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Religion and Science: Conflict or Convergence

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Abstract

Four models for relating religion and science – conflict, independence, dialogue and integration – originally suggested by Ian Barbour, are developed. Special consideration is given to several examples of dialogue and integration: the history of the science/religion relationship, methodological similarities between science and theology and the use of scientific models in theology. Ethical issues related to the environment and the debate on the permissible directions of research are discussed. Readers are encouraged to consider their own stance on the relationship between science and religion. A bibliography and list of websites is provided to encourage the reader to continue studying the subject.

Key Words: religion and science, scientific method, ethics

1. Where do I stand on the issue?

Perhaps the best place to begin our inquiry into the relationship of religion and science is to first ask a seemingly simple question – "Where do I stand on the issue?" or "What do I see as the relationship between science and religion?" Among both scientists and non-scientists alike there would be a wide variety of opinions.

Some would perhaps argue that science has shown that religious belief is untenable. After all, science is now able to explain many things that in previous times were explained as the direct activity of a divine being – the development of the solar system, the evolution of the various animal and plant species, the rise of the human species.

Or perhaps it's the other way around. Marxism considered itself *the* scientific philosophy. Its almost total collapse as a governing philosophy may be indicative of a fatal flaw in the various atheistic philosophies. Science is good for solving a rather limited array of problems, but has nothing to say about the larger issues of human meaning and the relationship of the human person to the divine.

Or perhaps, like myself, the reader is somewhere in between. I grew up in a relatively devout Catholic home, my Father was a Professor of Mechanical Engineering and my Mother a physical therapist. While, there were specific issues that could be problematic, the basic presumption was that science and religion were not opposed to each other. Thus I later became a Catholic priest as well as went on to study physical chemistry. While there are areas of seeming conflict, overall I find that my study of science reinforces my Christian faith and my Christian faith helps me to be a better scientist.

In reading this article, I would suggest two goals. First that each of us would become a little clearer about our own opinions on the topic. What do I believe about the relationship between religion and science and can I justify these beliefs? Secondly, whatever my current stance, I would hope this article is a stimulus to further reflection. The religion-science dialogue is currently a very hot topic of academic discussion and there are many resources to draw from.

Before we begin I would like to make a few comments about the terms we are using: "science" and "religion." When I use the term "science" I am referring primarily to the physical and biological sciences – the so-called "hard sciences." I will not try to define precisely what science is but rather depend on our shared understanding of what constitutes science.

If "science" is difficult to define, the term "religion" is even more so. Again I will depend on our shared understanding. Modern empirical science first developed in Christian Europe. Christians, together with the adherents of Judaism and Islam, share a belief in a single creator God and, in most cases, a belief that this God in some sense cares about human beings and their history. But there are other religious traditions, such as Buddhism, that would not necessarily even speak of God, at least not in the sense of the monotheistic traditions. And finally there are other belief systems that have many of the characteristics of traditional religion, and yet are also quite different – Confucianism in East Asia and various pantheistic beliefs in the West would be examples. Since I myself am a Christian and since most of the academic work in the science-religion dialogue has been done in the context of Christianity, most of what I will say will in some sense presume a Christian background. However, I also believe that much of the content would be relevant to other religious traditions.

2. Models for relating science and religion.

Ian Barbour in his magisterial work *Religion and Science: Historical and Contemporary Issues* outlines four patterns or models for relating religion and science: conflict, independence, dialogue and integration [Barbour 1997, 77-105]. Before going further I should add that anyone beginning in the field of religion and science would do well to begin with Barbour's book. The word "magisterial" that I used above truly describes Barbour's work. In less than 350 pages, he summarizes the main historical, philosophical and theological issues of the science-religion dialogue.

Conflict. Two examples of the conflict model would be an empiricist philosophy that would deny the existence of God, or at least the possibility of knowing God, and an absolute Biblical literalism that would argue that a literal interpretation of the Bible is to be preferred to any scientific conclusion. Both would argue that science and religion, as they are generally understood, are in conflict – one must prevail at the expense of the other.

Let me first give an example of scientific materialism, the author is Hu Shih (胡適), a key figure among 20th century Chinese intellectuals. He approvingly quotes an earlier 20th century Chinese intellectual, Wu Chih-hui (吳稚暉)

> In this essay the old scholar [Wu Chih-Hui] unreservedly accepted the mechanistic conception of the universe, and built up a philosophy of life which, in his own words, "ruled out the term 'God' and banished the soul or spirit." He defined man as the animal with two hands and a big brain, which enable him to make tools. This tool-making animal has been able to create a wonderful

> civilization merely through the accumulation of tools with which he subdues nature and betters his own living. . . .
>
> He maintains that no religion, but science alone, will be needed to make mankind even better and more moral. . . . It is science alone which has given man not only the new sympathy, but the new capability to do good which the mendicant saints of medieval times could never possess. . . . [Hu, Shih 1934, 91-92]

I could quote many Western authors. However, I chose to quote a very influential 20th century Chinese intellectual to indicate that the conflict model of the relationship between science and religion is influential well beyond Europe and the Americas.

Equally accepting the conflict model of the relationship between religion and science, would be those Christian thinkers who would argue that in understanding the origins of the universe and of the human species, the literal sense of the Bible is to be preferred to accepted scientific conclusions.

> . . . the details of the creation period – duration, order, methods, purposes, etc. – cannot be determined from science. The scientific method is limited to the study of processes as they occur at present, and these processes cannot create anything, as demonstrated conclusively by the laws of thermodynamics.
>
> If creation really is a fact, this means there is a Creator, and the universe is His creation. He had a purpose in creation and man is apparently at the center of that purpose, since only man is able to understand even the concept of creation. It is reasonable, therefore, that God, the Creator, would somehow reveal to His creature man the necessary information concerning the creation which could never be discovered by himself.
>
> This is exactly what He has done in His book of "beginnings," the book of Genesis. Rather than outmoded folklore, as most critics allege, the creation chapters of Genesis are marvelous and accurate accounts of the actual events of the primeval history of the universe. They give data and information far beyond those that science can determine, and at the same time provide an intellectually satisfying framework within which to interpret the facts which science can determine. [Morris 1985, 203]

In each of these cases, I would suggest that either science or religion has overstepped its bounds, making claims that go beyond its normal areas of competence.

These are extreme cases, but I would suggest that conflict in itself is not always negative. It may force scientists, theologians, or simply those of us who are on the sidelines, to rethink and nuance a particular theory. On the surface there does seem to be a conflict between an evolutionary understanding of the origin of the human species and the traditional doctrine in Christianity that the human person bears a special relationship to God. In the words of Genesis, "God created human kind in his image, in the image of God he created them (Gen 1: 27)." One possibility is to deny an evolutionary origin of the human species arguing that a special creation of the human person is the only way to salvage a special relationship with God. Another possibility is to accept a completely naturalistic understanding of our evolutionary origins, God is simply not in the picture and there is no special relationship. There is, however, a third possibility of accepting our evolutionary origins but recognizing that this is the way God used to create the human person. From a seeming conflict, there can arise a richer understanding of God's relationship to the cosmos. I am getting ahead of myself; this would fit better under the model of dialogue or integration. But the point is that conflict is not necessarily negative. Finally, as in other areas of human knowing, including science itself, we sometimes have to live with a still unresolved dilemma.

Independence (compartmentalization). In the examples given above, I already noted that both science and religion may make claims that seem to go beyond their area of competence. Recognizing this is the basis of the independence model describing the relationship of religion and science. Science and religion have different methodologies and different purposes. Science seeks knowledge of the natural world, religion seeks knowledge of God. Science tells us about natural mechanisms, religion tells us about how we should act. This view gained considerable currency with the philosophic recognition that there are different linguistic modes, different "language games."

The compartmentalization model in many cases accords with our common sense. When I go into the laboratory to do computer simulations of molecular collisions or talk with my graduate students about their latest results, theology and religion are left to the side. My religious faith may be an encouragement for me to do science, I may also believe that God sustains the universe in being, but such explanations are not invoked when doing science.

Similarly, scientists are not so different from other folks. Darwin in his later life became a strong agnostic, but the primary factor was not his theory of human evolution but rather the problem of evil. He could not accept the idea that those who did not believe in Christ were to be condemned to eternal punishment. Such a sentence, he noted, would include his father, brother and most of his friends. He was very aware of the cruelty in nature. But even more difficult for Darwin was the tragic death of his beloved ten-year-old daughter, Anne. We may agree or disagree with Darwin's agnosticism. But difficulties with the theology of his day or with the problem of evil are surely not confined to scientists. The Bible itself in the Book of Job, written long before the scientific revolution, is proof of the universality and the enduring character of the mystery of evil.

Dialogue. While in most of our daily life, science and religion pretty well go their separate ways, there are places where they come together. The point of contact is often what may be called a "boundary question." These are questions that lie at the boundary of science and what traditionally has been the domain of theology or metaphysics.

For example, what is the relationship between human knowing in religion (theology) and human knowing in science? While most or all would agree that scientific methodologies and theological methodologies are quite different, it is still the human person that knows scientifically and religiously. What are the similarities and what are the differences between religious and scientific knowing? In my own work, I have found the thought of the Canadian philosopher-theologian Bernard Lonergan to be most useful [Lonergan 1992, 1996]. His work is usually classified as "transcendental Thomism", "transcendental" not in the sense of religious transcendence, but in the sense that a consideration of the human person as a knower transcends the particular objects of that knowledge.

This is not the place to consider what is perhaps the most basic and difficult question of modern philosophy, "How can we know the real?" However, it is a good place to note one of the reasons why the study of the relationship between religion and science is notoriously difficult. Not only does it involve science and theology as commonly conceived, but also involves much of modern philosophy – the philosophy of science and more generally epistemology, the philosophy of knowing.

There are other boundary questions. Why is there something rather than nothing? Science can tell us much of the evolution of the universe, but seems to have nothing to say on this more basic question. Some philosophers argue that only the methods of science can give true knowledge and that therefore the question is meaningless. However, the question keeps coming up and it seems somewhat obscurantist to simply deny it is a meaningful question.

Beyond these philosophical questions, there is another area where religion touches science.

> O Lord, how manifold are your works! In wisdom you have made them all; the earth is full of your creatures.
>
> Yonder is the sea, great and wide, creeping things innumerable are there, living things both small and great.
>
> There go the ships, and Leviathan that you formed to sport in it.
>
> These all look to you to give them their food in due season; when you give to them they gather it up; when you open your hand they are filled with good things.
>
> When you hide your face, they are dismayed; when you take away their breath they die and return to their dust.
>
> When you send forth your spirit, they are created; and you renew the face of the ground.
>
> May the glory of the Lord endure forever; may the Lord rejoice in his works...
>
> [Psalm 104: 24-31]

For many religious believers, nature somehow reveals the divine to them. The poetry of the psalm evokes a deep-seated religious experience. And while the methodologies of science are not necessarily affected, the doing of science is for many believing scientists an important part of their religious life.

Integration. The dialogue model is concerned with boundary questions and with the faith of the one doing science. The integration model suggests that there can be more active ways of actually integrating the content of science and religion. It takes place in many ways and on many levels.

In a recent book, the Lutheran theologian Philip Hefner attempts to develop a systematic theology that takes full cognizance of the developments in the natural sciences, particularly evolutionary biology and cultural anthropology [Hefner 1993]. "Who are we as human beings? We are first of all, thoroughly natural creatures. We have emerged from the natural evolutionary processes. These processes have bequeathed to us a constitution that is informed by both genetic and cultural material. [p. 19]." In the human being, evolution has come to a stage of self-awareness and freedom. The purpose and meaning of human life flows from our evolutionary and cultural roots.

> Human beings are God's created co-creators whose purpose is to be the agency, acting in freedom, to birth the future that is most wholesome for the nature that has birthed us – the nature that is not only our own genetic heritage, but also the entire human community and the evolutionary and ecological reality in which and to which we belong. Exercising this agency is said to be God's will for humans. [p. 27]

In succeeding chapters, Hefner goes on to consider the emergence of myth and ritual within culture and the relationship of an evolved altruism to Christian love. Only with this basis does Hefner turn to traditional Christian themes such as creation, sin and grace, the nature of Christ and the trinity.

