# 行政院國家科學委員會專題研究計畫　期中進度報告

# 智慧型車輛之控制、感測與資訊處理技術研發－總計畫(2/3)

計畫類別：整合型計畫
計畫編號：NSC91-2213-E-009-028-
執行期間：91年08月01日至92年07月31日
執行單位：國立交通大學電機與控制工程學系

計畫主持人：李祖添
共同主持人：陳永平，鍾世忠，李永勳，林進燈，宋開泰，徐保羅，王晉元

報告類型：精簡報告

處理方式：本計畫可公開查詢

中　華　民　國 92年5月26日

## 摘　要

隨著經濟的快速發展，機動車輛已成為國民生活上之主要工具，本計畫之目的在研發機動車輛所應具備的被動式防撞系統，並進行防撞系統的研製工作。整個總計畫將結合語音溝通人機介面、聲響偵測與處理、毫微米防撞雷達、影像辨識及追蹤、智慧型導航等技術，以建構一個智慧型車輛的被動式防撞系統。以下對各主題簡單說明 (1)音訊控制技術開發部份包括「不特定語者語音辨識系統核心辨識器」與「環場音效系統之研究」兩項主題進行； (2)智慧型導航開發部份結合 GPS 與 INS 兩套導航系統開發一新型的 GIS 導航系統； (3) 防撞雷達製作開發部份完成了窄波束天線及前端電路關鍵元件的開發與整合;（4)在電池能量控制相關研究部分引入柔性切換的觀念來控制鋰電池串等化的過程以減低開關的切換損失。

**關鍵詞：智慧型車輛，安全車，先進車，智慧型控制**

## Abstract

This is the group project of "Research on Control, Sensing and Information Technology of an Intelligent Vehicle". In this group project, we integrate the linguistic man/machine interface, the collision avoidance radar, the image recognition and tracking system, and the intelligent guidance system of an intelligent vehicle. All subprojects are described as follows: (1)we adopt the principle component analysis technique to solve the problem of an invariant feature over different speakers as well as the acoustical environment effects and the phase or temporal difference. (2) we integrate the GPS/INS with the Geographic Information System to develop the car navigation system. (3)a millimeter-wave transceiver and folded microstrip reflectarray antenna with beam steering are developed. (4)we proposed a fuzzy logic controlled battery equalization controller to control the equalizing process of lithium-ion battery strings, and introduced soft-switching to reduce switching losses.

**Keywords: Intelligent Vehicles, Safety Cars, Advanced Cars, Intelligent Control**

# 行政院國家科學委員會專題研究計畫期中報告

# 智慧型車輛之控制、感測與資訊處理技術研發 - 總計畫(2/3)

計畫編號：NSC91-2213-E-009-028
執行期限：91年8月1日至92年7月31日

主持人：李祖添　　國立交通大學電機與控制工程系

## Abstract

This is the group project of “Research on Control, Sensing and Information Technology of an Intelligent Vehicle”. In this project, we integrate the linguistic man/machine interface, the collision avoidance radar, the image recognition and tracking system, and the intelligent guidance system of an intelligent vehicle. All subprojects are described as follows: (1) we adopt the principle component analysis technique to solve the problem of an invariant feature over different speakers as well as the acoustical environment effects and the phase or temporal difference. (2) we integrate the GPS/INS with the Geographic Information System to develop the car navigation system. (3) a millimeter-wave transceiver and folded microstrip reflectarray antenna with beam steering are developed. (4)we proposed a fuzzy logic controlled battery equalization controller to control the equalizing process of lithium-ion battery strings, and introduced soft-switching to reduce switching losses

## Introduction

In this group project, we focus on the study of some key technologies of an intelligent vehicle which integrate the linguistic man/machine interface, the collision avoidance radar, the image recognition and tracking system, and the intelligent guidance system of an intelligent vehicle. All subprojects are described as follows:

Most automatic speech recognition technologies were based on the so-called Hidden Markov Models (HMM) and used the connected word pattern matching method to achieve continuous speech recognition. A new speech recognition technique is proposed for continuous speech-independent recognition of spoken Mandarin digits. One popular tool for solving such a problem is the HMM-based one-state algorithm. However, two problems existing in this conventional method prevent it from practical use on our target problem. One is the lack of a proper selection mechanism for robust acoustic models for speaker-independent recognition. The other is the information of intersyllable co-articulatory effect in the acoustic model is contained or not. We adopt the principle component analysis technique to solve these two problems.

