaging. Effects of Packaging on the Electrical Performance. Future Trends and Challenges in Packaging.

### Mixed Signal Circuit Design

Specifics of semiconductor process technology and devices for the building of integrated circuits. Transistor level circuits and the implementation in CMOS technology: amplifier, current and voltage reference, power supply as well as clock generation, regulation and distribution, A/D and D/A converters.

### System-on-Chip Solutions & Architecture

Basics of CMOS integrated circuits from a system's perspective: From MOSFET transistor to realization of combinatorial/sequential logic, Finite State Machines (FSM), SRAM, DRAM, FLASH, FPGA, CPU core building blocks. Packaging and I/O technology; System modelling; Projection of IC technology scaling and implementation alternatives; Moore's law and what it will mean for different IC technologies today and in future.

## Specialisation Technical Elective Modules\*

(Choose 4 out of 7 modules)

### Advanced MOSFET & Novel Devices

Historical development of mainstream MOSFETs until today; economical, technological and physical fundamentals; properties

of long channel and short channel MOSFETs, hot carrier effects; short channel effects, scaling rules; basics of charge carrier transport (quantum mechanical, hydro dynamics, ballistics); proposed new MOSFET structures (strain engineering, metal-gate, high-k, vertical MOSFETs, double gate MOSFETs); hot electron transistors; tunneling transistors; low dimensional devices; single electron transistors, single electron memories, quantum electronics.

### Design for Testability of VLSI

Fault Models and Testability concepts. Test Generation and Fault Simulation Algorithms. Shift-register polynomial division. Pseudo-random sequence generators. Special purpose shift-register circuits. Random pattern BIST. Build-in boundary scan structure. Limitations and other concerns of random pattern test. Test techniques for automatic test equipment.

### Embedded Systems

The lectures cover the topics: Basics of embedded processor architectures; Bus and memory architectures; Performance/Timing analysis of embedded systems; Models for real-time systems; Principles of embedded software development; Basic real-time programming language concepts (e.g. Esterel); real-time operating systems; Power management; Design space exploration.

### IC Marketing / Business Management

Trends in the IC industry: technology and manufacturing trends, demand applications and product trends. Market characteristics: the customers, business cycles, demand lead and supply lag (the bull-whip effect), IC industry, supply and value chain, stakeholders, geographical distribution of excellence centres, technology centres, design centres, fabrication centres, the disintegration of the value chain and outsourcing trends. Managing the marketing function: the sources of product ideas, the role of standards, formats,

and intellectual property. Strategic partnership, distributorship, demand forecast, matching supply with demand.

### **Nano-Electronics**

Low dimensional structures: quantum wells, quantum wires and quantum dots. Electronic, optical, transport properties of nanostructures. Quantum semiconductor devices. Fabrication and characterisation techniques of nanotechnology. Applications of nanostructures, nanodevices and nanosystems. The bottom-up approach to nanotechnology: introduction to molecular electronics and optoelectronics. Organic materials for electronics: self-assembled monolayers, conducting polymers, carbon nanotubes. Circuit implementations and architectures for nanostructures: quantum cellular automata and cellular non-linear networks. Introduction to quantum computing.

### **RF IC Design**

System design considerations, CMOS RF components and devices, Low-noise amplifier (LNA), Mixers, Voltagecontrolled oscillators (VCOs), RF power amplifiers, Phase-Locked Loops and Frequency Synthesizers.

### **Simulation and Optimisation of Analog Circuits**

Principles of circuit simulation: DC/AC/TR analysis. Basic analog optimization tasks: worst-case analysis, yield analysis, nominal design and design centring. Basic principles of optimisation: optimality conditions, line search, Nelder-Mead method, Newton approach, Conjugate Gradient approach, Quadratic Programming and Sequential Quadratic Programming. Structural analysis of analog circuits.