Many scientists and even some liberal theologians would argue that Hefner has not gone far enough. Authors such as Ralph Wendell Burhoe argue that religion must be completely reinterpreted in terms of contemporary scientific concepts and images. "...God, thus defined, is the main preoccupation of physics: to discover the source or cause of anything we experience... The reality of such a God, a causal or at least correlatable system of events, is the basic postulate of physics." [Burhoe 1964, quoted Breed 1992, 94]

Others of a more traditional bent, such as adherents of Protestant neo-orthodoxy and many Catholic Thomists, would wonder if Burhoe and Hefner have not hopelessly muddled scientific naturalism and Christian belief. The point is that the integration model describes not so much the content of a particular theological system, but a basic theological strategy that argues that theology at its very core must be informed by the insights of modern empirical science.

It should be noted that the work of Burhoe and Hefner are quite controversial. However, integration between theology and the social sciences has become common place. Thus modern works on Christian spirituality and ecclesiology routinely make use of contemporary psychology and sociology.

Such then are the four patterns or models for relating science and religion – conflict, independence, dialogue and integration. On one level these patterns can be seen as mutually exclusive – if there is a basic conflict or if science and religion are completely independent, then dialogue and integration are impossible. I have, however, chosen to see them more as models, each of which may describe the science-religion interaction at specific times and places and each of which has its own validity.[1]

3. Dialogue and integration-further examples.

The history of the science/religion relationship. That there have been conflicts between religion and science is obvious. However, what is also becoming obvious is that the relationship between religion and science has been much more complicated than a simple conflict model would admit.

Perhaps the strongest statement of a positive relationship between the development of science and, at least, the Christian religion comes from the Hungarian-American Benedictine Stanley Jaki. Fr. Jaki is not alone in noting that modern empirical science developed in a Christian milieu. Why it did not develop in China, India or ancient Greece and Rome is perhaps a question that can never be given a definitive answer, but it is an engaging question. Fr. Jaki's basic thesis is quite simple [Jaki 1977]. The basis of empirical science is twofold: the world is intelligible, it can be known through human reason. At the same time, the world could be other than it is – we have to do experiments to learn what in fact the laws of nature are. For Jaki these two pillars of science correlate with the basic Christian doctrine of creation. God created the world, and therefore it is intelligible, open to understanding by human minds created in God's image. At the same time, as God's creation, the world is contingent. It could have been otherwise. Thus the only way to learn about the physical universe is to make observations and do experiments. Simple speculation will not do, experiment is the final arbiter.

While most historians would not accept Jaki's thesis in the rather absolute form in which it is presented, the fact that science developed in a Christian culture is not questioned. That religious thought had, in many ways, a positive influence on the development of science seems clear.

Methodological similarities between science and theology. Beginning already before the Second World War, philosophy of science was to undergo a quite dramatic shift [Murphy 1990, 52-61]. Earlier thinkers had suggested a simple linear development of science: observation, theory, and verification. But what thinkers like Carl Hempel and Karl Popper realized is that theories go well beyond the rather limited data on which they are based. Hempel argued that science begins with observation and statements about those observations. With this basis, a hypothesis or theory is "invented." Further deductions can be made from theory that may or may not be experimentally verified.

Karl Popper zeroed in on the problem of verification. What he pointed out was that in science, a theory is not really proved. For Popper good scientific theories must be falsifiable and verification is only probable – a verified theory survives the test of falsification over a long period.

Thomas Kuhn in his famous book *The Structure of Scientific Revolutions* [Kuhn 1970] showed that historically the confirmation of scientific theories has involved much more than the simple verification of hypotheses, even verification as understood by Karl Popper. His concept of paradigms, "standard examples of scientific work that embody a set of conceptual and methodological assumptions [quoted in Barbour 1997, 125]" revolutionized the philosophy of science and has since found its way into many other fields of study.

The philosopher of science that perhaps has had the greatest impact on the religion-science dialogue is Imre Lakatos. He builds on the earlier work of the neo-positivists Hempel and Popper as well as on the work of Thomas Kuhn. Science is described as ongoing research programs. Somewhat like an onion, there is the "hard core" as well as various auxiliary hypotheses. The hard core consists of those basic theories that elicit general agreement among scientists. Around the hard core are various auxiliary hypotheses that allow data to be incorporated into the theory. A research program is said to be progressive when it is able to broaden its empirical content and predict new facts that are corroborated by experiment or observation.

Lakatos' basic insight is not so different than the experience of many physics or chemistry students. The excited freshman brings his or her data to the professor and the professor sagely comments that the student has either disproved quantum mechanics (or some other "hard core" theory) or the student has made a mistake. We usually presume the second explanation. When the student returns four or five years later as a graduate student, the presumption is that some model or "auxiliary hypothesis" needs to be modified. Presumably the core theory of quantum mechanics remains intact. This is the way science normally develops. There are, however, also revolutionary periods when new paradigms (Kuhn) or new research programs (Lakatos) come to the fore.

I think you can see the point. All of a sudden theological and scientific knowing don't seem so completely different. Theological research programs will have a hard core, for example, that human beings are created in the image of God. There will also be auxiliary hypotheses defining what we mean by terms such as "image of God" and describing how this creation occurred, for example through evolution. Verification will depend on the ability of the various auxiliary hypotheses both to account for the data of the religious tradition (Scripture and Church teaching) and our contemporary experience. In recent years, words like paradigm, model and research program have become quite fashionable in theology. Probably the person who has worked out these similarities in the clearest way is Professor Nancy Murphy of Fuller Theological Seminary in California. Her book *Theology in an Age of Scientific Reasoning* [Murphy 1990] is well worth looking into.

The use of scientific models – evolution. The previous two examples are somewhere between the dialogue and integration models. They deal with the history and philosophy of science. An example of direct integration is the use of evolutionary thought in understanding the world in relationship to God. Earlier I discussed the Lutheran theologian Philip Hefner.

The premier thinker in this area was a Catholic priest, the Jesuit paleontologist Teilhard de Chardin [Teilhard de Chardin 1959, 1960]. Teilhard's works are not read so much today. Perhaps the reason is that no one is quite sure how to interpret them. They are neither science, theology nor philosophy in the strict sense. Some have suggested they are closer to poetry. But what Chardin did is give us a picture of the cosmos in which evolution is at its heart – the evolution of matter and spirit toward the consummation described by Saint Paul "That God may be all in all." [I Cor. 15: 28] Many of the details have been superseded. It is also recognized that Teilhard's vision of the cosmos may be too earth centered. But after Teihard, contemporary theology could never simply bypass evolutionary thinking.

4. Ethical issues.

So far we have stressed the relationship between science and religion basically in terms of scientific and religious knowledge. But besides knowing, there is doing. Many would argue that our age is in ethical crisis, brought about in large part by science and its handmaid technology. The relationship between ethics and religion is not a simple one. Most Western ethical theorists would argue for a basic universality and independence of moral norms from specific religious traditions. At the same time, most religions have a strong ethical component. [Cf. Green, 1987] Without going into details, I think that for the purposes of this paper we can agree on two basic principles. First, for the vast majority of religious believers, their religious faith implies strong ethical norms. Secondly, religious faith provides a deep motivation for putting those norms into practice.

The environment. What do our religious traditions have to say about the place of human persons within the larger "natural world"? Is the natural world primarily for the use of human persons or does it have its own intrinsic value? Answers to these questions will, at least in part, determine the ethical stance of the religious believer toward the environment.

Environmental questions almost inevitably have a basic science component. The worldwide response to the destruction of the ozone layer in the upper atmosphere was based on top-notch scientific research. The observation of the ozone hole first over the Antarctic and then over the Arctic required the best scientific instrumentation. The recognition of the role of the ozone layer in protecting the earth's ecosystem from harmful ultra violet rays is a major scientific development. But perhaps most amazing is the discovery in a few short years of the relationship between the ozone hole and the chlorofluorocarbon (CFC) gases released by humans into the atmosphere. For this Paul Crutzen, Mario Molina and F. Sherwood Rowland received the Nobel Prize in 1995. When the science was clear, the world community rallied together and the Montreal Protocol, gradually banning the production and use of CFCs, was the result.

Science can show us the ethical dilemma, but science by itself cannot provide the appropriate ethical response. Even less can science provide the motivation to do something. Ethical questions inevitably have a value component that goes beyond the facts of the case. Cynics will note that the banning of clorofluorocarbons had relatively little impact on the economies and lifestyles of the industrially developed countries and so an international consensus developed quickly. Much larger questions with much larger impacts are on the horizon-global warming due to increase of CO_2 in the atmosphere and the dangerous loss of topsoil in many so-called developing countries are just two examples. In some cases, religion can provide the necessary value component and, maybe even more importantly, provide a deep motivation to do something about the problem. However, it is also possible that a particular religious tradition or belief may be a hindrance in dealing with some environmental problems. Thus for better or for worse, the world's religions are going to have to play an important role in meeting the environmental challenges of the future.

Directions in research and the public debate. Science is often described as neutral. This may or may not be so, but what is clear is that scientific developments have consequences, good and bad. Recent developments in cloning animals have placed the question of the permissible directions of research in the spotlight. Should research on human cloning be allowed? But cloning is only one question. The explosion of nuclear weapons by India and Pakistan has one again raised the question of an ethical response to the continued development of nuclear weapons. Currently in the United States there is heated discussion on whether the public universities should be working on a new project to simulate nuclear explosions. The U. S. government argues that it will allow the American nuclear arsenal to be safely maintained without nuclear testing. The opponents argue that the project is really a way to continue developing new and improved nuclear weapons after the nuclear test ban treaty. What should be the response of religious believers to these issues? In democratic countries, citizens will vote for representatives who will ultimately decide these questions. Those of us who work in science may be even more directly involved.

Each country has its own way of dealing with the religiously pluralistic reality of contemporary society. Taiwan and Japan have followed the lead of the United States in arguing for a strict separation of Church and state. However, this does not mean that our faith and our religion should not inform our contributions to the national debate. We as Christians – or as Jews or Moslems or Buddhists or whatever – have to integrate our religious convictions into our contributions to the national and international debate on all the issues that affect our society.

CONCLUSION

Having worked for nearly twenty years in a Catholic University, I would like to close with a few remarks about the Catholic Church and Catholic higher education. The fact that my own institution, Fu Jen Catholic University in Taiwan, like Catholic universities and colleges throughout the world, supports faculties of natural science, medical sciences and engineering says something about the basic attitude of the Catholic Church to science and its applications. There may be mistakes and there may be times of tension, but the Church believes that science and the development of ethically guided applications is something worth doing. The current pope, John Paul II, in his own writings [John Paul II, 1996] and through the various conferences organized by the Vatican [Russell, Stoeger, Coyne, editors, 1990], has demonstrated his commitment to an integral understanding of the relationship between religion and science.

I would hope that each of us can move toward a more nuanced and integrated view of the relationship between science and religion. Obviously the details will differ according to one's religious tradition or, perhaps, lack of one. The bibliography of this paper offers some books that might be helpful. Most of the major centers for theology and science have well-developed home pages describing the religion and science dialogue. I also suggest that further reflection on religion-science issues will help us to deal in a better way with the ethical dilemmas facing humanity as we move into the 21st century.

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NOTE

[1]I am indebted to Dr. Robert Russell, the director of the Center for Theology and Natural Sciences in Berkeley, CA for developing this insight.

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American Scientific Affiliation: http: //asa.calvin.edu/ASA/index.html

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宗教與科學：衝突或聚合

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摘　　要

本文討論原來 Ian Barbour 建議的四個模型來解釋宗教與科學的關係一衝突，獨立，交談和整合。特別考慮交談和整合的幾個例子：科學與宗教的關係之歷史，科學與宗教研究方法類似的地方和在神學使用科學的模型。討論關於環保和許可之研究方向的倫理問題。鼓勵讀者考慮關於科學與宗教的關係之自己的立場。爲鼓勵讀者繼續研究這題目，將提供參考書和網址目錄。

關鍵詞： 科學與宗教，科學方法，倫理學

Tunable Full-Wave Precision Rectifier Using CFA

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Abstract

New configurations of voltage-mode and current-mode full-wave rectifier circuits using Current Feedback Amplifier(CFA) are presented. The proposed circuits can be synthesized tunable gain full-wave rectification functions using two CFAs connected to only two diodes and two resistors. The constructions of the tunable gain rectifiers are very simple. Finally, two experimental results are included to verity the theoretical prediction.