The Global Positioning System (GPS) used in navigation has long-term stability and acceptable accuracy. Based on such features, the divergent effect of an Inertial Navigation System (INS) might be calibrated with the aid of GPS [1, 2]. In addition, the autonomous characteristic of INS can supply the information of vehicle maneuvering or in the duration for the lost track conditions due to receiver or environment noises. Due to the reasons, we integrate the GPS/INS with the Geographic Information System (GIS) to develop the car navigation system. In this project, the car is used in a flat navigation system. Finally, the GIS system is performed in the notebook computer.

Among the various components of the advanced vehicle control and safety system, the collision avoidance radar (CAR) plays the key function, which utilizes the advanced communication and control technology to sense the environment so as to warn the driver of the potential hazard in his/her path [3]. To achieve these requirements, the millimeter-wave (MMW) technology is the most promising technology to implement the longitudinal CAR due to both high reliability and high position resolution. A millimeter-wave (38.1 to 38.4 GHz) transceiver and folded microstrip reflectarray antenna with beam steering are developed for autonomous cruise control radar applications.

We proposed a fuzzy logic controlled battery equalization controller (FLGBEC) to control the equalizing process of lithium-ion battery strings, and introduced soft-switching to reduce switching losses. The suggested battery equalization scheme [4, 5] modified from ĆUK converter to design the bidirectional nondissipative current diverter for a battery balancing system. It can reach full duty energy transferring in the switching period, so the efficiency is improved. Furthermore, we introduced ZVS soft-switching technology, using resistor and diode to produce dead time, so the switching losses can be large reduced. A fuzzy logic controller is constructed with a set of membership functions to prescribe the cells equalizing behavior within a safe equalizing region and to speed up cell voltage balancing. The simulation and experimental result are illustrated to validate the advantage of the proposed system for abbreviating the equalization time and reducing the switching loss.

## Design Method and Results

### A. Automatic Speech Recognition

A $N$ state, left-to-right continuous observation density HMM, denoted as $\Omega$, is considered. The initial probability for state $i$ is denoted by $\delta_i = P(\theta_0 = i)$, $1 \le i \le N$, and the transition probability from state $i$ to state $j$ by $a_{i,j} = P(\theta_t=j \mid \theta_{t-1}=i)$ for $1 \le i, j \le N$. Denote $\delta = \{\delta_i\}_{i=1}^{N}$, and $A = \{a_{i,j}\}_{i,j=1}^{N}$. For the calculation of the observation density in state $i$, denoted as $b_i(o_t)$, for observation $o_t$, the generalized common vector of $o_t$ given the matrix transformation of generalized common vector is first extracted. Then $b_i(o_t) = P(o_t \mid \theta_t=i)$, $1 \le i \le N$ assumed to be a mixture of Gaussians is then given as

$$b_i(o_t) = \sum_{k=1}^{M} c_{i,k}\, b_{i,k}(o_t), \quad 1 \le i$$

where $M$ is the mixture number, $c_{i,k}$ is the probability of mixture $k$ in state $i$, and $b_{i,k}(o)$ is the gaussian distribution given by

$$b_{i,k}(o_t) = \frac{1}{\sqrt{(2\pi)^{D_s}\left|\Lambda_{i,k}\right|}} e^{-\frac{1}{2}(y_{t,i,k}-\eta_{i,k})^T \Lambda_{i,k}^{-1} (y_{t,i,k}-\eta_{i,k})}$$

where $D_s=D-D_g$ is the dimension of the extracted GCV $y_{t,i,k}$ from $o_t$, $y_{t,i,k}$ is the GCV of $o_t$ for mixture $k$ in state $i$, and $\Lambda_{i,k}$ and $\eta_{i,k}$ are the covariance matrix and mean vector corresponding to mixture $k$ in state $i$, respectively. $\Lambda_{i,k}$ is assumed to be diagonal, i.e.,

