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In-Vehicle Power Control and Power Design Criteria

Author: Richard Hung

E-mail: Richard.Huang@advatech.com.tw

Recent innovations have made huge improvements in fleet management. Trucks, buses, taxis and other fleet vehicles are fitted with wireless satellite navigation systems that let dispatchers know the position, status, and fuel consumption of every vehicle, leading to great benefits in fleet operation optimization. Passengers are served as well. Display monitors provide entertainment, as well as useful, real-time information such as departure and arrival times, weather bulletins, and emergency notices.

The in-vehicle systems described above require sophisticated power management. The new Advantech solution based on the ARK-1388 Box IPC and designed especially for in-vehicle applications, offers outstanding hardware and firmware microcontroller-based safe-boot and safe-shutdown functions. The start up and shut down procedures are direct functions of the car battery and ignition status. The rugged industrial PC works with both 12-volt and 24-volt battery systems. The innovative power management system is designed primarily for taxicabs, trucks, wagons, mining vehicles, and city buses.

The Challenges of a Power Management System

No matter where the electronic system operates on the automotive power bus, it is required to perform under very stringent power requirements. These include load-dump, cold-crank, very low power consumption at light loads, and low-noise operation. How can the designer avoid load-dump conditions where the battery cables are disconnected while the alternator is charging the battery? How can the electronic systems be protected in the case of very high or low voltages caused, for example, by a built-in car air conditioner? How can the designer guarantee product stability and safety in the car? Let's examine some solutions.

The Most Common Constraints for Automotive Power-Supply Design

The voltage transient range (VIN) of a 12V battery powerline determines the input voltage range of converter ICs. A typical car battery operates in the 9V to 16V range. The nominal voltage of a healthy battery is 12V when the engine is off, and around 14.4V when the engine is on. This range, however, easily extends to over 100V peak when transient conditions are involved.

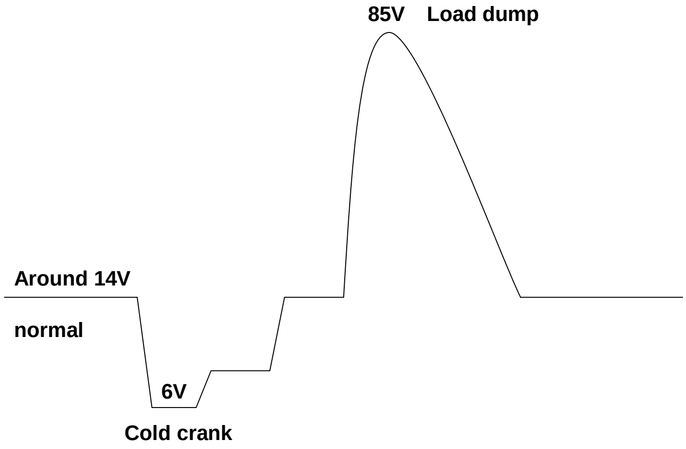

Figure1. Simulated Power Input Range

With the number of electronic control units (ECUs) in cars rapidly increasing, total current drawn from the car battery is also increasing and this affects the quiescent (IQ) and shutdown (ISD) current budgets. Some of electronic systems stay on even when the engine is off, and this depletes the battery. To keep the Quiescent (IQ) Current Budget under control, most customers set maximum limits for IQ per ECU. Devices such as a CAN transceiver, real-time clock, and microcontroller consume most of the IQ budget for an ECU, so the power supplies are allocated minimal IQ budget. Since ARK-1388, with one microcontroller, is monitoring vehicle power status, its power consumption during sleep mode is less than 10mA.

In the past, in order to address the challenges described above, designers had to adapt a separate automotive power module to connect electronic devices to the vehicle power system. This external, mostly customized module was sensitive to vibration and shock, and decreased stability of the automotive system.

The additional module also led to extra cost for the manufacturer, and took up space in the vehicle. Now with Advantech's all-in-one solution, safe bootups and shutdowns are guaranteed through hardware power protection and software-based smart monitor control features.

Tests According ISO 7637

ISO 7637-2:2004 specifies bench tests for the compatibility of conducted electrical transients for equipment installed in passenger cars and in commercial vehicles fitted with 12V or 24V electrical systems. Failure mode severity classification for immunity to transients is also given. The specification is applicable to all road vehicles with electrical systems, independent of the mode of propulsion.

A method of classifying the functional status of automotive electronic devices is described in specification ISO 7637 annex 2. The different test conditions represent possible environments in which the system may be working. The functional status is divided into several classes, reflecting different failure mechanisms. The selected levels and test times may be chosen according to the agreement between Advantech and the vehicle manufacturer.