***Key Words*:** rectifier, current feedback amplifier

INTRODUCTION

In the past, some literature on the configuration of full-wave rectifier circuits have been published.[(1)~(4)] However, most of these schemes are usually some arrangement of operational amplifiers, transistors, diodes and resistors. None of them have been built by using current-mode active elements. The current-mode amplifiers can operate at high signal bandwidth, with greater linearity and have larger dynamic rang, than their voltage-mode counterpart.[(5)(6)] Hence, the realization of current-mode circuits have been drawn much attention in analogue signal processing circuits.[(6)] A new amplifier called current feedback amplifier(CFA) can provide independent of bandwidth[(7)] and high slew rate (i.e. 2000 V/μS).[(8)(9)] CFA has been used to construct filters.[(10)(11)] However, rectifier contained CFA has never been published. In this paper, a new voltage-mode gain-adjusted precision full-wave rectifier circuit using two CFAs is proposed. Furthermore, the adjoint transformation[12] is applied to create a current-mode tunable current-gain full-wave rectifier from the voltage-mode circuit. The aim of the contribution is to introduce a newly developed rectifier circuits. The positive features of rectifiers constructed in this way are a simple structure and a small number of components.

CIRCUIT DESCIPTION

The symbol of CFA is shown in Fig.1. Using standard notation, the terminal variables of the CFA are indeed related by $V_x = V_y$, $V_o = V_z$, $I_z = I_x$ and $I_y = 0$.[13] A voltage-mode full-wave rectifier circuit using two CFAs, shown in Fig.2, is presented. Considering the proposed configuration of Fig.2, two cases are analysed. Assume that all the components are ideal.

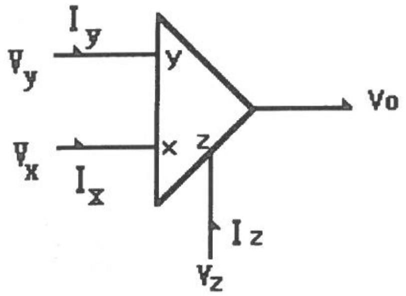

Fig. 1. Circuit symbol of CFA.

Case1: When V_{in} is in the positive half-period, D_1 is on, D_2 is off, the current flows through D_1 and R_1. The transfer function is expressed by

$$\frac{V_0}{V_{in}} = \frac{R_1}{R_2} \tag{1}$$

Case2: When V_{in} is in the negative half-period, D_1 is off, D_2 is on, the current flows through D_2, R_1 and CFA(2). The transfer function is expressed by

$$\frac{V_0}{V_{in}} = -\frac{R_1}{R_2} \tag{2}$$

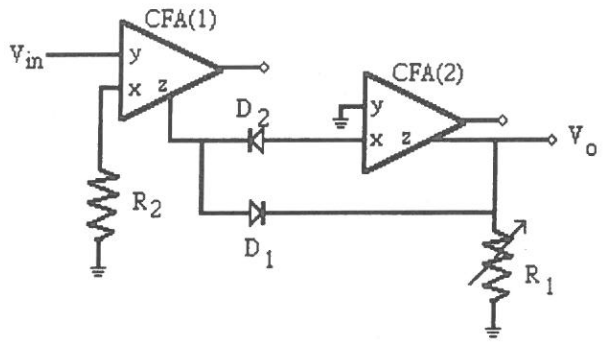

Fig. 2. Voltage-Mode Full-Wave rectifier with tunable voltage gain.

From equations (1) and (2), the voltage-mode full-wave rectifier is implemented. No matter whether V_{in} is in a positive or negative half-period, V_o is always positive. Apparently, the amplitude of the output signal can be adjusted by using potentiometer R_1.

Creating an alternative linear network realization of a given transfer function can be performed using the principle of adjoint networks shown in Fig.3. Based on the concept of adjoint networks, the voltage-mode gain-adjusted full-wave rectifier circuit can be converted to the current-mode counterpart shown in Fig.4. This proposed current-mode gain-adjusted full-wave rectifier circuit is analyzed below:

Case1: When I_{in} is in the positive half-period, D_1 is on, D_2 is off, the current I_o flows through D_1. The transfer function is expressed by

$$\frac{V_0}{V_{in}} = \frac{R_1}{R_2} \tag{3}$$

Case2: When I_{in} is in the negative half-period, the current I_o flows through D_2 and CFA (2). The transfer function is given by

$$\frac{V_0}{V_{in}} = -\frac{R_1}{R_2} \tag{4}$$

Clearly, the current-mode full-wave tunable-gain is implemented from equation (3) and (4). No matter whether I_{in} is in a positive or negative half-period, I_o is always positive. The different gain can obtained by adjusting the value of R_1.

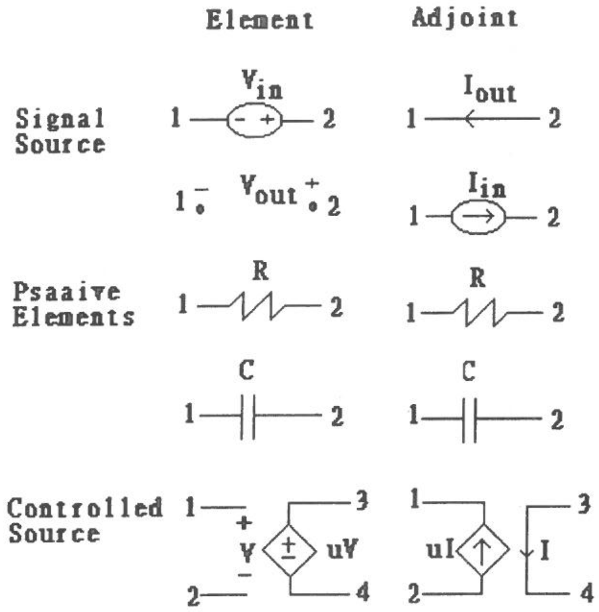

Fig. 3. Several network elements and their corresponding adjoint elements.

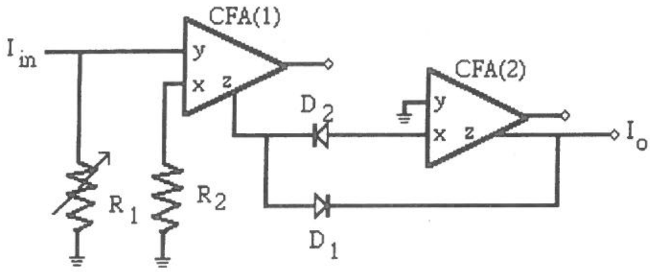

Fig. 4. Current-Mode Full-Wave rectifier with tunable current gain.

EXPERIMENTAL RESULTS

In order to verify the theoretical analysis, the proposed circuits are experimentally demonstrated. The two CFAs rectifier circuit in Fig.2 was constructed by using two AD844 and two ISS97 Schottky diodes. The Tektronix 7623A oscilloscope was used to measure the experimental results. From the case of voltage-mode rectifier circuit of

Fig.2, the circuit is constructed below:

(1) When $R_1 = R_2 = 1k\ \Omega$, f = 100k Hz and $V_{in} = 2V$, the input and rectified waveforms are shown in Fig-5(a).

(2) When $R_1 = 3k\ \Omega$, $R_2 = 1k\ \Omega$, $f = 100k$ Hz and $V_{in} = 500mV$, the input and rectified waveforms are shown in Fig-5(b).

Because the bandwidth of the AD844 is up to 60MHz, the rectifier circuit can possess high performance bandwidth feature.

It appears that the experimental results are in good agreement with the theory presented.

CONCLUSION

The full-wave rectifier circuits constructed by using CFA as the only active element are presented. The tunable voltage-mode full-wave rectifier circuit using CFA is first formed. Furthermore, a tunable current-mode full-wave rectifier circuit is constructed from the voltage-mode one via the principle of adjoint networks. The tunable voltage-mode full-wave rectifier circuit has been experimentally verified.

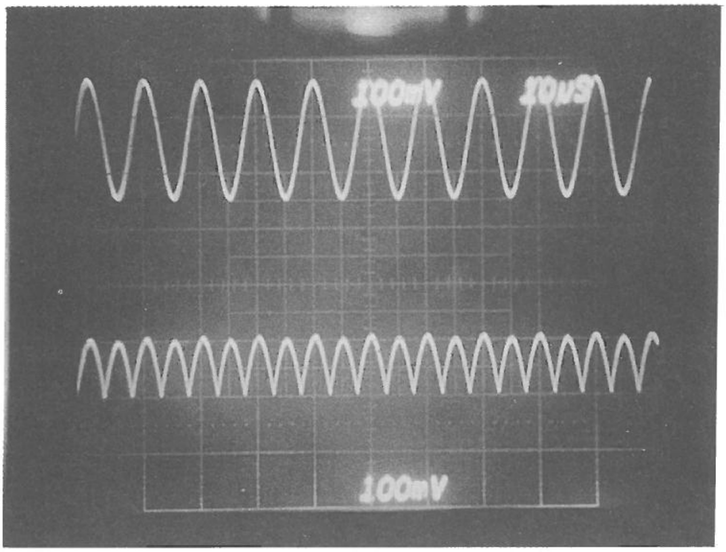

Fig. 5 (a). Shows the input and rectified waveforms of $R_1 = R_2 = 1k$ ohms, f = 100kHz and $V_{in} = 2V$.

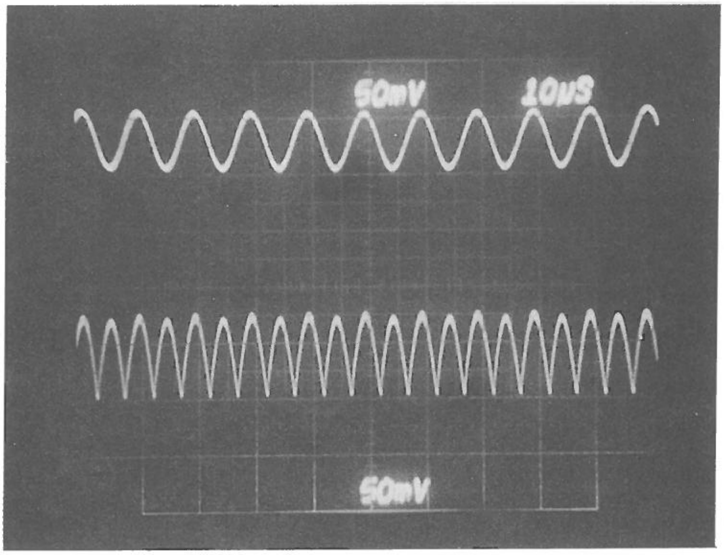

Fig. 5 (b). Shows the input and rectified waveforms of $R_1 = 3R_2 = 3k$ ohms, f = 100kHz and $V_{in} = 500$ mV.

The purpose of this experimental investigation is to present the simplification of the tunable-gain rectifier using only two CFAs. Under the condition, the current-mode rectifier circuit would have the same behavior.

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使用電流迴授放大器合成可調式精密整流器

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摘　　要

本文提出使用電流迴授放大器合成可調電壓式與電流式全波整流器，此電路以電流迴授放大器作為主動元件並只連接兩個二極體與兩個電阻合成可調增益大小之全波整流器。此可調式整流器之結構非常簡單。最後並以實驗驗證所設計之可調式整流器之可調增益大小之全波功能。

關鍵詞： 整流器，電流迴授放大器

Cost-Effective Design of SONET Self-Healing Rings for Asymmetric Video Traffic

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Abstract

SONET is being widely deployed as the standard fiber optic transport infrastructure for existing wideband and broadband circuit-based services and for new and future broadband services including cell-based services. Current services as well as network equipment are based exclusively on symmetric traffic. As the regulatory climate changes, video services have gradually emerge as a new source of increasing future revenues for telecommunications carriers. Video services will consume large amounts of bandwidth across broadband networks, but are highly asymmetric in nature. It is expected that new SONET equipment with asymmetric characteristics to appear on the market soon. This paper describes different network architectures and how they can be used for the asymmetric transport, in comparison to the current symmetric use. A simple example tries to illustrate that proper network design has a tremendous impact on capital spent on the network.

