

工学研究科 創造工学センターにおける外国人向け ものづくり講座の報告

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概要

工学研究科 創造工学センターでは、平成14年度より工学研究科・工学部の学生・教員を対象に「ものづくり講座」（機械工作コース、電子回路コース）を開催している。ものづくりに興味があっても入口のわからない方、少し始めたが行き詰まった方、一度も経験が無いが一度やってみたい方、もう少し高度な事をしてみたい方など、様々な人が参加している。一方、これだけ多くの外国人が在籍しているのにも関わらず、外国人の参加者が少ないのはどうしてだろうと考え、今回、工学研究科国際交流室と共催で英語による外国人を対象としたものづくり講座（電子回路工作講座）を企画実施したので、その内容を中心に報告する。

1 創造工学センターものづくり講座と講座内容

創造工学センター「ものづくり講座」の開催趣旨は、

- 1) 工学系の学生に「ものづくり」の楽しさ、おもしろさ、難しさを知ってもらう。
- 2) 創造工学センターを公開し、同センターの役割・活動状況を紹介してセンターの利用促進を図る。
- 3) 「ものづくり」を通して、技術職員と学生との技術的、人的交流を図る。

である。平成14年から今日までに開催してきた学内向けものづくり講座への外国人留学生の参加が少ないことから、今回、英語によるものづくり講座を企画し、英語版のテキストや部品表などを準備した。内容は、今年度夏季休業中に行った学内向けものづくり講座と同じ、最近静かなブームとなっている？世界最古の電子楽器「テルミン Theremin」の製作を行った。完全版のテルミンはコストと回路の複雑さや工作時間の関係で出来ないため、簡易版の「テルミン」を作ることにした。この簡易版については、増田俊雄電子回路班専門技術職員が、最少部品でテルミン回路となるよう最適な回路を模索し、回路定数や部品を検討して試作に試作を重ね、安価でそれなりの機能を持った回路を設計した。テルミンは通常、右手で音階を、左手で音の強弱を掌って両手で演奏するが、今回の簡易版では曲中で音の強弱を変えることが出来ないため、音楽性はやや犠牲になっているが、妙なる音色による演奏を楽しむことは十分に出来る。尚、全体の音量調節用のボリュームは付けてあるのでこっそり一人で練習することも可能。演奏はバイオリンや三味線・尺八のように自分の音感を頼りに、手と耳と頭を使って自動制御で演奏しなければならないため、慣れるまで練習が必要であるが、慣れるとバイオリンとも笛ともいえない美しく妙なる音色と相まって結構楽しめる楽器である。

本電子回路コースの特徴として、単に電子回路工作の実技のみ一作って終わりではなく、大学で行うものづくり講座として、動作原理、回路理論や回路構成にも興味を持ってもらうために、簡単な特性実験を自分の手で行うことによって、「テルミン」という楽器の原理や音とは何かを体験してもらった。併せて実験に必要な電源や測定機器の説明と実際の扱いを学ぶことにより、一歩進んだ電子回路工作を体験してもらえたと思う。その他、座学において感電や電気の安全に関する講義も行った。また、1日で実技と座学の両方を行うことは無理ではとの声もあったが、使用部品を名前や値を記入した一枚の厚紙に整理して、事前に貼り付けておくなどの工夫により、製作時間の短縮を図った。また実際の基板上での部品配置図と実体配線図の併記など、スタッフが知恵を出し合い工夫した。

テルミン (Theremin) 概説

テルミンはロシアのレオン・テルミン博士(1896 ~ 1993)が 1920 年に発明した世界最古の電子楽器 (Thereminvox) である。発音原理は、2つの高周波発振器を用意し、片方の発振器は周波数固定の発振器とし、他方は、周波数を決めるコンデンサに並列にアンテナ (実際は奏者とテルミン間の静電容量を構成されるコンデンサの一方の電極) を付け、外部の静電容量の変化、即ち演奏者の手とアンテナ間の静電容量の変化で周波数が変化する可変周波数発振器とする。この二つの発振器が出力するそれぞれの周波数の「うなり」の信号を取り出して増幅し、スピーカを鳴らす。二つの高周波発振器の周波数の差の信号を利用することにより、手とアンテナ間のごく微量な静電容量の変化を、数オクターブの音程の変化に換えることができる。