The ARK-1388 Box IPC has been tested for use with 12V and 24V battery systems. One test is a simulation of transients due to supply disconnection from inductive loads. A simulation has also been run testing a sudden interruption of currents in a device connected in parallel with the tested device as a result of the inductance of the wiring harness. One test simulated the transients from DC motors acting as generators after the ignition was switched off. As result of a simulated switching process, transients can occur which are influenced by distributed capacitance and inductance of the wiring harness.

In cases where no specific values are defined, it is recommended to use levels selected from columns I through IV. ARK-1388 passes test level III for 12V and 24V systems; please refer to ISO-7637-2 certification for detailed specifications of each test pulse.

Table A.1a - Suggested test levels for 12 V system

Test Pulse [1)]	Selected test level [2)]	Test level U_s [3)] V				Minimum number of pulses or test time [7)]	Burst cycle time / pulse repetition time	
		I min. test level	II	III	IV max. test level		Min.	max.
1		- 25	- 50	- 75	- 100	5 000 pulses	0,5 s	5 s
2a		+ 12	+ 25	+ 37	+ 50	5 000 pulses	0,2 s	5 s
2b		+ 10	+ 10	+ 10	+ 10	10 pulses	0,5 s	5 s
3a		- 37	- 75	- 112	- 150	1 h	90 ms	100 ms
3b		+ 25	+ 50	+ 75	+ 100	1 h	90 ms	100 ms
4 [4)]		- 4	- 5	- 6	- 7	1 pulse	[5)]	[5)]
5 [6)]		+ 22	+ 43	+ 65	+ 87	1 pulse	[5)]	[5)]

Table A.1b - Suggested test levels for 24 V system								
Test pulse [1]	Selected Test Level [2]	Test levels U_s [3] V				Minimum number of pulses or test time [7]	Burst cycle time / pulse repetition time	
		I min. test level	II	III	IV max. test level		min.	max.
1		- 150	- 300	- 450	- 600	5 000 pulses	0,5 s	5 s
2a		+ 12	+ 25	+ 37	+ 50	5 000 pulses	0,2 s	5 s
2b		+ 20	+ 20	+ 20	+ 20	10 pulses	0,5 s	5 s
3a		- 50	- 100	- 150	- 200	1 h	90 ms	100 ms
3b		+ 50	+ 100	+ 150	+ 200	1 h	90 ms	100 ms
4		- 5	- 8	- 12	- 16	1 pulse	[5]	[5]
5 [6]		+ 43	+ 73	+ 123	+ 173	1 pulse	[5]	[5]

Figure 2: test level for 12V/24V system from ISO-7637-2

Advantech Hardware Power Design

The in-vehicle power protection mechanism measures and monitors numerous system conditions, and alerts for failures.

The power reserve protection system guards the equipment from potential damage caused by reverse polarity. Even when batteries have been installed backwards, or when the wires from a DC power source have been reversed, the mechanism permits normal functioning of DC-powered equipment.

To protect the electrical devices from sudden voltage spikes, a voltage surge protector has been implemented. The mechanism regulates the voltage supplied to an electrical device either by blocking or shorting the voltage to a ground if voltage goes above a safe threshold.

Cold-crank is a severe condition in an automotive environment. It occurs when a car’s engine is subjected to cold or freezing temperatures for a period of time, and the engine oil becomes very viscous and requires the starter motor to deliver more torque, which in turn needs more current from the battery. This large current load can pull the battery voltage as low as 4V at ignition, after which it typically returns to a nominal 13.8 V. Problems can arise when certain subsystems require a constant well-regulated 5 V output throughout the cold-crank period. These applications include ECU, environmental and emergency system microprocessors which are critical to the car’s safe and reliable performance.

Advantech's qualified power solution also supports a load dump condition, where the battery cables are disconnected while the alternator is generating charging current with other loads remaining on the alternator circuit. The battery can be disconnected as a result of cable corrosion, poor connection, or intentionally while the engine is running. Abrupt disconnection produces transient voltage spikes as high as 60 V as the alternator is attempting a full-charge. Under these conditions most computer systems would be damaged. The load dump amplitude depends on the alternator speed and on the level of the alternator field excitation at the moment of battery disconnect. The load dump pulse duration on the other hand depends essentially on the time constant of the field excitation circuit and on the pulse amplitude. In most new alternators, the load dump amplitude is suppressed by the addition of the limiting diodes.

Advantech Software Power Design

Apart from the hardware power management functions, Advantech has implemented software-based smart monitor and control features. A microcontroller is installed to stabilize the in-vehicle power system. A friendly utility interface allows the user to set up timing and voltage on his own. For example, multiple powers of delay times can be set using the utility and the hardware jumper. In the case of overwriting the settings, an alarm message can be generated.

