

# Interdisciplinary Integration and Innovation of the Analog Electronic Technology Course under the Emerging Engineering Education Concept

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**Abstract:** Analog Electronic Technology is a foundational course for engineering programmes, yet its conventional organization around device physics and circuit topology no longer matches the competency demands created by intelligent manufacturing and electromechanical integration. This paper examines how the course can be reorganized through interdisciplinary integration under the emerging engineering education concept. The analysis is situated in a mechanical engineering programme, where the course already occupies the boundary between mechanical systems and electronic information. Three contradictions in current practice are identified: the separation of circuit theory from system application, the dominance of verification experiments over design tasks, and the mismatch between a single written examination and the multidimensional competencies expected of graduates. A four-dimensional integration framework is proposed, connecting knowledge modules, disciplinary methods, engineering tools, and application scenarios, and the course content is reorganized into five modules ranging from signal conditioning to system-level design. Teaching is then restructured around project-driven tasks supported by circuit simulation, and assessment is shifted toward process evidence and design artefacts. The paper argues that interdisciplinary integration in this course should be treated as a redesign of learning tasks rather than an addition of cross-disciplinary content, and that the mechanical engineering context provides a natural setting for such redesign.

**Keywords:** Emerging Engineering Education; Analog Electronic Technology; Interdisciplinary Integration; Curriculum

## Innovation; Competency Development

### 1. Introduction

The emerging engineering education initiative in China calls for engineering programmes to respond to new industries, new business forms, and new modes of production through systematic curriculum reform. This initiative shifts the orientation of engineering education from knowledge transmission to innovation capability, and it places interdisciplinary competence at the centre of graduate profiles [1][11]. For electrical and electronic foundational courses, the shift means that content selection can no longer be justified by disciplinary completeness alone; it has to be justified by the competencies that graduates actually need when they enter engineering practice.

Analog Electronic Technology occupies a difficult position in this reform. It is simultaneously a theoretical course with a demanding mathematical apparatus and a practical course whose value is realized only when circuits are built, measured, and debugged. In mechanical engineering programmes the difficulty is greater, because the course serves students whose primary disciplinary identity is mechanical rather than electronic. Teaching practice shows that students in such programmes often master the calculation of a bias point without being able to explain why the corresponding circuit matters for a measurement system, and they can reproduce a prescribed amplifier on a breadboard without being able to specify an amplifier for a given sensor.

The gap between calculation ability and engineering judgement has been noted in curriculum studies of analog electronics under engineering education accreditation [9], and reform efforts have been reported from several angles, including the integration of post, course, competition, and certificate requirements [2], the

reconstruction of course content under the emerging engineering education background [3], and the optimization of curriculum systems for electrical engineering majors [12]. These studies converge on one point: incremental adjustment of teaching hours or laboratory equipment is insufficient, and the organization of the course itself has to be reconsidered.

This paper addresses the question of how Analog Electronic Technology in a mechanical engineering programme can be reorganized through interdisciplinary integration. Three sub-questions are examined: what the concept of emerging engineering education requires of a foundational electronic course; where the structural contradictions of current practice lie; and how content, teaching, and assessment can be redesigned in a coherent way. The discussion draws on curriculum design frameworks developed for interdisciplinary engineering education [4][5] and on empirical accounts of interdisciplinary teaching in higher education [6].

## 2. Theoretical Basis

### 2.1 The Emerging Engineering Education Concept and Its Curriculum Implications

The emerging engineering education concept emerged from the recognition that engineering problems in intelligent manufacturing, new energy, and robotics do not present themselves in disciplinary packages. A vibration monitoring system, for example, requires knowledge of mechanical dynamics, sensor transduction, analog signal conditioning, data acquisition, and decision logic at the same time. Zuo et al. [1] describe the Chinese policy trajectory of this concept and note that its implementation depends on curriculum structures that allow students to work across disciplinary boundaries rather than only within them. Li et al. [11] characterize the transition as a movement from a knowledge-based model to an innovation-based model, in which the unit of curriculum design is the engineering task rather than the knowledge chapter.

Two implications follow for foundational courses. First, the justification for retaining a content item is no longer its place in the disciplinary system but its function in an engineering task. Second, the boundary between foundational and specialized courses becomes permeable, because a foundational concept can be introduced through the specialized scenario in

which it is used. This second implication is what makes interdisciplinary integration a design principle rather than a supplement.

### 2.2 Interdisciplinary Integration as a Curriculum Design Strategy

Interdisciplinary integration in higher education takes several forms, and the differences matter for course design. Lam [5] identifies curriculum integration strategies used in undergraduate interdisciplinary programmes and shows that integration is enacted through the alignment of intended learning outcomes, content sequencing, and assessment rather than through the mere co-presence of two disciplines in a syllabus. Ripley et al. [6] report a phenomenographic investigation of how teachers understand interdisciplinary teaching and learning, finding that conceptions range from adding content from another discipline to restructuring problems so that they cannot be solved from a single disciplinary position. Beldad and Miedema [4] propose a framework for designing interdisciplinary engineering curricula aimed at complex sociotechnical challenges, in which the selection of disciplinary contributions is driven by the nature of the problem to be addressed.