テルミンはロシア国費による接近センサ開発研究の副産物として生まれ、その音色はレーニンを感激させ、600 台をロシア中に配らせた。またロシアの最新技術の宣伝として各国を渡り歩いて実演を行った。その後アメリカの電機メーカーの RCA に製造権を渡し、戦後はアナログシンセサイザで有名な Moog 社 (Robert Moog 電子工学博士が創設) などにより現在でも製造されている。最近では、ロシアの民芸品マトリョーシカ人形に組み込んだものも日本国内で売られている。

2 Outline of Construction Course, Schedule & Staff

Outline of Construction Course

Theme	Electronic Circuit Construction Course Make a simplified “Theremin”, Theremin is Music Instrument
Date	December 6, 2007 9 am ~ 5 pm
Place	Creation Plaza, The 10th floor Integrated Building (IB) North, Nagoya Univ.
Applicant	Non-Japanese affiliated with Nagoya Univ. (First 10 applicants)
Fee	1,000 Yen

Schedule

- 9:00~11:30
 - Greeting Prof. Sato (head of Creation Plaza)
 - Performance of Theremin.
 - Explanation of Theremin’s History and Demo. Visual
 - Electricity system safety course
 - Explanation of Theremin’s Circuit and some Electronic Parts.
 - Basic Experiment (CR Circuit; charge, discharge)
 - Practice of soldering.
- 11:30~12:30
 - Lunch Time
- 12:30~16:00
 - Theremin’s Circuit Construction.
- 16:00~17:00
 - Clean Up
 - Questionnaire
 - Play the Theremin & Meeting

Staff

Creation Plaza	Prof., Kazuo Sato(Head) Assistant Prof., Kazue Kaneko Clerical staff, Sanae Yamada,
Technical Section	Technician, Toshiyuki Sasaki, Toshio Masuda, Tsutomu Fukumori
International Academic Exchange Office	Associate Prof., Reiko Furuya

3 Text & Poster

Creation Plaza, Graduate School of Eng, Nagoya Univ.

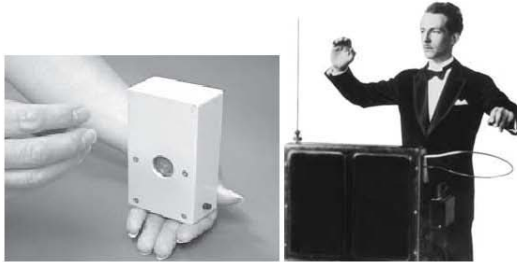
ものづくり (MONOZUKURI) Open Course

- Electric Circuit Construction Course -

Thu. 06-Dec-2007 9:00 ~ 17:00

Making Simplified "Theremin"

- a strange musical instrument played without being touched -



The theremin was invented in 1919 by a Russian physicist and cellist named Lev Sergeyevich Termen. This name was later changed to Leon Theremin.
It has two r.f. (100k or several 100kHz) oscillators, one having fixed, the other a variable, frequency, with their output signals combined in a mixer/amplifier stage. At "tune-up", the oscillators are preset to "ZERO BEAT" at the same frequency. The frequency of the variable oscillator is controlled by an external tuning capacitance -- the "ANTENNA" -- which is a "whip" or metallic plate.
As the player's hand is moved near this antenna, the variable oscillator shifts frequency and a beat note is set up between the two oscillators. (A few percent r.f. frequency shift makes several octave audible tone range.)

The theremin was a by-product of studying proximity sensor, and Bolshevik leader Lenin liked it enough to take lessons and ordered 600 to be made and sent around the world to show how awesome Russian electronic music was. Afterward, Lev gave Manufacturing licence to RCA (USA). After WWII Moog (famous synthesizer maker, founded by Robert Moog, D. Electronics). Today, this marvelous instrument is once again in the musical spotlight.