Key Words: SONET, asymmetric equipment, video services, network design

INTRODUTION

The introduction of broadband video services such as broadcast video distribution and interactive video applications requires economical methods of transporting highly asymmetric video traffic in telecommunications networks. Traditionally, telecommunications networks were designed for symmetric traffic. Network design and design tools were dealing exclusively with symmetric traffic. This paper analyzes the impact of asymmetric video traffic on SONET network design considerations.

Current networks of symmetric traffic include standard SONET networks [1] which are being introduced at an accelerating rate as a transport infrastructure for wideband and broadband circuit-based and cell-based services. Circuit-based services utilize the Synchronous Transfer Mode (STM) and represent the large majority of today's traffic; cell-based services utilize the Asynchronous Transfer Mode (ATM) and are expected to grow rapidly in the future. It is possible to adapt SONET equipment to carry asymmetric traffic in several ways. Further, some supplier proprietary systems have appeared on the market that are specifically tailored to asymmetric video traffic. As telecommunications carriers begin to deploy equipment in broadband networks for business and residential video services, a need arises for design guidelines and tools for asymmetric network design.

Nonstandard, supplier proprietary systems may be cost-effective in special or limited video applications. However, there are strong economical and operational benefits in utilizing SONET transport systems that fit into a consolidated transport infrastructure. SONET provides a future-proof standard infrastructure for existing wideband and broadband services as well as emerging broadband services such as video and data services, some of which may be ATM-based. As more suppliers start offering asymmetric SONET equipment, carriers will be able to select and integrate the best-priced equipment into their transport infrastructure without making extensive network changes.

Asymmetric networks for video have been addressed in a number of previous studies [2] [3]. It is recognized that both ATM and SONET technologies will likely play key roles in transport and switching for video services [4] [5]. This paper focuses on the issue of using SONET transport systems to carry video traffic with the assumption that ATM functions are provided in broadband switching systems.

When integrating video traffic into a SONET transport infrastructure, SONET

Network Elements (NEs) may carry mixed symmetric and asymmetric traffic, or some SONET NEs may be designated for video only, i.e., carrying asymmetric traffic only. Two broad categories of video services can be distinguished: *unidirectional asymmetric and bi-directional asymmetric* [6].

Unidirectional asymmetric services provide one-way distribution of video, usually for broadcast or multicast applications of video programs, also referred to as point-to-multipoint (PTM) services. PTM video services are typically delivered by one of several Video Information Providers (VIPs) to many Video Information Users (VIUs) associated with one or many Serving End Offices (SEOs) on a scheduled basis (Pay-per-View, for example). This allows only downstream delivery of video services, and the subscriber cannot control the delivery once it is initiated.

Bi-directional asymmetric services provide highly asymmetric two-way distribution of video, usually for interactive applications of video services, also referred to as point-to-point (PTP) services. PTP video services are typically delivered by a VIP to one VIU or subscriber, with the time of delivery and content based on the subscriber's initiative and selection (Video-on-Demand, for example). A unique, bi-directional connection is set up, allowing the subscriber to exercise continuous control over the service (e.g., for pausing, rewinding, or other interactive transactions).

The rest of the paper is organized as follows: Section 2 describes different network architectures and how they can be used for the two categories of asymmetric transport, in comparison to the current symmetric use. Section 3 analyzes the implications of asymmetric transmission for equipment and for network design. Section 4 gives the conclusion.

SONET-BASED NETWORK ARCHITECTURES FOR VIDEO TRANSPORT

This section describes the different network architectures that may become candidates for the two categories of video transport outlined in Section 1.

1. Video Transport

Transport of video services starts at the head end with Video Information

Providers (VIPs) and proceeds through interoffice and access networks to many Video Information Users (VIUs). A group of VIUs is usually served by a Serving End Office (SEO), and many SEOs can be served by a single VIP. A community of SEOs may also be served by several VIPs providing different services or by duplicate VIPs providing identical services from different geographical locations for service survivability. The SEO is usually the boundary between the interoffice and the access network. This paper addresses mainly interoffice networks; local access networks may in some cases employ different technologies, including non-SONET equipment.

2. Point-to-Point Architectures

A point-to-point architecture for video transport, as shown in Fig.1, connects a number of VIPs to a group of SEOs, which in turn provide access to their subtending VIUs. Our focus here is on the VIP-to-SEO connections; access networks (SEO-to-VIU) may utilize their own technology that may be more specialized. Every single VIP-to-SEO connection may be equipped with a working line and a protection line, providing automatic protection switching. Thus, line failures can be protected within 60 milliseconds [1]. Working fibers and protection fibers may be routed separately to provide survivability in case of cable cuts. The VIP-to-SEO connection may be used soley for video transport, or the line capacity may be shared with regular symmetric SONET transport.

SONET asymmetric multiplex is a new type of equipment that is different from today's symmetric ones. Asymmetric point-to-point systems can be either unidirectional or bi-directional. Unidirectional asymmetric systems do not support two-way or return overhead signals and functions, nor signaling or control functions in the upstream directions; however, these functions may be provided by alternate means (for example through an external data communications network).

Bi-directional asymmetric systems may be achieved in two ways. One way is to provide a lower rate upstream signal (OC-3, for example, for the SEP-to-VIP direction) for every higher rate downstream signal (OC-12or OC-48, for example, for the VIP-to-SEO direction). Such systems could support two-way and return overhead signals and functions because the overhead signals can be coordinated by the single

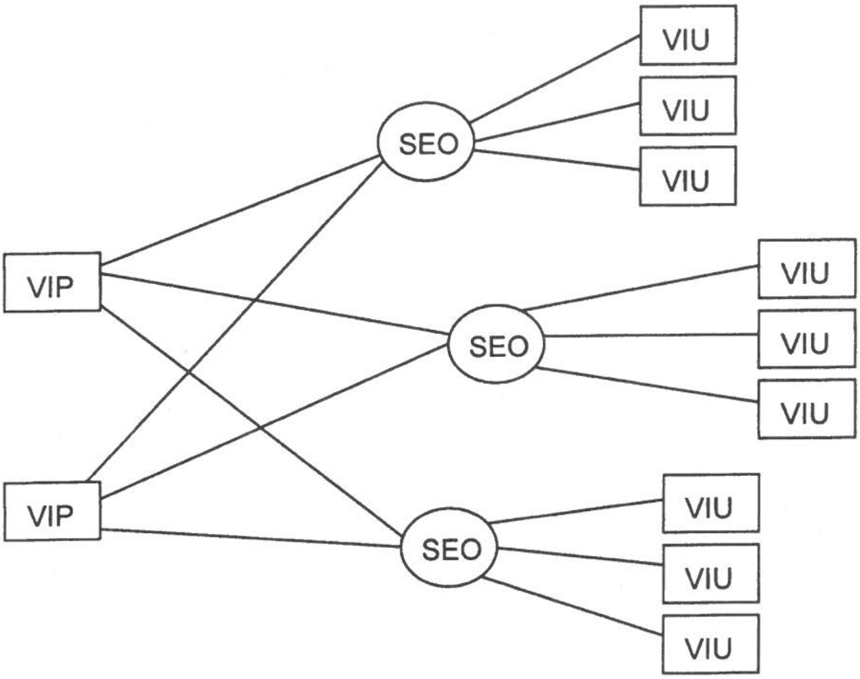

Fig. 1. Point-to-Point Architecture.

Terminal Multiplex (TM) at each end. Another way is to use a combination of existing bi-directional symmetric systems and new unidirectional asymmetric systems between the VIP and the SEO. For example, an existing bi-directional symmetric OC-3 system could be paired with a new unidirectional asymmetric OC-12 or OC-48 system for the VIP-to-SEO direction. Such a combination of two systems could not support two-way and return overhead signals and functions because the overhead signals cannot be coordinated between the two TMs at each end. It could, however, support signaling and control functions in the upstream direction.

Point-to-point architectures can be expanded to linear chain architectures by placing one or several Add Drop Multiplexes (ADMs) between the two TMs at the ends. These ADMs are linear ADMs and need not have the ring functionality.

3. Ring Architectures

SONET ring architectures can efficiently support asymmetric video services with existing bi-directional symmetric transmission equipment. This is in contrast to the above point-to-point and linear chain architectures that may require a new type of equipment designed for asymmetric transmission. Another distinction is the smaller number of facilities required to connect a number of geographically separated VIPs to a group of SEOs. This becomes evident when comparing Fig.2 with Fig.1 for the example where two VIPs are connected to the three SEOs. In the OC-N ring configuration in Fig.2, each VIP is connected to the nearest Central Office (CO) with ring access. An ADM in every ring node lets a signal enter or exit the ring via its low speed ports. Its high speed ports are interconnected and form the ring that operates at the OC-N level, where N can be 3, 12, 48, or 192.

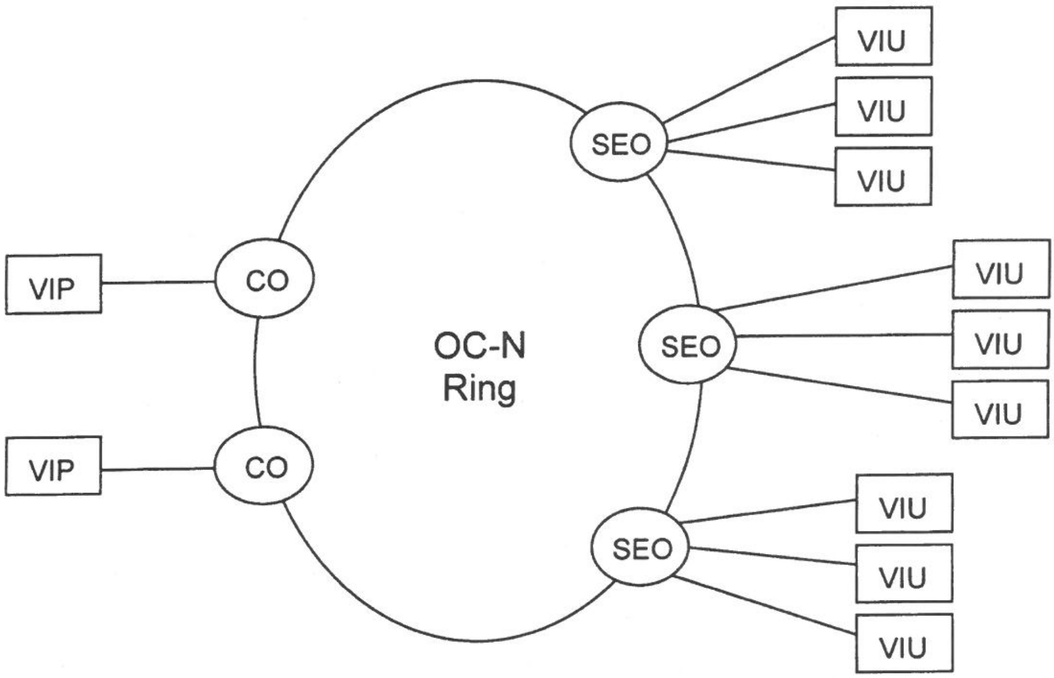

Fig. 2. Ring Architecture.

Ring architectures provide survivability by utilizing self-healing ring capabilities based on shared working and protection facilities, rather than separate working and protection lines between each pair of nodes [7] [8]. Single line failures as well as single node failures are protected, i.e., a node failure does not affect the other nodes. Both line and node failures are protected within 60 milliseconds. Ring architectures are specifically well suited for broadcast distribution of video channels (PTM), i.e., for unidirectional asymmetric distribution services in the broadcast mode. However, they can also handle point-to-point video services (PTP), i.e., bi-directional asymmetric services for interactive applications.

The above applies to both types of ring architectures: Unidirectional Path Switched Rings (UPSR) and Bi-directional Line Switched Rings (BLSR). The two types are discussed in the following two sections.

(1) Unidirectional Path Switched Rings (UPSR)

A UPSR is a 2-fiber ring where the two transmission directions of a working path (e.g., A-to-B and B-to-A) travel around the ring in one direction on one fiber, and the two transmission directions of a protection path in the other direction on the other fiber. Fig.3 shows the UPSR structure for an OC-N ring as currently in use for regular bi-directional symmetric transport. Traffic from A to B entering the ring is dual-fed at the source node (A) in both directions around the ring, on the working fiber in one direction, and on the protection fiber in the other direction. At the destination node (B), a path selector selects the better of the two received signals to exit the ring. Traffic from B to A is handled in the same manner. A ring can carry many such paths between many node pairs on the ring. The total bandwidth for all paths carried on the UPSR is limited to OC-N and is shared by all nodes on the ring. Bandwidth in non-overlapping sections of the ring cannot be reused. The UPSR provides protection against single line (or link) failures or single node failures.

