Technical University of Munich (TUM) Asia

TUM Asia

MASTER OF SCIENCE

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**

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Technical University of Munich

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 18 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's 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 two 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. 13 in employability — TUM is ranked no. 13 in the Global Employability Survey^

19 Nobel Prize recipients — 19 scientists and alumni of TUM have received the Nobel Prize

NO. 25 universitiy — TUM is ranked 25th among the best universities in the world#



* As rated by QS World Ranking 2027
^ As rated by The Global University Employability Ranking 2026
\# As rated by QS World University Ranking 2027

Programme
Overview

Jointly 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 to design, develop, and manufacture integrated circuits 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	Year 1	Year 2	Graduation
Arrival in Singapore	• Laboratory Modules • Core Technical Elective Modules • Specialisation Technical Elective Modules • Non-Technical Elective Modules	• Non-Technical Elective Modules • Internship • Master Thesis at a company, university or research institute (Supervised by an NTU or TUM professor)	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)

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 realisation 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)

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, Voltage controlled oscillators (VCOs), RF power amplifiers (PA), Phase-Locked Loops (PLL) and Frequency Synthesisers.

Simulation and Optimisation of Analog Circuits
Principles of circuit simulation: DC/AC/TR analysis. Basic analog optimisation tasks: worst-case analysis, yield analysis, nominal design and design centering. 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)

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.

Intellectual Property and Technopreneurship
This module covers different types of Intellectual Property (IP) and methods of protection. Students will acquire up-to-date knowledge about patents as a connecting link between science, research, and technical developments on the one hand, and Technopreneurship opportunities on the other hand. At first, fundamentals of international patent systems and patent data bases will be presented. Then, the elements of a patent application and the patent grant procedure are detailed. Finally, use cases such as IP-based company startups and the interaction between intellectual property and market needs are discussed.

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.

Paradigm Shift to Industry 4.0
Introduction to Industry 4.0; Core elements of Industry 4.0; Fundamental workshop on AR/VR and digital twin; Fundamental workshop on additive manufacturing; Fundamental workshop on collaborative robot; Site visit and workshop on indoor vertical farming with disruptive technologies; Case study on Aquaculture 4.0; Site visit to Competence Centre for Digitalisation, Technology and Innovation (CDTI) and Advance Manufacturing Transformation Centre (AMTC).

Cyber Physical Systems
Introduction to Cyber Physical System; Elements of Cyber Physical System and its importance for a smart production system; Communication networks and the physical systems within a single entity; Overview of technologies enabling connectivity, open communication protocols, and cooperation between systems in a highly digitalised manufacturing environment; Essentials of a digital representation of a networked Cyber Physical System; Cyber Physical System for advanced digital manufacturing; and Case studies and discussions.

Industrial Additive Manufacturing Quality Certification
Introduction to additive manufacturing and fundamentals of AM processes; Status quo of industry and first steps to AM production; Health and safety in AM; Quality and production management in AM; Risk assessment and management in AM; Industry standards in AM.

Augmented Reality, Virtual Reality and Digital Twin
Fundamentals of AR/VR technology; Benefit of AR/VR application in production environment to increase work efficiency; Hands-on exercises to access information about production operation; Considerations for AR/VR development; Virtual design and commissioning of a factory layout; Design and verification of a manufacturing process in a 3D environment; Human modelling and ergonomics.

*__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. NTU and TUM Asia reserve the right to cancel or postpone the module under such circumstances. TUM Asia will update the list of non-technical electives from time to time. Kindly refer to our webpage for the updated list of non-technical electives.

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 was founded in 2010 as a research arm to foster research collaborations between TUM, Singapore and other top universities in the world in the advancement of electromobility, smart cities, medical technology and now food science. To date, TUMCREATE contributed more than close to 650 publications, developed 10 patents and innovations with more than 69 PhD candidates successfully trained in various specialisations. Graduates have the opportunity to apply for positions at TUMCREATE. especially if your interest lies in the areas of energy, medical technology and food science.

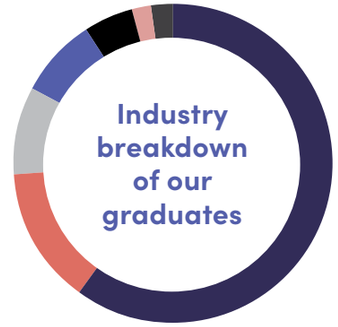
Industry Outlook

Did you know that some of your gadgets today - **computers, mobile phones, tablets or video consoles - 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.

Industry breakdown of our graduates



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

Source: Singapore Economic Development Board

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

	Before GST	After GST
Registration Fee+ Per application	SGD 5,000	SGD 5,450
Tuition Fee+ Integrated Circuit Design	SGD 51,520	SGD 56,156.80

Scholarships & Grants

For more information, please visit:
https://tum-asia.edu.sg/admissions/graduate-studies/scholarships/

Admission Criteria

- **Bachelor's degree** in **Electrical or Electronics Engineering** or a closely related discipline
- **Bachelor's degree certificate** or **enrolment letter*** (if you have not completed your bachelor's degree)
- **Academic transcripts** or **mark sheets**, including the credits/grading system of your university*
- **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 (≥88 for Internet-based test, DI code: 7368) or **IELTS** test score (≥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, India and Vietnam

+ 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).

+ All fees quoted are in Singapore dollars and are subject to the prevailing Goods and Services Tax (GST) rate imposed under the Singapore GST Act. Final tuition fees are subject to revision due to changes in GST rate and/or at the discretion of TUM Asia, and students will be informed accordingly. Please refer to our website for the final tuition fee and other fee updates.

* Documents that are not in English must be translated by a certified translator. Credits/ grading system of your university is required:
  - min. passing score (e.g. 50 out of 100);
  - max. possible score (e.g. 100 out of 100); and
  - the equivalent score/range of scores for each grade (e.g. 'A' grade is equivalent to a score of 90 to 100).

The full application process and documents required for submission is available at **www.tum-asia.edu.sg/admissions/graduate-studies/application/**

Applications open on 1 October every year.

TUM Asia

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