Our "Simplified Theremin" is a pitch-only instrument (lacking dynamics / volume control) that demonstrates the basic theremin concept. Although it doesn't have the qualities of more expensive and complex theremins, it is easy to make and sufficiently sensitive and stable for playing a melody.

Circuit Description

Two identical popular integrated circuits are used for this "Simplified Theremin's" basic functions. These ICs are CMOS (Complementary-Symmetry/Metal Oxide Semiconductor) devices, typically used in digital circuits to perform a logic function called "inversion." Each IC contains six identical sections; thus called "hex inverter."

Left upper part of the schematic: Two inverters, resistors, a capacitor and "ANTENNA" as an extra capacitor form the theremin's variable oscillator that operates in a frequency range around 300kHz. The antenna forms one-half of a variable capacitor of this oscillator's frequency-determining network, and the player's hand forms the other half. As the distance between the hand and the antenna varies, so does the capacitance and therefore the oscillator's frequency.

Left down part: Local oscillator that is adjusted to make ZERO-BEAT (PITCH-NULL) with two potentiometers used to calibrate the local oscillator's frequency. With potentiometers properly adjusted, coarse and fine respectively.

Construction Tips

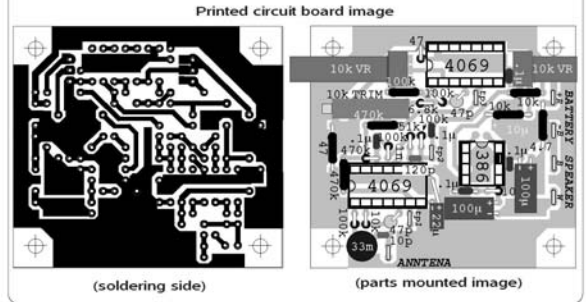
- Parts Installation order (Basically, Low-profile parts first)
1. IC socket
 2. trimmer (multi-turns) potentiometer
 3. fixed resistors
 4. capacitor (except poly-styrene)
 5. inductor
 6. poly-styrene capacitor (47pF x 2)
 7. potentiometers (long & short, black shaft)

tively, the local oscillator's frequency will equal the variable oscillator's frequency with the hand furthest away from the antenna. Then no audible tone will be produced.

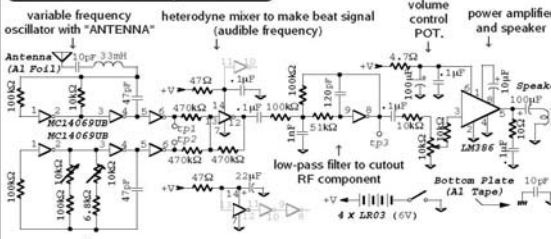
Center part: Three resistors and an inverter comprise a summing amplifier which is the theremin's mixer. The mixer "heterodynes" the two oscillator signals, producing sum and difference terms of their fundamental frequencies and harmonics. Next section is a low-pass filter which reduces the inaudible heterodyne sum products, leaving the audible "beat frequency" product.

Last (most right) part: The beat frequency signal is applied to a power amplifier IC via 10nF capacitor comprising low-cut filter and potentiometer (volume-control), then fed into small speaker.

For "antenna-hand capacitor" to work properly, "Bottom Plate" is located inside bottom of the case. To keep sufficient capacitive coupling between the player's body and the other part of circuit, player must grasp bottom part of "Simplified Theremin" or place it on the desk made of conductive material.



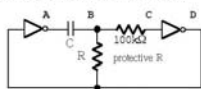
Schematic Diagram



local oscillator with BEAT-ZERO tuning potentiometers.

Square wave OSC using inverter

Let's rewrite oscillator part of this circuit, to make simple and can see like a differentiation circuit.

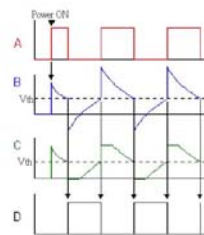


Below, notations "A-D" mean letters in fig 1 & fig 2, and, "0" or "1" means logical value of inverter's output. (Actually, "0 volt" or "supply voltage", 6volts here. Right four columns chart shows the voltage at A thru D of this rewired circuit.)