The UPSR can be efficiently used for broadcast distribution of video channels (PTMs), i.e., for unidirectional asymmetric distribution services in the broadcast mode. The drop-and-continue feature makes it possible to drop paths at multiple broadcast destination nodes on the ring, as can be seen in Fig.4. A path originating at the VIP source node A can be dropped-and-continued at all broadcast destination nodes around the ring and may finally exit at the source node for monitoring purpose. The protection path is fed at the VIP source node and travels around the ring in the

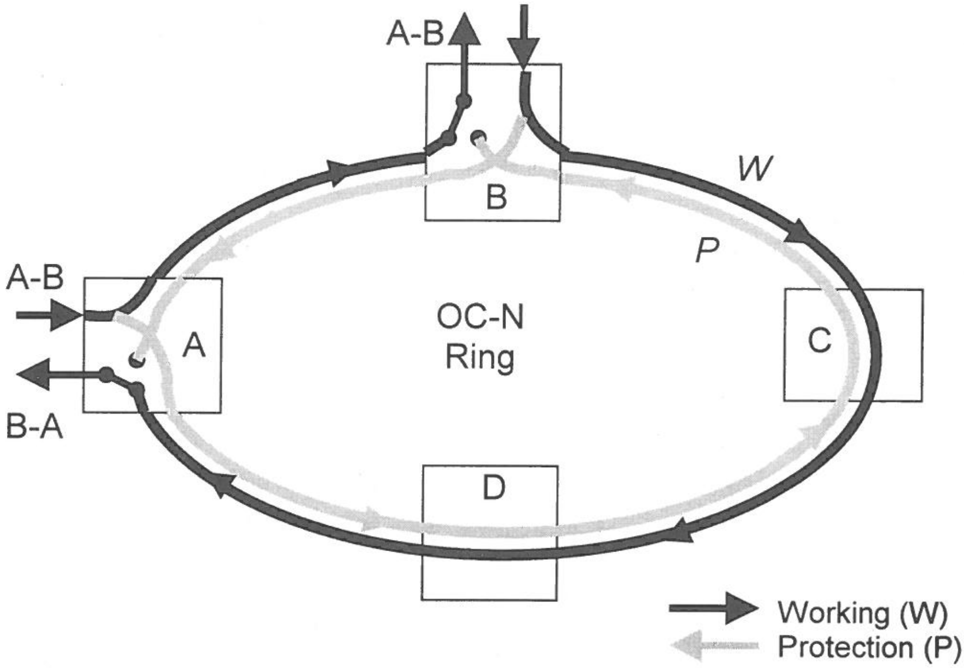

Fig. 3. Regular UPSR.

opposite direction, allowing any broadcast destination node to select the better one of two paths. The protection path, too, may travel around the whole ring back to the source node for monitoring purpose. The UPSR can carry many such broadcast paths, up to the total bandwidth of OC-N.

The UPSR can also be used for interactive video applications, i.e., for bi-directional asymmetric services in a two-way mode. Fig.5 shows an example where a path originating at the VIP source node A is again dual-fed onto the working fiber an the protection fiber, traveling on the ring in opposite directions. At the destination node C a path selector selects the better of the two received signals to exit the ring, providing protection against single line failures or single node failures. The return path (shown with dotted lines) is dual-fed at node C onto the working fiber and the protection fiber. At node A the better of the two return signals is selected. Only a very small amount of bandwidth will be used on the return path (for example for signaling

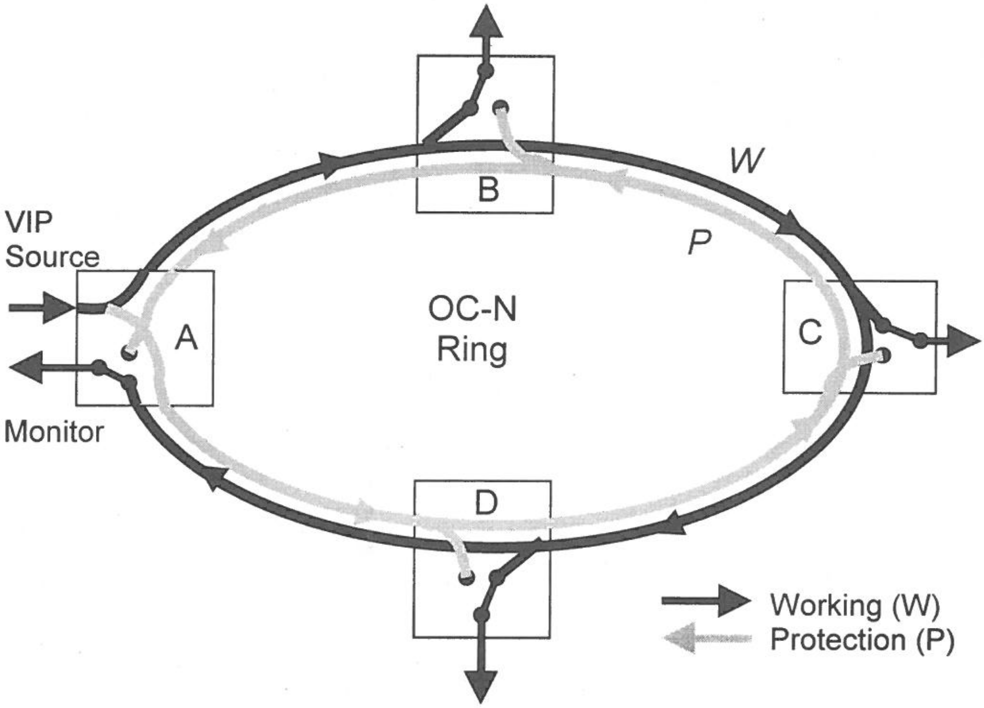

Fig. 4. UPSR for Broadcast Video.

and control functions), thus wasting most of the return bandwidth.

(2) **Bi-directional Line Switched rings (BLSR)**

A BLSR can be a 2-fiber or a 4-fiber ring, where the two transmission directions of a working path travel on the same route in opposite directions. Protection switching is performed at the line level, whereas it is done at the path level in the UPSR. Protection mechanisms are slightly different between the two types of BLSRs, as explained in the following.

Fig.6 shows the 2-fiber BLSR structure for an OC-N rings as currently in use for regular bi-directional symmetric transport. Protection is provided by reserving half the bandwidth (half the time slots) on each fiber for protection. The working half of each fiber (W 1 and W 2) is protected by the protection half on the other fiber (P 1 and P 2 ,

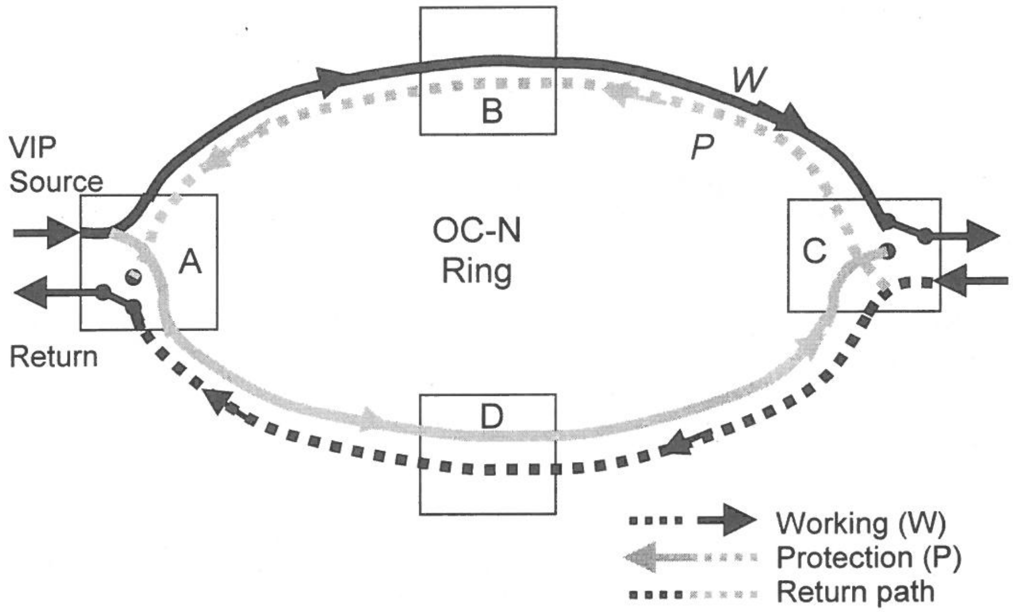

Fig. 5. UPSR for interactive video.

respectively), traveling around the ring in opposite direction. This limits the span capacity to OC-N/2; however, bandwidth in non-overlapping sections of the ring can be reused. A cable cut between A and B, as indicated in Fig.6, causes the ADMs in the two adjacent nodes to perform a ring switch (a loop back), connecting the working channels facing the cable protection against single line failures or single node failures.

Fig.7 shows the 4-fuber BLSR structure for an OC-N ring as currently in use for regular bi-directional symmetric transport. Protection is provided by two separate fibers in addition to the two working fibers. This allows a span capacity of OC-N, and further, bandwidth in non-overlapping sections of the ring can be reused. A cable cut between A and B, as indicated in Fig.7, causes the ADMs in the two adjacent nodes to perform a ring switch (a loop back), connecting the working fibers facing the cable cut to the protection fibers in the opposite direction. This mechanism provides protection against single line failures or single node failures.

Both types of BLSRs can provide highly efficient broadcast distribution of video channels , i.e., unidirectional asymmetric distribution services in the broadcast

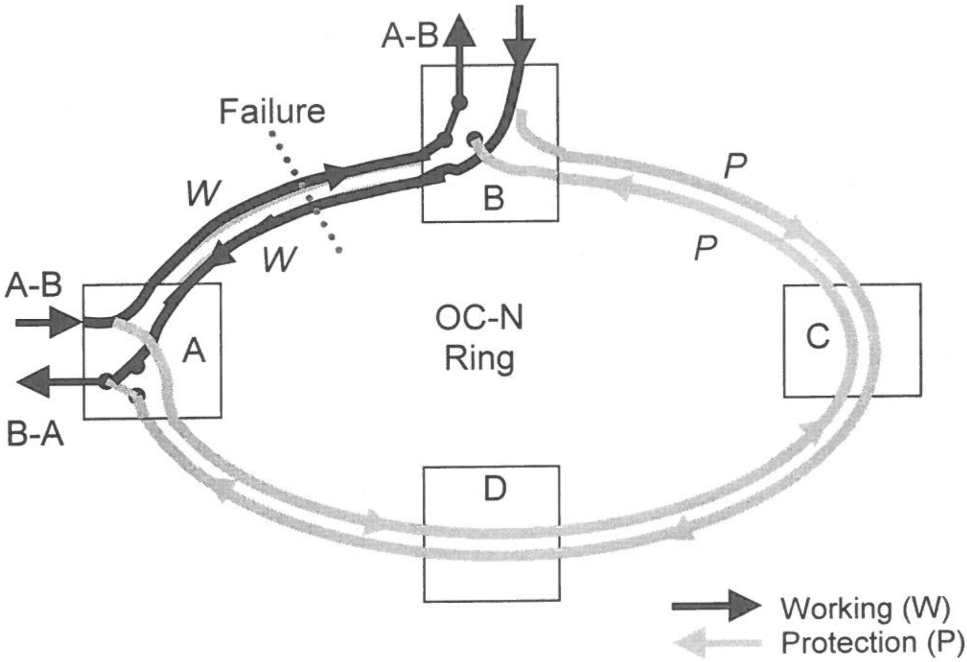

Fig. 6. Regular 2-Fiber BLSR.

mode. Since the "return" path can be used for a second set of unidirectional broadcast signals, this arrangement doubles the normal BLSR span capacity to OC-N for the 2-fiber ring and OC-2N for the 4-fiber ring. In order to reach this capacity, the ring ADMs must have a 200 percent add-drop ratio as will be discussed later. The drop-and-continue feature in the ADM, when extended to a multinode drop-and-continue feature, makes it possible to drop paths at multiple broadcast destination nodes on the ring, as can be seen in Fig.8 for the 2-fiber ring (the case for the 4-fiber ring is similar). A first path originating at the VIP source node A can be dropped-and-continued at all broadcast destination nodes around the ring may finally exit at the same source node for monitoring purpose. A second path that normally would be the reverse path, also originating at the VIP source node A, travels around the ring in the opposite direction and provides bandwidth for a second set of unidirectional broadcast signals.