The user can set power to “vehicle mode” or “ATX mode” by jumper. On vehicle power mode, the microcontroller-based PIC firmware checks the vehicle’s ignition and battery condition. Before the system turns on, the software automatically judges the battery type, and measures the threshold voltage of either 12V or 24V. If the battery voltage is high enough to power on the system, then software checks the ignition status. The ignition voltage has to be high, for example above 8V, as set up in the utility. The firmware ensures that the computing system won't start automatically without turning on the ignition. And during a sudden ignition switch on/off/on, the system power turns on smoothly. The timing conditions for a stable voltage can be set up by default, for example after 10s. In case the voltage has not been stabilized after this time period, the system automatically goes down.

During system operation, the PIC firmware continuously monitors the battery voltage status. If battery voltage becomes insufficient, the driver is informed and the system will shut down automatically within a certain given time window.

The PIC firmware also checks ignition condition. After switching off the car ignition, the operating system needs time to shut down and to store data before the system turns off completely. The delay time can vary from 30s (off delay) to 180s (hard off delay), depending on the firmware settings. If the system for some reason cannot shut down smoothly, the PCI firmware still makes sure that all data is automatically saved. These unique features assure safe boot up and shut down procedures.

The Advantech BOX IPC manager offers a user-friendly interface under XP/XPe; it provides power, ignition, and battery status on demand; adjusts the minimum voltage according to battery condition; delays the on/off timing based on application purpose; and provides alarm functions via UI message or email to server.

System Functions of the Box IP

Advantech's power management solution is based on its entire product family of robust and flexible Box IPCs, and targeted especially to meet the numerous, demanding in-vehicle requirements. The key advantages of the embedded Box IPCs are their very compact size, their reliability, and their passively cooled, thermally efficient designs. According to an IMS research report, the fastest growing markets for IPCs in the next years will be in the traffic, transportation, and infrastructure sectors. This trend has been accelerated by the availability of embedded, rugged IPCs, which are vibration resistant and well suited to harsh environments. Digital signage and customer information systems are currently popular applications of embedded IPCs.

The Advantech Box IPCs are compact, highly rugged computers that run an embedded operating system, e.g. Windows® CE, Windows® XPe, or Linux Embedded.

The Box IPCs have improved performance under extremely harsh environments. The industrial computers do not integrate a hard disk drive or rotating components and are thus highly tolerant of shock and vibration. The fanless IPC design and the aluminum casing, along with limited internal cabling, ensure high reliability in a wide range of applications. Due to the superior thermal design, the PC family is dedicated to outdoor and automotive applications. Advantech offers a comprehensive ARK Box IPC product portfolio with scalable computing and I/O performance.

The new ARK-1388 Box IPC belongs to the ultra compact size ARK-1300 standard family that can be easily installed in a limited space. The low power computer solution integrates either an Intel® Celeron M ULV 423 or an Intel® Core™2 Duo U7500 processor with 1.06 GHz clock frequency, combined with the Intel® 82945GM chipset. 2GB of DDR 2 memory are onboard.

The Box PC offers a flexible installation space for GSM/GPRS/EDGE or UMTS/HSDPA modules and 50-channel GPS functionality for easy integration of special navigation modules. For wireless LAN communication, the 802.11b/g WLAN specification is supported. On the front panel, the system offers VGA and 18/36-bit LVDS for the easy connection of display or touch panels. The ARK-1388 supports dual independent displays, one for the driver and one for the passenger. Furthermore, the computer supplies 4 x USB 2.0 ports, four serial port interfaces, 4 x digital inputs with isolation, and 2 x digital outputs with relay. For entertainment and customer information purposes, the ARK-1388 audio line out sports a stereo 6W amplifier for left and right channels, which does a lot to overcome the noisy environment problem. Data storage is possible via Compact Flash up to 8 GB.

Advantech's Box IPC ARK-1388 works flawlessly in an extended temperature range from -20°C to 60 °C (Intel® Celeron M processor), or up to 55°C (Intel® Core 2 Duo CPU) and supports a 9 V – 32 V wide-range power input.

Designed for in-vehicle applications, the ARK-1388 controls a media and information system ready to download data through UMTS/HSDPA or GSM/GPRS/EDGE. The industrial PC also integrates a power control mechanism that monitors the car engine and battery status. The boot up/off delay timing can be set up by utility quickly.

Figure 3: ARK-1388 In-vehicle Box IPC

Conclusion

Advantech's all-in-one solution replaces the external power management module, and ensures power stability for in-vehicle applications. The compact ARK-1388 Box IPC based system saves both on space and extra cost. Its industrial PC specifications support extended temperature ranges and high resistance to shock and vibration, just the thing for automotive applications.

The in-vehicle power design includes hardware power protection and software-based smart monitoring and control features that ensure safe boot up and safe shut down.

For more information on these products, visit http://www.advantech.com/ePlatform/box-ipc .