Just after power turned on, these inverters' output is indefinite. Suppose A starts "1", B equal A at just after A turned "1", but, as capacitor's charge increasing, lower voltage B. Its rate is proportional to product value of RC.

"Vth" in the chart B & C means "threshold voltage" that "inverter" decides its input voltage as logical value "0" or "1". While B is higher than Vth, D stays "0". After capacitor has been charged enough, B dropped than Vth, D changes to "1". Therefore A changes "1" to "0".

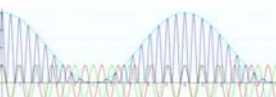
At this moment, capacitor's charge makes voltage B as -(Vth) and charging current of capacitor is reversed, then voltage B starts to rising up. And if B reaches to Vth, D switches to "0" therefore A turns to "1". These sequence continues and it works an oscillator circuit.



"Heterodyne", Make beat signal

Below illustration shows how to generate beat frequencies by mixing two signals in a nonlinear device (such as a transistor, or diode mixer).

Heterodyne principle is applied to wide area, such as, Radio / TV, original theremin thru physical / astronomical studies (optical measurement e.t.c.).

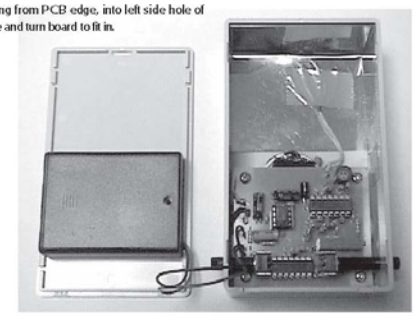


Our "Simplified Theremin" using square wave oscillators, therefore, only logical OR (addition) and low-pass filter can produce their beat frequency signal. "Simplified Theremin" consist of "Simplified heterodyning".

Assembly Instruction

- 1) Assemble PCB (Printed Circuit Board)
 - I. Verify no insufficiency of parts.
 - II. Form the leads of each parts, insert and solder, referring to board image and circuit diagram.
 - III. Attach standoffs to each corner of the PCB with washer attached pan head screws. (don't tighten up still)
- 2) Fittings inside plastic case
 - Speaker
 - I. Remove released paper on both sides adhesive tape pasted around the center hole.
 - II. Push the speaker to paste at the center hole, verifying its position by looking from outside front.
 - III. Strip green lead (three leads soldered to speaker) about 1-inch or less, then disperse it to the fan shape, and fix it on "Bottom Plate" using adhesive tape.
 - "Antenna" (aluminum foil)
 - I. Remove released paper on both sides adhesive tape pasted upper 4 sides.
 - II. Strip antenna lead and disperse it to the fan shape, then place it on a adhesive tape near the speaker.
 - III. Form aluminum foil into box-shape and paste it on adhesive tapes.
 - Installing PCB to the plastic case
 - I. Insert black shaft (BEAT ZERO fine potentiometer), protruding from PCB edge, into left side hole of the case and turn board to fit in.

- II. Draw out black and white leads, soldered to the speaker, from left edge of the PCB.
- III. Fix PCB to the case loosely, with four countersunk flat head screws into standoffs on PCB. (tighten up after next step).
- IV. Attach a knob to Volume control potentiometer through right side hole, with a piece of resin tube, half covers the knob, another half covers the potentiometer's shaft.
- V. Tighten-up all (eight) screws, checking two potentiometers' shafts turnable.
- Battery box (Attach to rear cover)
 - I. Remove released paper on the battery box.
 - II. Place the slide switch fit to the hole of rear cover and push to adhere.
- 3) Wiring
 - Speaker: Solder two leads (black & white) from speaker to the wire terminals (B & W) marked on schematic diagram.
 - Antenna: Solder Antenna lead to the terminal.
 - Battery box: Two leads (red & black) to the terminal (red to "+", black to "-").
Caution: Reverse connection will cause permanent damage for ICs.



a trial model of "Simplified Theremin"

Adjustment

Set two potentiometers knobs middle position (these have click stop at middle position).