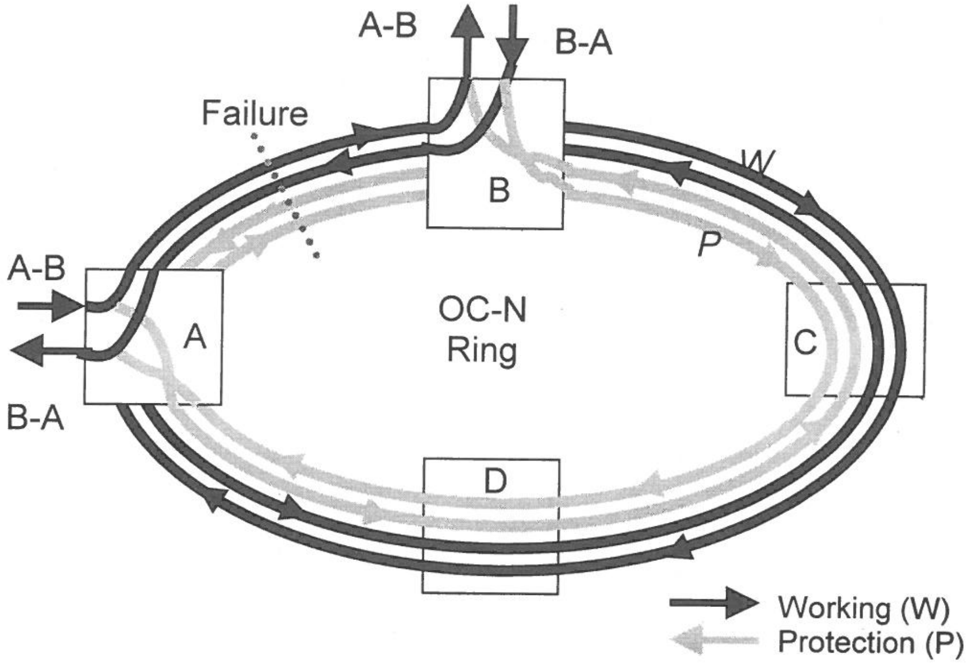

Fig. 7. Regular 4-fiber BLSR.

Both types of BLSRs can also be used for interactive video applications, i.e., for bi-directional asymmetric services in a two-way mode. Fig.9 shows an example where a path originates at the VIP source node A and is dropped at the ADM at the destination node C, for the 2-fiber ring and the 4-fiber ring, respectively. Only a very small amount of bandwidth will be used on the return path (for example for signaling and control functions), thus wasting most of the return bandwidth. The BLSR can carry many such point-to-point paths between many node pairs on the ring, up to the total span capacity of OC-N/2 for the 2-fiber ring and up to OC-N for the 4-fiber ring.

(3) SONET ATM VP Rings

The SONET ATM VP ring is a SONET-based OC-N ring, either a UPSR or a BLSR, enhanced with ATM Virtual Path (VP) processing to carry ATM traffic. Within the SONET OC - N payload , some of the bandwidth (e.g., one or several

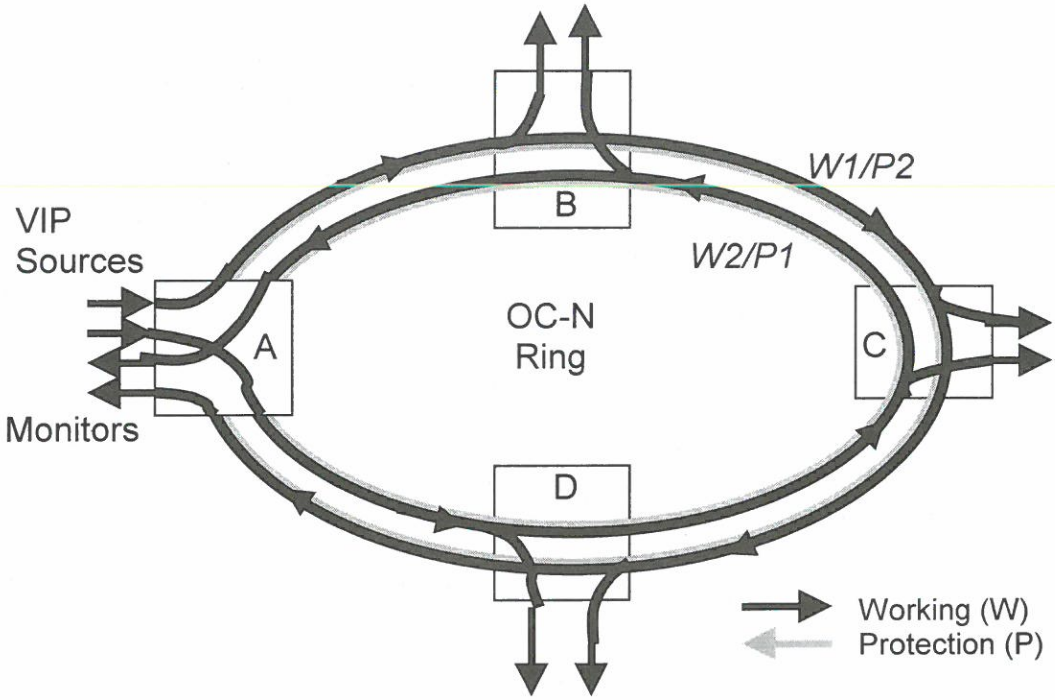

Fig. 8. 2-Fiber BLSR for Broadcast Video.

STS-1 or STS-3c paths) is reserved for ATM traffic. This reserved bandwidth can be shared by many ATM VP connections between different sets of nodes on the ring. This is made possible by a ring ADM enhanced with a Virtual Path Identifier (VPI) processor. The ATM traffic is processed at the VP layer and individual VPs can be passed through, added, or dropped. Ring capacity could be utilized much more efficiently for certain video encoding schemes (e.g., MPEG-2 encoding, where many channels could fit into a single STS-1 or STS-3c signal carrying ATM) if the rings were of the ATM VP type and video signals were converted to ATM for transmission. The ATM VP ring architecture may also provide an effective future migration path from broadcast video services to interactive video services.

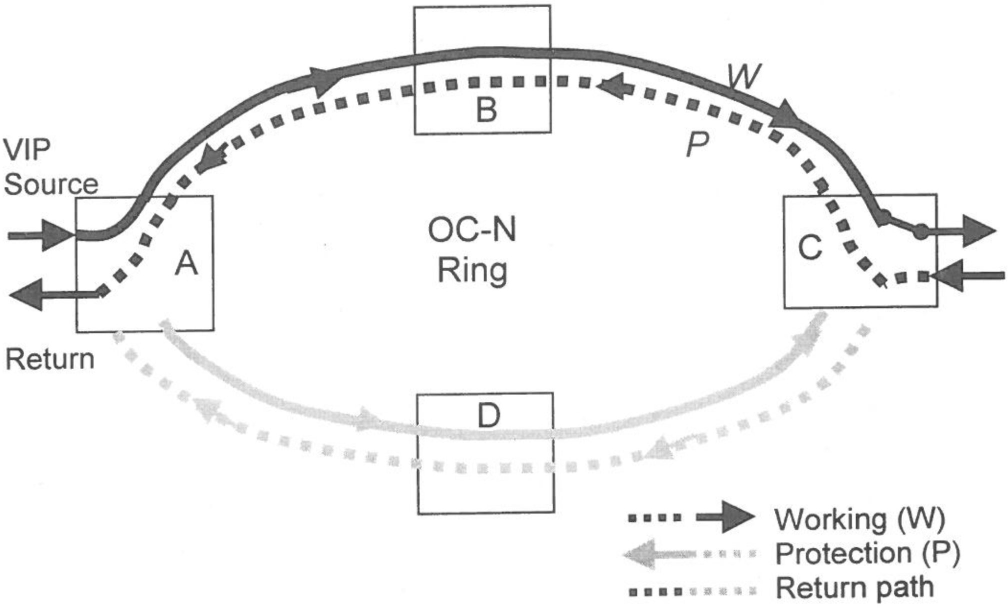

Fig. 9. 2-Fiber BLSR for Interactive Video.

IMPLICATIONS OF ASYMMETRY

1. Main Differences with Symmetric Systems

Current symmetric SONET transport facilities normally carry point-to-point services. One major difference is that asymmetric transport facilities allow for point-to-multipoint services for broadcast applications in a more efficient manner. However, SONET rings are an exception; current equipment can provide efficient asymmetric transport for broadcast applications. This is made possible by using the drop-and-continue feature in ring ADMs, a feature that is currently used for dual node ring interconnections by activating it at two ring nodes. In broadcast video applications, the drop-and-continue feature would be expanded to a multinode drop-and-continue feature that can be activated at many or most nodes on a ring. However, this new use of an existing feature is likely to require new management system support capabilities for such functions as provisioning and service assurance.

2. Asymmetric SONET Multiplex Equipment

It is expected that asymmetric SONET equipment will appear on the market in two stages. The first stage is represented by unidirectional asymmetric multiplexes, including both TMs as well as ADMs. Such unidirectional asymmetric equipment would support only downstream transmission from VIPs to SEOs/VIUs, likely for broadcast applications. The second stage would encompass bi-directional asymmetric multiplexes, again TMs and linear ADMs. In this case, the drop-and-continue feature may not be required because the main application would be for interactive video, i.e., for point-to-point services. Such bi-directional asymmetric equipment would provide a low rate upstream path (e.g., OC-3) from VIU to VIP for every high rate downstream path (e.g., OC-12 or OC-48).

Another alternative would be to achieve the second stage characteristics by using first stage equipment at an earlier point in time. This could be done in two ways. First, a combination of two first stage unidirectional asymmetric systems could be used, one with a high capacity for the downstream path and one with a low capacity for the upstream path. Second, another combination could be used with a first stage unidirectional asymmetric system of high capacity and existing bi-directional symmetric system of low capacity that could be part of an existing network.

3. Evolution of Asymmetric Equipment and Traffic

Asymmetric video services will evolve as asymmetric transport equipment and networks become available. Broadcast video services are expected to be the first services transported over SONET networks because the required equipment is much more readily available. Rings can handle broadcast video services with current equipment. Interactive video services can only be transported over SONET networks in a cost-effective manner when second stage asymmetric equipment is available. The complexity required in transport networks for providing interactive services, and the relatively low take rate experienced in several early video dial tone trials, has discouraged many telecommunications carriers from an early introduction of interactive services.

Types of SONET Equipment Used		Traffic Types: Bi-directional Symmetric, Current Mode	Traffic Types: Unidirectional Asymmetric, Broadcast PTM	Traffic Types: Bi-directional Asymmetric, Interactive PTP
Symmetric, Bi-directional	**Point-to-point Linear Chain** (TM, Linear ADM)	**A** Current use	**B** Return path wasted Use **E**	**C** Return path partly wasted
Symmetric, Bi-directional	**Ring** (Ring ADM)	Current use	Efficient use	Return path partly wasted
Asymmetric, Unidirectional	**Point-to-point Linear Chain** (TM, Linear ADM)	**D** Current use	**E** Good match	**F** Not practical
Asymmetric, Bi-directional	**Point-to-point Linear Chain** (TM, Linear ADM)	**G** Not practical	**H** Return path Wasted Use **E**	**J** Good match

Fig. 10. SONET Equipment types and Traffic Types.

Fig.10 illustrates the three types of SONET equipment that may be used for the basic three traffic types being discussed in this paper, and the impacts of supporting various traffic types for video services. The table discusses nine cases and the implications of different equipment and traffic type combinations.

The nine combination are marked with letters A through J. Obviously, Cases A, E, and J are the best matches between equipment and traffic types. Case A is the current mode of operation, while Case E and J can be expected in the near future. The other cases except F and G are also workable to various degrees indicated. Case B is very inefficient for point-to-point and linear chain systems because the return path is completely wasted; it should be avoided until Case E is available. However, Case B is very efficient for rings and represents the first priority for new asymmetric network design procedures. In Case C the return path is partly wasted (and may be deferred until second stage asymmetric equipment is available (Case J)).