$$\Lambda_{i,k} = \begin{bmatrix} \sigma_{i,k,1} & 0 & \cdots & \\ 0 & \sigma_{i,k,2} & \cdots & \\ \vdots & \vdots & \ddots & \\ 0 & 0 & \cdots & \sigma_{i,k,D_s} \end{bmatrix}$$

so that $\left|\Lambda_{i,k}^{-1}\right| = \prod_{l=1}^{D_s} \sigma_{i,k,l}^{-1}$. The GCV $y_{t,i,k}$ from $o_t$ for mixture $k$ in state $i$ is defined as

$$y_{t,i,k} = V_{i,k}\, o_t$$

where

$$V_{i,k} = \left[ v_{i,k,1}, v_{i,k,2}, \ldots, v_{i,k,D_s} \right]^T$$

is matrix transformation of generalized common vector for mixture $k$ in state $i$. For convenience in the following derivation, we also define

$$\eta_{i,k} = V_{i,k}$$

then we can write

$$z_{t,i} = y_{t,i} - \eta_{k,} \left( i = {}_{k}V_{,} \right) \quad o_{,} -$$

Denote $B = \{ b_i \}_{i=1}^{N}$ and $\Omega = \{\delta, A, B\}$.

For an observation sequence $O = (o_1, o_2, \dots , o_T)$ unobserved state sequence $\Theta = (\theta_0, \theta_1, \theta_2, \dots , \theta_T)$, and unobserved mixture component sequence $K = (k_1, k_2, \dots , k_T)$, the joint probability density of $P(O, \Theta, K \mid \Omega)$ is defined as

$$P( O, \Theta , K \mid \Omega) = \delta_{\theta_0} \prod_{t=1}^{T} | {}_{t-,\theta} {}_{1} {}_{k\theta_t} a_{t\theta} {}_{,t} \theta$$

where $T$ is the number of observation in $O$. It follows that the likelihood of $O$ given $\Omega$ has the form

$$P( O \mid \Omega) = \sum_{\Theta} \sum_{K} ( P \quad , O \quad K$$

where the summations are over possible state sequences and mixture component sequences.

The earliest multichannel reproduction system format was brought up for theatre by Dolby Liboratories Inc in 1950s. The main difference between the conventional stereo (two or three dimension) and multichannel sound system is the setup of surround sound channel. The main purpose of surround channel is to produce the effect liveness, sense of envelopment, and wide spatiality. We generate different quality of audio sound sources by a room effect emulator, and then turn the conventional stereo into 5.1 channel sound system by a modified Dolby Surround decoder.

The block diagram in Fig 1 shows how the decoder works. The Lt input signal passes unmodified and becomes the left output. The Rt input sign likewise becomes the right output. Lt and Rt also carry the center signal, so it will be heard as a "phantom" image between the left and right speakers, and sounds mixed anywhere across the stereo soundstage will be presented in their proper perspective.

We modified the mono Dolby surround decoder into a simplified surround sound decoder for generating stereo surround, which is shown in Fig 2. As the definition of surround sound described above, this channel is just to present the reverberant effect and feeling of ambiance, but not to present location of sound sources. The terms L-R and R-L referred to Dolby Surround Decoder are to reduce the contents of front channel but not entirely (called leakage). In addition, surround sound sources, L-R and R-L, are out of phase with each other, so the surround channels will diffuse the image in surround sound field. We also use the blocks, *Audio Time Delay* and *7 kHz Low-Pass Filter*, which are described above to make surround sounds more difficult to localize. Moreover, the entire structure of the Multi-band rom effect emulator is shown in Fig 3 below.