Using a small flat-blade screwdriver, set BEAT-ZERO trimer-potentiometer (though left side hole) to its fully ccw, about 15 counterclockwise rotations.

Turn on power switch and grasp bottom part.

Turn BEAT-ZERO trimer-potentiometer clockwise.

After rotating few turns, a very high pitch sound will become evident. And it will become successively lower with continued rotation, and it stops abruptly. Then, rotate reverse about 1/4 turn.

Place your another hand 1 feet or more, does the sound stop? Repeatedly adjust the BEAT-ZERO potentiometer (left side knob) to the point where the sound stops when your hand is furthest away. (This point may occur either new fully cw or ccw. If so, re-adjust trimer-pot.)

- MEMO -



図1 創造工学センター長と受講生

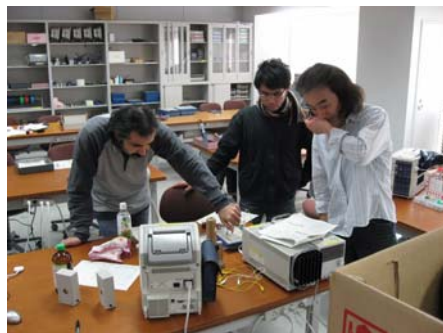


図2 CR 充電・放電実験



図3 製作中の受講者

Creation Plaza, Technical Section, International Academic Exchange Office, Graduate School of Eng., Nagoya Univ.

Call for Participation

ものづくり(MONOZUKURI)

Electronic Circuit Construction Course

Simplified "Theremin"
(The first electronic musical instrument)
Play music by your move without touching the instrument.

Date: December 6, 2007 (Thu.) 9 am ~ 5 pm
Place: Creation Plaza, The 10th floor
 Integrated Building (IB) North, Nagoya Univ.
Applicant: non-Japanese affiliated with Nagoya Univ.
 (first 10 applicants)
Fee: 1,000 yen

Application
-Deadline: November 29, 2007 (Thu.)
-Application Method:
 Please send your name, grade, phone num., e-mail addr.,
 to the following mail address
 mono@cplaza.engg.nagoya-u.ac.jp (Japanese or English)

-Demonstration Video & More Information Available:
 URL: <http://www.cplaza.engg.nagoya-u.ac.jp/>

-Contact: Technical Section, Toshiyuki Sasaki (佐々木敏幸)
 ext. 6367, e-mail: sasaki@nuae.nagoya-u.ac.jp



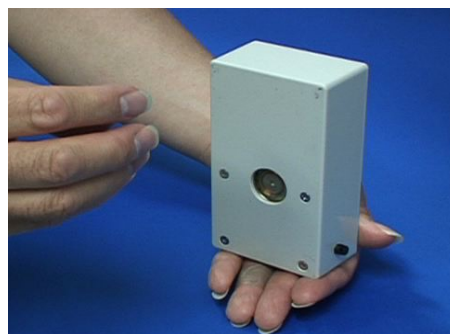


図4 テルミン演奏中

図5 ポスター

4 Questionnaire

Electronic Circuit Construction Course (Theremin)