Case C may be acceptable for rings, especially if rings are of the ATM VP type. In the latter case, interactive video signals would be converted to ATM for more effective transmission over ATM VP rings, where such signals could share STS-1 or STS-3c paths. Without ATM VP rings, i.e., with regular STM rings as described so far, every individual point-to-point service over the ring would use up a full STS-1 or STS-3c path. Case D represents an option to handle bi-directional symmetric traffic with a combination of two unidirectional asymmetric systems in opposite directions. A LAN could replace the two-way and return overhead functions a bi-directional symmetric system could provide. Case H is inefficient because the return path is completely wasted.

4. Enhanced Ring Capacity

As explained in previous section, ring architectures can efficiently support asymmetric video services with existing equipment, in particular for broadcast video applications. Fig.11 summarizes the maximum span capacities for the three ring types when used for the basic three types of traffic. The capacities are all referenced to OC-N rings, i.e., rings that carry OC-N signals on the fibers around the ring and on the high speed interfaces of the ADMs.

The span capacities for the BLSRs in broadcast applications are twice the normal amount because the "return" paths can be used for a second set of broadcast signals. This applies when the ring ADMs have a 200 percent add-drop ratio, i.e., the ADMs must be equipped with sufficient drop interfaces to drop 100 percent of the traffic from both sides of the ring. In practice, not all makes of ADMs may provide the full drop capability.

5. Network Demand Example

This section gives an example to illustrate the drastic differences that may be

OC-N Ring Types	Traffic Types: Bi-directional Symmetric, Current Mode (→ ←)	Traffic Types: Unidirectional Asymmetric, Broadcast PTM (→)	Traffic Types: Bi-directional Asymmetric, Interactive PTP (→ ←)
UPSR 2-Fiber	OC-N	OC-N	OC-N
BLSR 2-Fiber	OC-N/2	OC-N	OC-N/2
BLSR 4-Fiber	OC-N	OC-2N	OC-N

Fig. 11. Maximum span capacity of rings.

encountered between different network design approaches for the same set of user demands. Although the difference in the amount of equipment required for the same demands is quite obvious at the outset for this example, the best network design approach for complex networks is often not obvious and calls for an automated design mechanism.

The user demand chosen for this example consists of ten SEOs to be supplied with survivable broadcast video services from two VIPs with different programming, with a bandwidth of two OC-3s from each VIP. All SEOs and VIPs are assumed to be at different locations. We will compare two network layouts: Layout 1 using multiple point-to-point systems with current bi-directional symmetric equipment similar to Fig.1, and Layout 2 with a SONET self-healing ring through all 12 locations with current ring equipment, similar to Fig.2. Layout 1 and 2 correspond to Case B for point-to-point systems and Case B for rings, respectively, in Fig.10.

Layout 1 uses two OC-3 point-to-point systems between each VIP and SEO, which adds up to 40 point-to-point systems with 80 TMs. To provide survivability, each system needs two working fibers and two protection fibers, and to maximize survivability in the case of cable cuts, the protection fibers are routed separately from the working fibers. In the extreme case, this adds up to 80 separate fiber routes.

For Layout 2 we are choosing a 2-fiber OC-12 UPSR through the 12 locations with an ADM at each location; the ADMs at the SEOs are equipped with the drop-and-continue feature. This ring is of the type shown in Fig.4 and is filled to capacity with the four OC-3s from the two VIPs. It also provides survivability against single line or single node failures. The total equipment count is 12 ADMs and 12 fiber routes.

From the above it is obvious that the total length of all fiber routes together is drastically different in the two cases. To get a rough estimate of the difference we assume that the ring shape is close to a circle with a diameter d and that the nodes are roughly evenly distributed. For Layout 2, the total length of the fiber routes corresponds to one circumference, i.e., $d\pi$ or $3.14d$. For Layout 1, if we assume that the average route length is half the circle diameter d (i.e., an even distribution of route lengths between zero and d , which is probably a low estimate), then the total length of the fiber routes would be $40d$, or over 12 times the total length for Layout 2.

Fig.12 summarizes the characteristics of the two layout. The difference in capital required for the two layouts is drastic, even if one considers that an OC-12 ADM may cost somewhat more than an OC-3 TM, and that some of the cable routes in Layout 1 may be combined without sacrificing survivability. One point in favor of Layout 1 is the fact that it could survive multiple simultaneous failures among the separate systems. However, such failure densities are not expected in networks in general and thus this feature is of little use. In summary, the example illustrates the importance of proper network design, especially for more complex networks.

CONCLUSIONS

In this paper we investigated various SONET network design trade-offs in supporting video traffic. From a bandwidth utilization standpoint, SONET rings are well suited for serving point - to - multipoint video connections for broadcast applications

	Number of Network Elements	Number of Fiber Routes	Total Length of Fiber Routes
Layout 1 Multiple Point-to-point Systems	80 TMs	80	40*d*
Layout 2 UPSR with Drop-and-Continue for Broadcast	12 ADMs	12	3.14*d*

Fig. 12. Comparison of Two Network Implementations.

by carrying the video signal in the same time slots around the ring to be dropped-and-continued at each node. The self-healing mechanism of SONET rings provides excellent survivability against single equipment or single facility failures. Bi-directional symmetric point-to-point systems are very inefficient to support point-to-multipoint connections since half of the bandwidth is wasted. Unidirectional asymmetric SONET systems are better suited for this case. For asymmetric bi-directional interactive video traffic, this traffic can be best supported by bi-directional asymmetric systems, which present a good match to the characteristics of interactive video.

The introduction of asymmetric characteristics adds more complexity and challenges to the already complicated SONET network design procedure. It is almost intractable for planners to design an integrated SONET network (i.e., one employing both symmetric and asymmetric systems) manually that can support both symmetric and asymmetric traffic cost-effectively, given the large number of possible scenarios to be investigated.

It is possible to achieve better bandwidth efficiency be serving interactive video traffic with SONET ATM VP rings. Each interactive video connection could be mapped to a VP connection and the video signal would be converted to ATM cells before being transmitted onto the ring. The VP technology allows an OC-N ring to support as many VP connections as it takes to fill up the STS-1 or STS-3c paths designated for ATM VP use. Further study is necessary to identify the advantages and disadvantages of employing the VP ring architecture for video transport.

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適用於非對稱性視訊資料之同步光纖網路自復環之設計探討

呂 俊 賢

摘 要

同步光纖網路正在被廣泛地佈建作爲光纖傳輸之標準基礎架構，用以支援現有之寬頻電路交換服務，以及未來包括利用小封包之新式服務。現今之服務以及網路設備是專爲對稱性交通而設計。隨著政策之發展，視訊服務已逐漸顯現成爲電信業者將來一新興市場所在。視訊服務將會耗用網路上相當大的頻寬，但其雙向流量本質上卻極不對稱。具備非對稱特性的同步光纖網路設備可預見的將會很快出現於市場上。本篇論文描述各種不同的網路結構，並對於這些結構如何能用於支援非對稱交通及對稱性交通做一比較，同時藉由簡單範例來說明適切的網路設計對於整體網路成本能產生相當大的影響。

關鍵詞： 同步光纖網路、非對稱式設備、視訊服務、網路設計

Realization of Lowpass, Highpass and Bandpass Biquadratic Filters Using a Single CFA

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Abstract

New biquadratic lowpass(LP), highpass(HP) and bandpass(BP) filters using a single current-feedback amplifier(CFA), two resistors and two capacitors are suggested. The passive sensitivities of the proposed filters are either 1/2 or zero. Moreover, the quality factor and the central frequency of the proposed filters are insensitive to the voltage and current tracking errors of a CFA. Finally, three experimental results and simulative ideal curves on the theoretical analysis are included.

***Key Words*:** current-feedback amplifier, sensitivity

INTRODUCTION

The applications and advantages in the realization of various active filter transfer functions using current feedback amplifier(CFA) have received considerable attention.[(1)~(6)] This is attributed to its higher slew rate and larger bandwidth compared to the conventional operational amplifiers. Hence, analogue signal processing circuits built around the CFA are expected to operate at high frequencies than the conventional operational amplifiers.[(7)]

Recently, a number of CFA-based filters have been proposed. Abuelma'atti proposed an universal filter using two CFAs and five passive elements.[(6)] Chang proposed a voltage-mode notch/lowpass/bandpass filter using three CFAs and five passive components.[1] Liu proposed an universal filter using two CFAs and six passive elements.[4] However, the above mentioned circuits use many active and passive elements and their active and passive sensitivities are not less than 1. For these reasons, a new configuration for second-order highpass/lowpass/bandpass filters are developed. These filters have been realized using a single CFA together with two resistors and two capacitors. They require less active and passive components than the previous filters. In addition to few components (only one active element and four passive elements), the proposed circuit can provide the low values of active and passive sensitivities. Sedra proposed that the single-amplifier biquadratic active filters are more sensitive to the tolerances of the values of resistors and capacitors than the multiple-amplifier biquadratic ones.[8] However, the passive sensitivities of the proposed single-CFA filter are equal to either 1/2 or zero. Furthermore, the resonant angular frequency ω_0 and the quality factor ϑ of the proposed circuit are insensitive to the voltage and current tracking errors of a CFA. Therefore, the natural frequency and the quality factor in filtering applications would not be degraded.

CIRCUIT DESCRIPTION

A CFA symbol is shown in Fig.1. Using standard notation, its port relations are characterized as $V_x = V_y$, $V_o = V_z$, $I_z = I_x$ and $I_y = 0$. The proposed configuration for synthesizing second-order lowpass/highpass/bandpass filters using a CFA is shown in Fig.2, where the CFA is connected to four passive one-port RC networks. By applying a routine circuit analysis, the transfer function can be derived as

$$\frac{V_0}{V_{in}} = \frac{Y_1 Y_3}{Y_1 Y_3 + Y_1 Y_4 + Y_2 Y_3 + Y_2 Y_4} \tag{1}$$

where Y is admittance.

From Eq.(1), this circuit configuration can perform LP, BP and HP functions. These functions are as follows:

(1): If $Y_1 = G_1$, $Y_2 = SC_2$, $Y_3 = SC_3$ and $Y_4 = G_4$, the transfer function has a biquadratic BP characteristic with

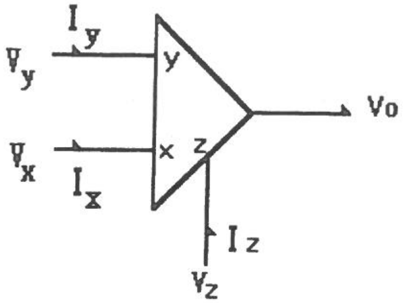


Fig. 1. A symbol of CFA

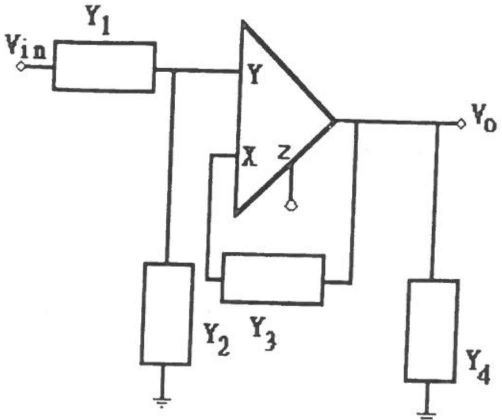


Fig. 2. Proposed configuration for bandpass, highpass and lowpass filter using a single CFA

$$\frac{V_0}{V_{in}} = \frac{s(G_1/C_2)}{s^2 + s[(C_3G_1 + C_2G_4)/C_3C_2] + (G_1G_4/C_3C_1)} \tag{2}$$

From Eq.(2), the resonant angular frequency ω_0 and the quality factor ϑ are given by

$$\omega_0 = (\frac{G_1G_4}{C_3C_2})^{1/2} \tag{3}$$

$$\vartheta = \frac{(G_1G_4C_2C_3)^{1/2}}{G_1C_3 + C_2G_4} \tag{4}$$

(2): When $Y_1 = G_1$, $Y_2 = SC_2$, $Y_3 = G_3$ and $Y_4 = SC_4$, this circuit is a biquadratic LP filter with

$$\frac{V_0}{V_{in}} = \frac{(G_1G_3/C_2C_4)}{s^2 + s[(C_2G_3 + C_4C_1)/C_2C_4] + (G_1G_3/C_2C_4)} \tag{5}$$

From Eq.(5), the resonant angular frequency ω_0 and the quality factor ϑ are given by

$$\omega_0 = (\frac{G_1G_3}{C_2C_4})^{1/2} \tag{6}$$

$$\vartheta = \frac{(G_1G_3C_2C_4)^{1/2}}{C_2G_3 + C_4G_1} \tag{7}$$

(3): Similarly, If $Y_1 = SC_1$, $Y_2 = G_2$, $Y_3 = SC_3$ and $Y_4 = G_4$, the circuit performs a biquadratic HP function with

$$\frac{V_0}{V_{in}} = \frac{s^2}{s^2 + s[(C_1G_4 + C_3G_2)/C_1C_3] + (G_2G_4/C_1C_3)} \tag{8}$$

From Eq.(8), the resonant angular frequency ω_0 and the quality factor ϑ are given by

$$\omega_0 = (\frac{G_2G_4}{C_1C_3})^{1/2} \tag{9}$$

$$\vartheta = \frac{(C_1C_3G_2G_4)^{1/2}}{C_1G_4 + C_3G_2} \tag{10}$$

Apparently, three kinds of filters are derived from equation (1).