## **Non-Technical Elective Modules**

(Choose 2 out of 6 modules)

### **Business Administration**

The primary purpose of the module is to introduce students to the different areas of business administration with the final objective to give them a basic understanding of how to face decision problems in a company. Most importantly, we will analyse long-term investment decisions, how to set up strategic planning in a company, how to gather timely information about the current situation of a company, and how to set up its long-term financial structure.

### **Industrial Marketing**

Marketing strategies are developed for a typical commodity and speciality business. Students will work in teams to develop business cases, make their own business decisions and develop marketing concepts based on provided information of a real case study.

### **Innovation and Technology Management**

This module presents the dynamics of technological development through innovation and the related management issues, the difference between creating a new product (invention) and improving an existing product/idea (innovation), start-ups and financing of innovation, innovation-driven economic cycles and innovation impact on growth and jobs.

### **International Intellectual Property Law**

This module will give a brief introduction to intellectual property rights and focus on insights into general principles of patent law and international conventions governing the patent law. Current developments and criticism of the current patent law system will also be addressed. In addition, practical (legal) aspects of the commercialisation of patents will be dealt with.

### **Modern Developments in Industry**

The module will provide insights in the core elements of Industry 4.0 such as: introduction to Cyber-Physical System, Radio Frequency Identification (RFID) technologies, information collection with intelligent sensors, industrial networking to connect the machines and processes together, Manufacturing Execution System (MES) for order management, production control and value adding to the complete supply chain management.

### **Production Planning In Industry**

Manufacturers are confronted with special requirements of their production processes. Cycles, by-products, batches and campaigns are difficult to handle by Enterprise Resource Planning (ERP) software packages nowadays. Concepts of material requirements planning, supply chain management (SCM) combined with basics in cost accounting will be explained.

\*Disclaimer: Elective modules available for selection are subject to availability. Unforeseen circumstances that affect the availability of the module include an insufficient number of students taking up the module and/or the unavailability of the professor. TUM Asia reserve the right to cancel or postpone the module under such circumstances.

# The TUM Experience



The Integrated Circuit Design programme offered a module that was related to intellectual property and invited a German professional patent attorney to teach it. The module opened a new window for me and helped me to discover a career path that I was passionate about.

Minghui Sun  
Alumni  
Master of Science  
in Integrated Circuit Design

## Entrepreneurial Thinking and Engagement

You will formulate and discuss ideas based on the diverse economic realities and learn to see from multiple vantage points. The unique joint degree programme equips you not only with the technical knowledge, but also with the business and cultural aspects of the subject.

## Industry Relevance

Our professors - the world's best - are industry experts and active researchers. This allows you to learn from a curriculum that is built around the latest technological trends and knowledge.

## Highest International Standards

You will receive a holistic learning experience with the local lecturers from academia and industry. Our TUM modules are covered by professors who fly in from Germany on an exclusive teaching basis, to ensure that you get the undivided attention of their lecturers.

## Global Prospects

You can choose to complete your internship and thesis in Singapore or anywhere in the world with a company, university or research institute. Your internationally recognised degree and experience is a great boost to your profile for future global job opportunities.

## TUMCREATE

TUMCREATE is a joint programme between the Technical University of Munich (TUM) and the Nanyang Technological University (NTU). The electromobility institute brings together the expertise and innovation of Germany and Singapore to drive innovation and shape the future of sustainable mobility by tackling issues ranging from molecules to the megacity. Graduates have the opportunity to apply for positions at TUMCREATE, especially if your interest lies in the area of transportation and mobility research.

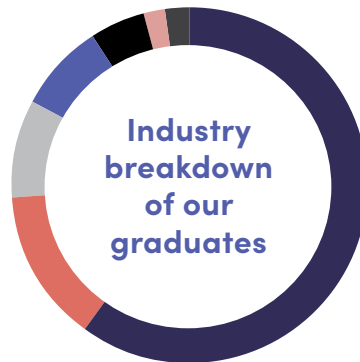
# Industry Outlook

Did you know that a part of your gadgets today - **computer, mobile phone, tablet or video console** - were designed or manufactured in Singapore? Leaders of the Singapore electronics industry are working to push the boundaries of Artificial Intelligence (AI), Autonomous Vehicles (AVs), and Industry 4.0.