- 1) Which is your affiliation (School, department) and grade? [Number of ticks]
- (1) Graduate of Undergraduate School, (2) Department,:
- > *School of Eng., Dept. of Aero space Eng.* [1] *School of Science, Dept. of Physics* [1]
- (3) Grade
- > *B4* [1] > *Post-doctoral fellow* [1]
- 2) Why did you join this program ? [Number of ticks]
- (1) Because I had a great interest in content of the program. [2]
- (2) Because my Professor recommended us this program. [0]
- (3) Because my friends recommended us this program. [0]
- (4) Because I got interested in by the Poster. [0]
- (5) Because I got interested in by the Web site. [0]
- (6) Others > *Because Mr. Saitoh recommended me this program.* [1]
- 3) How did you impressed about this program? [Number of ticks]
- (1) Creation Plaza was user-friendly. [2]
- (2) Creation Plaza was not easy to use. [0]
- (3) Equipments were suitable and enough. [2]
- (4) Equipments were not enough. [0]
- (5) It was very good experience. [2]
- (6) I would like to recommend this program to my friends. [2]
- (7) Planned time table was not enough to complete the work. [0]
- (8) The time required was too long and mu professional work was inhibited. [0]
- (9) Other. [1]
- > *This program is very good for foreigner to experience Japanese work, work with Japanese people. They are very kind.*
- 4) Could you understand the content of this program? [Number of ticks]
- (1) Yes, I understood well. [2] (2) Partly yes. [0] (3) No, I didn't understand enough. [0]
- 5) How much can you accept the cost for such programs in future ?
- > Within *1,500Yen* [1] > Within *2,000Yen* [1]
- 6) If another program will held in future, which do you recommend the season and the time period?
- > *For me it is a good timing. Concerning the undergraduate students beginning of the semester could be better.*
- > *I'll prefer this season but not start from morning, may be from afternoon is good.*
- 7) In this program we did some basic experiments. How did you think or feel about such experiments ?
- > *It was wonderful. I have enjoyed well. The experiment is well organized and perfectly described and explained.*
- > *A good effort*
- 8) Please write down your requests about themes or contents for future programs.
- > *1) Robot, 2) Basic digital camera, why not ?*
- > *If you don't mind, maybe we could try to build a robot, the simple one,*

9) Please write down anything about this Construction Course.

> The number of people participating this course, unfortunately, just 2. In my opinion the reason is as follows. In the poster it was written that first 10 applicant will be accepted. So the people are thinking that the application already finished and people despaired. I have several friends in lunch time when I said just 2 people they become upset because they didn't apply to course.

> I heard this course is opened to foreigner for the first time. It is a good effort to get close with foreigner to create an international environment. And it is a good chance also for foreigner to work together with Japanese people.

5 成果と今後の課題

5.1 成果

異なる文化をもつ外国人留学生・研究者とのやり取りから多くの情報を得た。

アンケートの結果をみると、好評のようで、受講者が集まらない原因は宣伝方法等に問題ありか？
アンケートより

- 1) 日本人とともに電子回路を製作する機会が得られて有意義
- 2) ただ作るだけでなく、回路の動作原理に関する基礎実験を行ったことは有意義
- 3) 講座の内容に満足している。

5.2 英語力

テキストを英語で書き、講義および実技指導を英語で行う、「ものづくり講座」を企画・実施した。当初は英語力、英会話力が心配であったが、国際交流室の先生からも英語を母国語とする留学生は少ないから、平易な英語で十分とのご指導を受けたこともあり、当日は英語を基本として日本語も多少交えて、じっくり内容の説明をすることができた。「案ずるより産むが易し」で、構える必要は無かった。逆に受講生から教えてもらう場面もあり、お互いに有意義であった。

5.3 開催時期とアナウンスと参加費

留学生入学試験後の、留学生にとって比較的余裕のある時期を選定したが、現役の留学生にとっては授業期間中であった。そのこともあり応募者3名で、実際の参加者2名という結果になった。

やはり、夏季・春季休業中に開催するのが妥当か？アナウンスも今回は、レジデンスや留学生室なども含めて、ポスター掲示のみであったが、メールでの案内もできると良いと思う。また、参加費（部品代実費）を1000円としたが、今回の受講者では妥当のようであったが、不参加の留学生からはもう少し安くという声があった。それが高いか/安いかわかりませんが一考を要するところである。ブレッドボードなどの試作基板を使って電子回路組立の体験をするコースやマイコンのプログラム演習であれば、参加費無料でやれるので、将来はその辺りも視野に入れて企画を考えていきたい。また、募集人数が先着順で10名としたため、希望しても既に満杯で受け付けてもらえないと思ってあきらめたとの声も聞いているので、募集方法も検討する必要があるようだ。

最後に、英語によるテキストやポスターならびにアンケート作成において適切にご指導・ご助言を頂いた、創造工学センター長の佐藤一雄教授、創造工学センターの兼子一重助教、国際交流室の古谷礼子准教授に感謝申し上げます。