For a course such as Analog Electronic Technology, the distinction between additive and restructuring integration is decisive. Additive integration would mean inserting a lecture on sensor principles into an existing chapter without changing what students do. Restructuring integration means replacing a verification experiment with a task in which students must specify, simulate, build, and test a conditioning circuit for a stated measurement requirement, and in which mechanical constraints such as mounting space, supply availability, and signal range are part of the problem statement. The framework proposed below adopts the second form.

## 3. Structural Contradictions in Current Course Practice

Four contradictions constrain the contribution of the course to emerging engineering education. They were identified through a review of the existing syllabus, laboratory manuals, and examination papers used in the programme, together with the reform literature on this course [2][3][9][12].

The first is a contradiction in knowledge organization. Content is arranged by device and

circuit type, so that diodes, bipolar transistors, field-effect transistors, operational amplifiers, and power supplies appear as successive self-contained units. Each unit is internally rigorous, but the connections among them, and especially the connection to a complete signal chain, are left to students to construct. Students therefore acquire a set of local models without a system-level map.

The second is a contradiction in experimental work. Laboratory sessions are dominated by verification tasks in which the circuit, the component values, and the expected waveform are all given. Such tasks build procedural familiarity, but they do not require students to make a design decision, to predict behaviour before measurement, or to diagnose a discrepancy between prediction and observation. Autonomous learning in analog electronics laboratories requires structured guidance that verification manuals do not provide [14].

The third is a contradiction in tool use. Circuit simulation software is available and is used in teaching, but it is typically deployed as a demonstration aid for showing waveforms in lectures. Its more consequential function, namely allowing students to test a design against specifications before committing hardware, is rarely exercised [7]. The result is that the design iteration cycle, which is where engineering judgement is formed, is largely absent from the course.

The fourth is a contradiction in assessment. A single written examination at the end of the semester determines most of the grade. Written examinations assess analysis of given circuits reliably, but they cannot assess whether a student can specify a circuit for an unstated requirement, document a design decision, or explain a measurement result. Course reforms based on outcome-based and CDIO-oriented models have repeatedly identified this mismatch between assessment form and competency target [8][10].

**Table 1. Structural Contradictions and Corresponding Integration Strategies**

| Contradiction          | Manifestation in current practice                                                      | Integration strategy                                                     |
|------------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Knowledge organization | Content arranged by device and circuit type, leaving signal-chain connections implicit | Reorganize content around complete signal chains from sensor to actuator |
| Experimental work      | Verification tasks with given circuits, values, and expected                           | Replace part of verification with design tasks under                     |

|                       | waveforms                                                                       | stated performance constraints                                      |
|-----------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------|
| Tool use              | Simulation used as a demonstration aid rather than a design instrument          | Make simulation an obligatory step before physical implementation   |
| Assessment            | Single written examination determining most of the grade                        | Combine process evidence, design artefacts, and oral defence        |
| Disciplinary boundary | Electronic content treated as self-contained with no link to mechanical systems | Embed measurement and control scenarios from mechanical engineering |

## 4. Framework for Interdisciplinary Integration

### 4.1 Four Integration Dimensions

The proposed framework organizes integration along four dimensions. The first is knowledge integration, which determines which concepts from which disciplines enter a module and in what order. The second is method integration, which concerns the analytical procedures students are expected to use, for example combining circuit small-signal analysis with error propagation from a measurement requirement. The third is tool integration, which aligns simulation, instrumentation, and documentation tools with the tasks students perform. The fourth is scenario integration, which places every module inside a mechanical engineering situation in which the electronic content is instrumental rather than decorative.

The four dimensions are not independent. A change in the scenario dimension forces a change in the knowledge dimension, because a scenario determines which circuit behaviours are relevant. A change in the method dimension requires a corresponding change in assessment, because methods are demonstrated through performance rather than through recall. Treating the four dimensions together prevents the common failure mode in which a course adopts an application example while leaving its content sequence, laboratory tasks, and examination unchanged.

### 4.2 Reconstruction of Course Content Modules

On the basis of the four dimensions, the course content is reorganized into five modules. The ordering moves from component behaviour toward system behaviour, and each module

carries a mechanical engineering scenario.