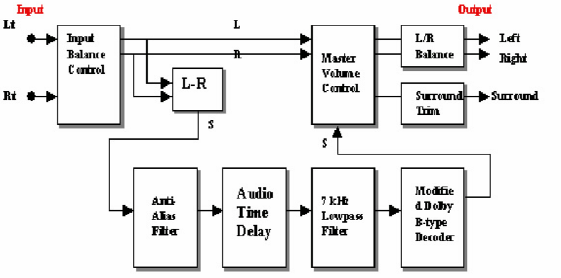


**Fig 1 Surround decoder block diagram**

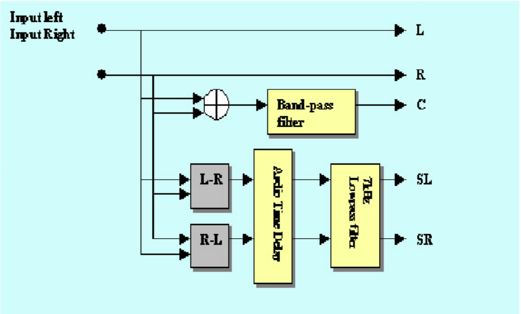


**Fig 2 Simplified Surround decoder.**

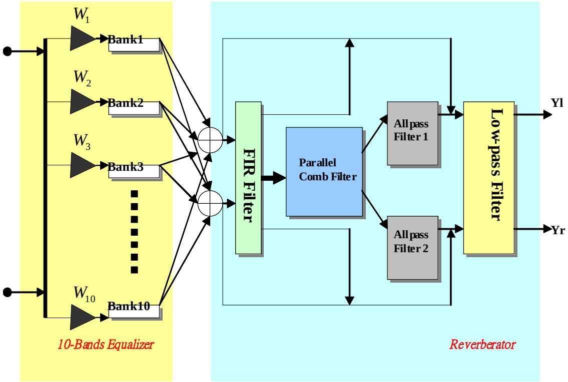


**Fig 3 The proposed multi-bands room effect simulator.**

## B. GPS/INS/GIS for Vehicle Navigation System

Inertial Navigation System (INS) is an autonomous system. The angular velocity and acceleration information can be measured by using gyros and accelerometers. However, the inertial measurement units (IMU) still have drift problems in navigation system. These errors might increase with time by the integral procedure. Therefore, INS always combined with the GPS to calibrate the errors.

Besides, we can develop the car navigation system with the help of Geographic Information System (GIS). The integrated GPS/INS/GIS system block diagram is shown in Fig 4.

GPS depends on the concepts of “ positions ” and “ absolute coordinates. ” On the other hand, GIS depends on the concepts of “ locations ” and “ relative coordinates. ” With GPS, users can get to know the positions (i.e., the coordinates that specify where the users are); combined with map and GIS data users can know the locations (i.e., where the users are with respect to objects around the users). Besides, the digital map data is more accurate than the positioning data provided by GPS.Therefore, we can integrate GPS with GIS to get the more accurate location in the vehicle navigation system.

In the developed vehicle navigation system, the GPS receiver module copes with the received GPS data. The map orientation module and the map data displaying system facilitate the map reading of the drivers. The map matching module use the fact that “A vehicle moves always on a road network” to integrate the GPS absolute position with a digital road map to get the more accurate location. The Graphic User Interface (GUI) for vehicle navigation system will display driver’s location on the map and provide drivers with the basic map functions as Fig 5.

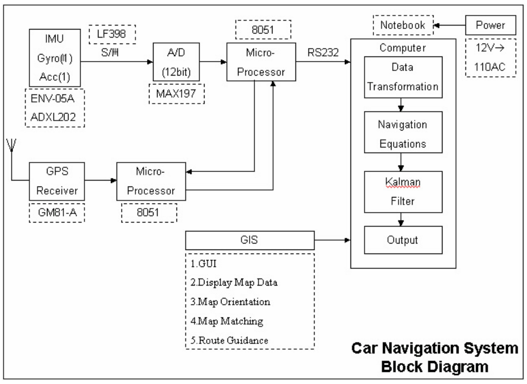
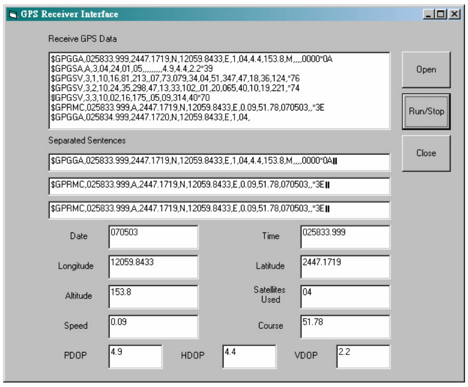