## Rich and diverse manufacturing hub

Singapore has one of the most diverse semiconductor industries in Asia Pacific. Some of the world's biggest pure-play foundries have manufacturing facilities here, as do many other top outsourced semiconductor assembly and test companies. Beyond semiconductors, Singapore is also a key node in the global supply chain for products ranging from storage and memory products, to microelectromechanical systems (MEMS). These manufacturers are supported by a rich ecosystem of leading materials and equipment and electronics manufacturing services players. Looking ahead, the Electronics Industry Transformation Map (ITM) aims to grow the sector by transforming companies through productivity, automation, and upgrading the manufacturing product mix.

Source: Singapore Economic Development Board



Semiconductor	60%
Computing and IT	14%
Academic	9%
Electronics	8%
Research	5%
Integrated Circuit Products	2%
Others	2%

## Our Graduates

Our graduates in Integrated Circuit Design are employed all over the world, with a majority in Singapore, China and Europe.

The most commonly accepted positions are Analog IC Design Engineer, Electronics Engineer, Development Engineer, Reliability Engineer, Product Development Engineer.

Others may also choose to continue their academic journey with a doctoral candidate position (PhD).

Today, Singapore is home to over

# 20

semiconductor assembly and test operations.

In 2015, Singapore's Electronics industry achieved an output of over

# \$64.8 billion

This accounts for 31.6% of Singapore's total manufacturing output.

The Singapore industry trains over

# 13,000

engineers and technicians regularly to ensure a steady stream of talent to the industry

There is a

# 2% - 5%

annual growth in productivity over the past decade registered by the electronics sector.



## Programme Fees

### Processing Fee

SGD79 per application

### Tuition Fee

SGD42,800\*

## Admission Criteria

- **Bachelor Degree in Electrical or Electronics Engineering** or a closely related discipline
- Bachelor Degree certificate or enrolment letter\* (if you have not completed your Bachelor Degree)
- Academic transcripts or mark sheets\*
- **2 Recommendation Letters** from your professors or employers
- **Statement of Purpose** indicating the reason(s) you are interested in this programme
- **Curriculum Vitae / Résumé**
- **TOEFL** test score ( $\geq 100$  for Internet-based test, DI code: 7368) or **IELTS** test score ( $\geq 6.5$  overall) taken no more than two years ago from date of submission
- **Akademische Prüfstelle (APS) certificate** for applicants who hold a degree from China, Vietnam, or Mongolia



The full application process and documents required for submission is available at [www.tum-asia.edu.sg/application-process](http://www.tum-asia.edu.sg/application-process)

Applications open 1 October every year.

\* Tuition fees are to be paid in 3 instalments.

\* The tuition fee includes teaching fees, laboratory expenses and cost of mandatory events. The tuition fee does not include airfare, accommodation, living expenses, and miscellaneous fees (registration, IT facilities, matriculation, examination, amenities, copy right, sports, insurance and medical).

\* The tuition fee stated is accurate as of 1 January 2020. All fees are subject to revision due to currency fluctuations, at the discretion of TUM Asia. All fees quoted are inclusive of 7% Singapore's Government Goods & Services Tax. Please refer to our website for fee updates.

\* Documents which are not in English must be translated by a certified translator. All applicants are also required to submit an additional of

- 2 notarised copies of official or provisional Bachelor's Degree certificate
- 2 notarised copies of official academic transcript, and
- 2 passport-sized photographs when you have accepted the offer of admissions and are being matriculated into our programme.



### Technical University of Munich (TUM) Asia

510 Dover Road, #05-01 SIT@SP Building, Singapore 139660

Tel: +65 6777 7407

Fax: +65 6777 7236

Email: [admission@tum-asia.edu.sg](mailto:admission@tum-asia.edu.sg)

German Institute of Science & Technology -  
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