**Table 2. Interdisciplinary Integration Modules of the Course**

| Module                        | Disciplinary sources                    | Core content                                                  | Competency target                                   |
|-------------------------------|-----------------------------------------|---------------------------------------------------------------|-----------------------------------------------------|
| Signal and Device Foundations | Electronics, physics                    | Semiconductor devices, amplifier bias, small-signal models    | Modelling circuits and extracting parameters        |
| Signal Conditioning           | Electronics, measurement technology     | Instrumentation amplifiers, active filters, noise suppression | Selecting circuits against measurement requirements |
| Power and Drive Interfaces    | Electronics, mechanical transmission    | Power amplification, motor drive, thermal constraints         | Matching electrical output to mechanical load       |
| Sensor and Feedback Systems   | Sensing technology, control theory      | Transducer interfaces, closed-loop feedback, stability        | Building and debugging feedback loops               |
| System Integration Project    | Mechanical design, electronics, control | Complete measurement and control prototype                    | System-level design and team collaboration          |

The first module retains the theoretical core of the conventional course, but the selection of topics is driven by what the later modules require. Feedback, for instance, is introduced early because it recurs in signal conditioning, drive interfaces, and control. The second module addresses the situation that most frequently arises in mechanical measurement: a transducer produces a small, noisy, and possibly differential signal that must be brought into the range of a data acquisition input. The third module deals with the opposite direction of the signal chain, where electrical output must be matched to a mechanical load, and where thermal and efficiency constraints become design variables rather than footnotes. The fourth module closes the loop, connecting sensing to actuation through a control law. The fifth module is a capstone task in which students build a working prototype of a measurement and control system of their own choosing, subject to stated performance and cost constraints.

Interdisciplinary integration at the module level is therefore not achieved by adding lectures from other disciplines. It is achieved by deriving module content from an engineering function that genuinely requires more than one discipline.

## 5. Teaching Innovation and Implementation

### 5.1 Project-Driven Teaching Supported by Simulation

Each of the five modules is delivered through a project task with a specification, a set of constraints, and a deliverable. The task for the signal conditioning module, for example, states the output range and bandwidth of a piezoelectric vibration sensor, the input range of the available acquisition card, and the allowable supply voltage, and asks students to produce a conditioning circuit that meets a stated signal-to-noise requirement at a stated cost.

Simulation is made an obligatory and graded step in every task. Students submit a simulation model together with a short design note explaining the choice of topology and the reasoning behind key component values, before any hardware is assembled. This sequencing changes the function of the laboratory session: instead of confirming a given circuit, the session becomes the point at which a prediction is tested against reality, and discrepancies become the object of analysis. The pedagogical value of simulation in analog electronics teaching lies precisely in this iteration [7], and the availability of autonomous laboratory guides shows how such iteration can be structured for independent work [14].

Project-driven delivery also changes the role of the teacher. Because tasks are specified in terms of performance rather than procedure, students arrive at laboratory sessions with different designs, and the teacher's main activity becomes the diagnosis of design reasoning rather than the supervision of uniform activity. Reports from related course reforms indicate that this shift is feasible but requires task specifications to be written with care, because an underspecified task produces frustration rather than design behaviour [2][13].

### 5.2 Assessment Reform

Assessment is restructured to match the competencies that the modules target. The written examination is retained but reduced in weight, and its content is shifted from the analysis of given circuits toward the interpretation of measurement results and the justification of design choices. Process evidence, including simulation models, design notes, and laboratory records, is assessed continuously. The capstone prototype is assessed through a

demonstration and an oral defence in which students must explain why a particular topology was chosen and what they would change if a constraint were relaxed.

Three difficulties have to be managed. The first is reliability of judgement, because design artefacts are assessed against criteria rather than against a single correct answer; rubrics with explicit performance levels are used to address this and are shared with students when the task is issued. The second is workload, since continuous assessment of design work is more demanding than marking uniform reports; this is partly offset by assessing the design note rather than the full laboratory record at intermediate stages. The third is consistency with programme-level outcome requirements defined for accreditation [9][10], which is addressed by mapping each module task to the corresponding outcome at the design stage.

## 6. Discussion and Conclusion

The argument of this paper is that interdisciplinary integration in Analog Electronic Technology is best understood as a redesign of learning tasks rather than as an expansion of content. Adding cross-disciplinary material to an unchanged course leaves the activity structure intact, and the activity structure is what determines what students learn to do. Reorganizing content around engineering functions, requiring simulation before implementation, and assessing design reasoning instead of only circuit analysis changes what students practise, and therefore what they become able to do.

Two conditions shape the feasibility of this approach in a mechanical engineering programme. The first is the scenario base. Mechanical engineering provides a rich supply of measurement, drive, and control situations in which analog electronics is instrumental, and this supply is what makes the scenario dimension of the framework workable. Programmes without such a base would need to construct scenarios from their own application domain. The second condition is teacher capacity. Delivering project-driven modules requires teachers to be comfortable with design diagnosis under uncertainty, and the conceptions teachers hold about interdisciplinary teaching vary considerably [6]. Structured task specifications and shared rubrics reduce, but do not remove, this requirement.

Three limitations should be acknowledged. The framework is derived from the practice of a single programme, and its transferability to other institutional contexts remains to be examined. No longitudinal data on student performance across cohorts are presented, so the claim that design-oriented tasks improve engineering judgement rests on task design logic rather than on measured outcomes. The weighting of assessment components has not been calibrated against large-sample grade data and may need adjustment after several delivery cycles. Future work can proceed in three directions: comparative implementation across programmes with different scenario bases, tracking of successive cohorts to assess the effect of design-oriented tasks on later capstone performance, and refinement of assessment rubrics against accumulated grading records.

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