**Fig 4 Car navigation system block diagram**



Receive GPS Data

```
$GPGGA,025833.999,2447.1719,N,12059.8433,E,1,04,4.4,153.8,M,,,,0000*0A
$GPGSA,A,3,04,24,01,05,,,,,,,,,4.9,4.4,2.2*39
$GPGSV,3,1,10,16,81,213,,07,73,079,34,04,51,347,47,18,36,124,*76
$GPGSV,3,2,10,24,35,298,47,13,33,102,,01,20,065,40,10,19,221,*74
$GPGSV,3,3,10,02,16,175,,05,09,314,40*70
$GPRMC,025833.999,A,2447.1719,N,12059.8433,E,0.09,51.78,070503,,*3E
$GPGGA,025834.999,2447.1720,N,12059.8433,E,1,04,
```

Separated Sentences

```
$GPGGA,025833.999,2447.1719,N,12059.8433,E,1,04,4.4,153.8,M,,,,0000*0A
$GPRMC,025833.999,A,2447.1719,N,12059.8433,E,0.09,51.78,070503,,*3E
$GPRMC,025833.999,A,2447.1719,N,12059.8433,E,0.09,51.78,070503,,*3E
```

Date 070503
Time 025833.999
Longitude 12059.8433
Latitude 2447.1719
Altitude 153.8
Satellites Used 04
Speed 0.09
Course 51.78
PDOP 4.9
HDOP 4.4
VDOP 2.2

**Fig 5 GPS Receiver Interface**

The vehicle navigation system hardware consists of a GPS receiver, a battery, a voltage transforming circuit, RS232 interface, and a notebook computer in Fig 6. The notebook computer is regarded as a main navigation processor. All modules and algorithms are performed in the notebook computer. The navigation results are also displayed on the notebook monitor.

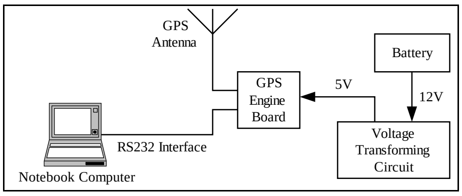


**Fig 6 Hardware Structure**

The Visual Basic software and the GIS component, MapObjects, are utilized to develop the vehicle navigation system. The vehicle navigation system consists of the GPS receiver module, the combination of GPS with GIS, the digital map data, the display map data, the basic map functions, the map matching module, and the map orientation module. The complete vehicle navigation system interface is shown in Fig 7.

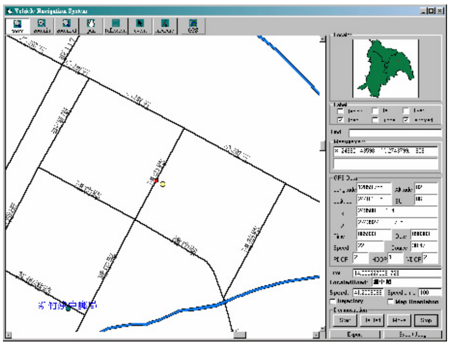


**Fig 7 Vehicle Navigation System Interface**

### C. Novel Vehicle Longitudinal Collision- Avoidance Radar

In order to design a radar system that is small and cost effective, the design process is broken into modules. The modules are designed individually using commercially available microwave design software (MWOffice 4.2) and then integrated together to form a front-end transceiver. Before assembly, each component is examined by the measurement.

The 38 GHz FMCW radar front-end sub-system presented here is a forward-looking, radar based, detection system for CW application. Fig 8 shows the system block diagram. It generates a FMCW waveform using a voltage-controlled oscillator by using a linearizer (frequency locked loop) to stabilize the RF frequency and improve system phase noise. The frequency of the coupled signal is compared to a low frequency linear sweep reference to generate an error signal, which corrects the VCO sweep rate. The 38GHz transceiver for FMCW radar was integrated with micro-strip line VCO and discriminator to form a frequency locked loop, which provide clean souse and high linear sweeping frequency. Figs 9 and 10 show the photos of the finished transceiver circuits. The measured output power and conversion loss of the integrated transceiver are presented in Figs 11 and 12, respectively.

The main reflector includes hundreds of microstrip antennas used to produce twisted re-radiated fields and provide phase compensation for focusing. The sub-reflector parallel with the main-reflector is made of a substrate printed with high-density metal grid, which is transparent to one polarization but would reflect the other polarization. The feed antenna is a microstrip patch antenna located on the main reflector. The position of this feed antenna is movable so as steering the radiation beam of the antenna. Measured results showed good agreement with the calculated ones

Fig 13 depicts the measured antenna patterns for different feed positions d. It is seen that the antenna has the antenna gain of 25dBi, side-lobe-level of -15dB SLL, and -3dB beamwidth of 4.6°. As the feed position d changes from -4 mm to 4 mm, the beam scans over a range of 7.2°.

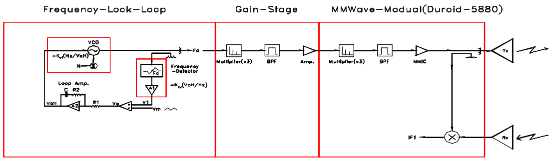


**Fig 8 Block diagram of the front end for FMCW**

**forwar d-lookingradar.**

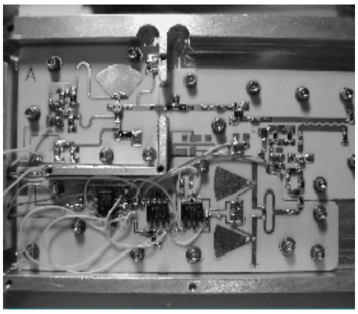


**Fig 9 Frequency locked loop of the 38GHz transceiver.**
**Output frequency is around 4.25GHz.**

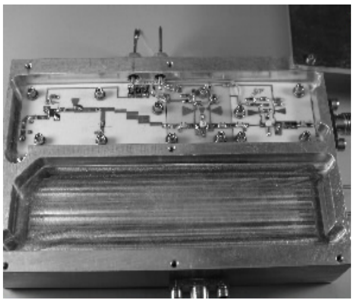


**Fig 10 Tripler and gain stage of the 38GHz transceiver.**

**Output frequency is around 12.75GHz.**

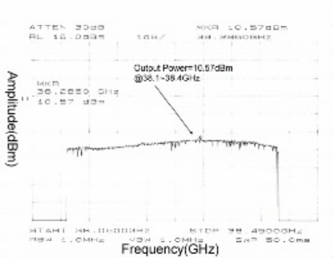


**Fig 11 Output power v.s. frequency for the transmitter.**

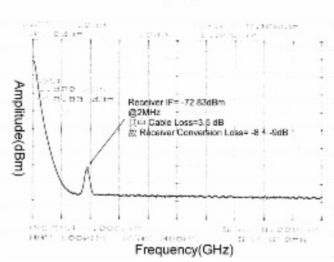


**Fig 12 Conversion loss for the receiver.**

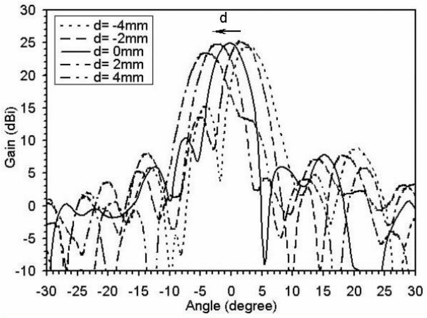


**Fig 13 Measured H-plane pattern of the folded reflectarray antenna.**

## D. Battery Energy Management System

Fig 14 shows a battery charging system configuration for a series connected battery stack with individual cell equalizers (ICE). Fig 15 shows our suggest system, where the cell voltage are balanced by the fuzzy logic equalization controller and a microprocessor based battery management system. The energy between the two battery cells is transformed through an energy transferring capacitor (C$_1$) The cell voltage difference (Vd) determines the direction of the energy transfer. The fuzzy logic equalization controller is used to regulate the equalizing current and the linguistic variable decision rule table in the fuzzy logic controller. It is used to explain the basic motioning theorem of the proposed, where two cells are balanced by PWM signals. The PWM signals corresponding to the respective cell voltage through the microprocessor based battery management system (BMS), which control variable switching S$_{C1}$ and S$_{C2}$. For example, if the B$_{C1}$ cell voltage V$_1$ is higher than the B$_{C2}$ cell voltage V$_2$, a variable switching S$_{C1}$ is turned-on by BMS, the positive PWM signals is transferred to complimentary pair MOSFET, so the MOSFET Q is on, and the voltage is transferred from V$_{B1}$ to V$_{B2}$. Similarly, if the voltage V$_2$ is higher than the voltage V$_1$, a variable switching S$_{C2}$ is turned-on, the negative PWM signals is transferred to complimentary pair MOSFET, so the MOSFET Q is on, the voltage is transferred from V$_{B2}$ to V$_{B1}$.

A FLC technique is employed to regulate the equalizing current of the proposed equalization scheme. The FLC consists of the rule base, inference engine, fuzzification, and defuzzification, as shown in fig.6. We use fuzzy rule base to describe the knowledge and experience of the battery equalization scheme. The decision rule table for the linguistic variables for the FLC is two-dimensional (5x5) shown in Table 1.

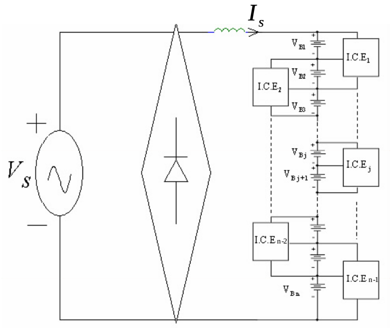


Fig 14 System configuration of battery strings

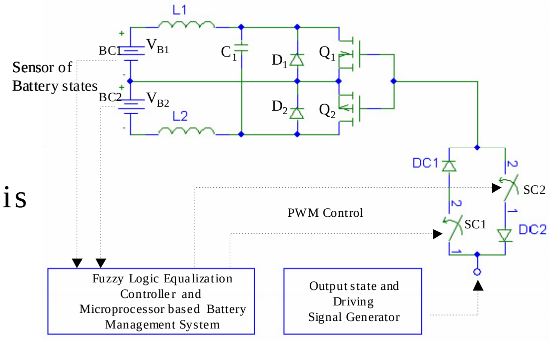


Fig 15 Principle of capacitor energy transferred battery balancing system

Table 1 Control rule base of the FLC-BEC for linguistic variable

$V_d$

$V_B$

| Output | VS | S | M | L | VL |
|---|---|---|---|---|---|
| VS | VS | M | L | VL | VL |
| S | VS | M | L | VL | VL |
| M | VS | M | L | VL | VL |
| L | VS | S | M | L | VL |
| VL | VS | S | M | L | VL |

There are two inputs in the FLC, the voltage difference (V$_d$) between cells and the cell voltage (V$_B$) in the battery strings. The numerical inputs are converted into linguistic fuzzy sets by the fuzzifier. The linguistic control values are generated in the inference engine based on the input fuzzy values and the pre-constructed fuzzy rule base. The linguistic inference results are converted into numerical output I$_{BEC}$ by the defuzzifier. The fuzzy controlled output I$_{BEC}$ is the desired battery equalizing current of the proposed cell equalization scheme.

To verify the analysis results discussed above, a computer simulation and experiment was performed for a three-modular battery stack with the fundamental equalization scheme. The simulation battery models were replaced by capacitors, and the experimental battery stacks were MRL/ITRI 1-Ah lithium-ion battery cells. First, we suggest that $V_{B1}>V_{B2}>V_{B3}$, the battery initial voltages were $V_{B1}=3.9V$, $V_{B2}=3.6V$, and $V_{B3}=3.3V$. The circuit parameters were $L_1=L_2=100uH$, and $C_1=470uF$. The switching frequency for the equalization scheme was 20KHz, and the duty cycle was 0.53. The driving signals were constructed using a logical switching algorithm, and instructed by an 8052 microprocessor. Fig 16 shows the simulating and experiment results of the inductor currents and voltages.

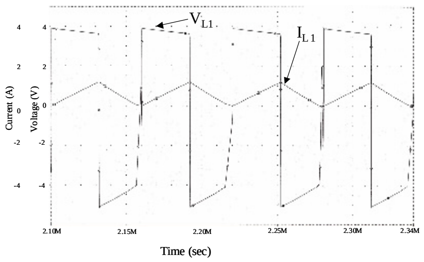
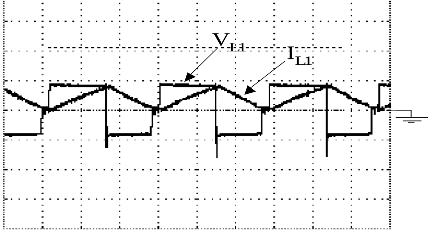


**Fig 16 (a): Simulation results**



**5V/div 、1A/div 、20us/div**

**Fig 16 (b): Experimental results**

**Fig 16 The results of inductor currents and voltages**

## Conclusion

This year, the project integrates the linguistic man/machine interface, the collision avoidance radar, the image recognition and tracking system, and the intelligent guidance system of an intelligent vehicle.

In the linguistic man/machine interface subproject, it shows 26.039% improvement when we replace GCVHMM with Decision Tree State Tying based on GCVHMM. And, at last we can further investigate how to extract vocal signal from music in advance, and then we can use a *Vocal Signal Extraction System* to replace the block, *Band-pass filter*, to generate the center channel of our 2-to-5.1 channel sound system.

In the intelligent guidance system project, we integrate GPS with GIS to develop a real-time vehicle navigation system. The developed vehicle navigation system consists of many modules to assist drivers or users to manipulate the navigation system.

In the collision avoidance project, the radar operates at 38 GHz and adopts the frequency-modulation continuous wave (FMCW) for both distance and velocity detection. A millimeter-wave (38.1 to 38.4 GHz) transceiver and folded microstrip reflectarray antenna with beam steering are developed for autonomous cruise control radar applications. The transceiver has an output power of 10.6 dBm for transmitting and about 7dB conversion loss for zero IF receiving.

In the battery equalization control project, according to the results of experiment and simulation, it is clear that the proposed battery equalizer operating in full duty cycle, so the efficient and equalizing time of the proposed battery equalization system is improved. The ZVS soft-switching is really reduced power loss about 30%. The proposed FLC-BEC is not only used to maintain the equalizing process operation in safe region but also reduced the equalizing period about 16%.

## Reference

[1] M. Kennedy, *"The Global Positioning System and GIS: An Introduction"*, Ann Arbor Press, 1996

[2] Farrell and M. Barth, *"The Global Positioning System and Inertial Navigation"*, McGraw-Hill, New York, 1998.

[3] L. Reindl, "Design, fabrication, and application of precise SAW delay lines used in an FMCW radar system," *IEEE Transactions on Microwave Theory and Techniques*, vol. 49, 2001.

[4] S. T. Tung, D. C.Hopkins, and C. R. Mosling, "Extension of battery life via charge equalization," *IEEE Transactions on Industrial Electronics*, vol. 40, pp. 96-104, 1993.

[5] **Z.** Zhang, and S. *CÛK* , "A high efficiency 1.8 kW battery equalizer," *Applied Power Electronics Conference and Exposition, APEC '93, Conference Proceedings, IEEE Eighth Annual*, pp 221 -227, 1993.

計畫成果自評

本研究內容與原計畫主要方向及目標君相符。部份研究內容已獲2003 IEEE International Conference on Systems, Man, and Cybernetics及 2003 IEEE International Conference on Machine Learning and Cybernetics 接受，吾人將在大會宣讀論文。俟獲致更深入成果後，也將投稿至國際著名期刊上發表。目前所獲研究成果，主要在於學理上的突破，較具學術價值。