SENSITIVITY ANALYSIS AND EXPERIMENT RESULTS

Let the character of a non-ideal CFA be given by $V_x = \alpha V_y$, where $\alpha = 1\text{-}\varepsilon$ and $\varepsilon(|\varepsilon| \ll 1)$ denotes the voltage tracking error from the Y terminal to the X terminal of a CFA. The transfer function of the Figc2 through a complete analysis is:

$$\frac{V_0}{V_{in}} = \frac{\alpha Y_1Y_3}{Y_1Y_3 + Y_1Y_4 + Y_2Y_3 + Y_2Y_4} \tag{11}$$

By relating a sensitivity parameter F to the element of variation X_i by

$$S_{X_i}^F = \frac{x_i}{F}\frac{dF}{dx_i} \tag{12}$$

it is easy to show that the active and passive sensitivities of the parameters ω_0 and ϑ can be expressed as:

(1) BP filter [for equations (3), (4) and (11)]:

$$S^{\omega_0}_{G_1} = S^{\omega_0}_{G_4} = \frac{1}{2},\ S^{\omega_0}_{C_2} = S^{\omega_0}_{C_3} = -\frac{1}{2},\ S^{\omega_0}_{\alpha} = S^{\vartheta}_{\alpha} = 0$$

If $G_1C_3 = C_2G_4$, then $S^{\vartheta}_{G_1} = S^{\vartheta}_{G_4} = S^{\vartheta}_{C_2} = S^{\vartheta}_{C_3} = 0$.

(2) LP filter [for equations (6), (7) and (11)]:

$$S^{\omega_0}_{G_1} = S^{\omega_0}_{G_3} = \frac{1}{2},\ S^{\omega_0}_{C_2} = S^{\omega_0}_{C_4} = -\frac{1}{2},\ S^{\omega_0}_{\alpha} = S^{\vartheta}_{\alpha} = 0$$

If $G_3C_2 = C_4G_1$, then $S^{\vartheta}_{G_1} = S^{\vartheta}_{G_3} = S^{\vartheta}_{C_2} = S^{\vartheta}_{C_4} = 0$.

(3) HP filter [for equations (9), (10) and (11)]:

$$S^{\omega_0}_{G_2} = S^{\omega_0}_{G_4} = \frac{1}{2},\ S^{\omega_0}_{C_3} = S^{\omega_0}_{C_1} = -\frac{1}{2},\ S^{\omega_0}_{\alpha} = S^{\vartheta}_{\alpha} = 0$$

If $G_4C_1 = C_3G_2$, then $S^{\vartheta}_{G_2} = S^{\vartheta}_{G_4} = S^{\vartheta}_{C_1} = S^{\vartheta}_{C_3} = 0$.

Clearly, all the active sensitivities are equal to zero and all the passive sensitivities are either 1/2 or zero.

Lowpass, highpass and bandpass filter prototypes have been constructed with discrete components to explain the reliability of the circuit given above. Moreover, the Matlab has carried out simulating the ideal curves of these filters. The AD844 was used as the CFA. The experimental results for the gain and phase responses of the above mentioned filters are as follows:

(1) A second-order BP filter with the condition of Eq.(2) is constructed with $C_2 = C_3 = 1$uF and $G_1 = G_4 = 1$m $(\Omega)^{-1}$. The proposed BP filter circuit is shown in Fig.3. The experimental results and simulative ideal curves are shown in Fig.6 (a)(b).

(2) A biquadratic LP filter, shown in Fig.4, under the condition of Eq. (7) is constructed with $C_2 = C_4 = 1$uF and $G_1 = G_3 = 1$m $(\Omega)^{-1}$. The experimental results and simulative ideal curves are shown in Fig.6(c)(d).

(3) A biquadratic HP filter, shown in Fig.5, with the condition of Eq. (10) is constructed with $C_1 = C_3 = 1$uF and $G_2 = G_4 = 1$m $(\Omega)^{-1}$. The experimental results and simulative ideal curves are shown in Fig.6(e)(f).

Clearly, the measured frequency response of the filter satisfactorily supports the theory.

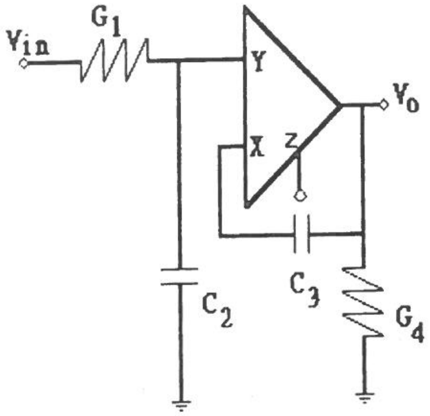


Fig. 3. Second-order bandpass filter

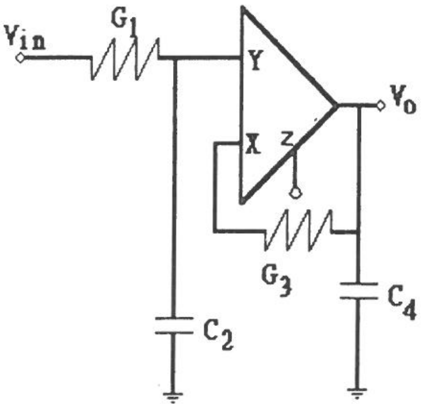


Fig. 4. Second-order lowpass filter

CONCLUSION

The realization of lowpass, highpass and bandpass filters using a single CFA and four passive elements has been presented. These filters use only one active element and four passive elements. The passive sensitivities of the proposed circuit are either 1/2 or zero. Moreover, the resonant angular frequency ω_0 and the quality factor ϑ of the proposed circuit are insensitive to the voltage and current tracking errors of a CFA. Hence , the resonant angular frequency and the quality factor of the proposed circuit

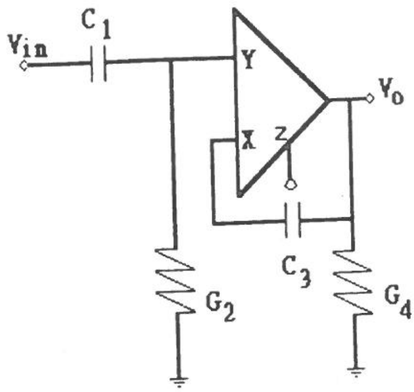
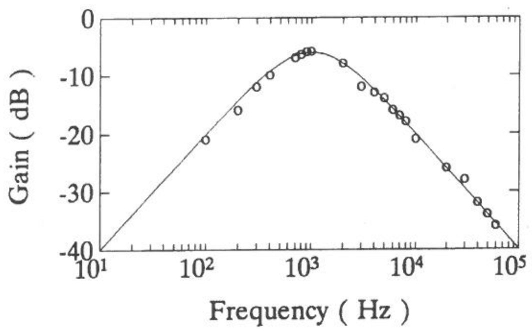
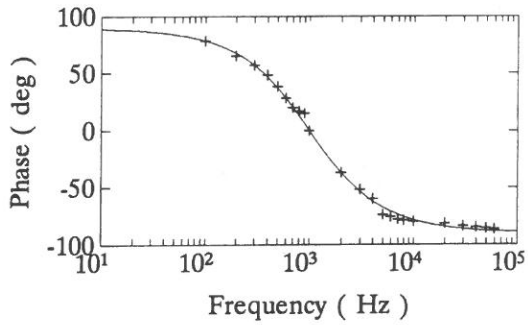


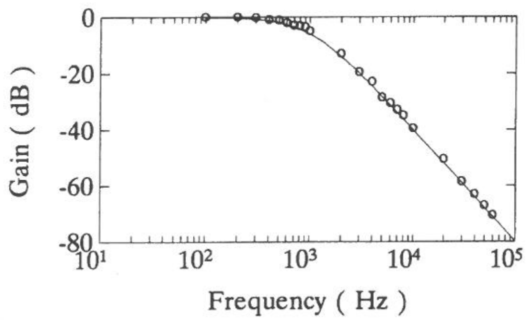
Fig. 5. Second-order highpass filter



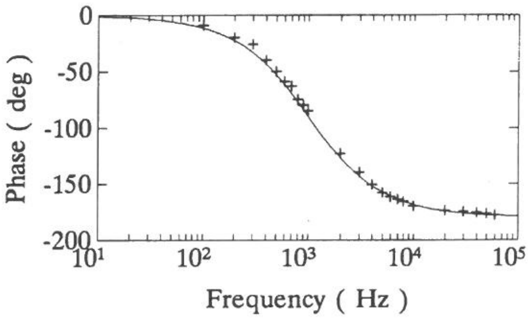
6 (a)



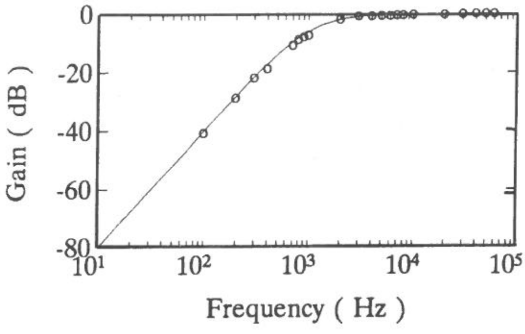
6 (b)



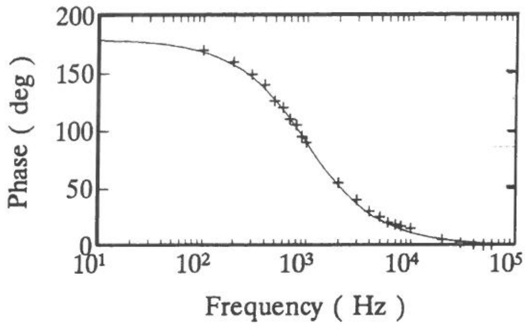
6 (c)



6 (d)



6 (e)



6 (f)

Fig. 6. (a) Bandpass magnitude-frequency response.
(b) Bandpass phase-frequency response.
(c) Lowpass magnitude-frequency response.
(d) Lowpass phase-frequency response.
(e) Highpass magnitude-frequency response.
(f) Highpass phase-frequency response.
Solid curves: simulative ideal curve.
0: experimental result for gain.
+ : experimental result for phase. D

would not be degraded. Finally, three experimental results agree well with the theoretical analysis. The results will be useful in analogue signal processing applications.

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使用單一電流迴授放大器合成二階式低通,高通與帶通濾波器

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摘　要

本文提出使用單一電流迴授放大器配用兩個電阻與兩個電容合成二階式低通,高通與帶通濾波器。此濾波器所使用的元件非常少。另外,被合成之濾波器其被動靈敏度是二分之一或是零，主動靈敏度爲零。所以其品質因素與中心頻率沒有電流與和電壓軌跡誤差問題。最後除理論的分析外三種濾波器的實驗結果也被包含在內。

關鍵詞： 電流迴授放大器，靈敏度

Studies of Hydrated Surface Layer on Calcium Aluminogermanate glasses by IR Spectroscopy

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Abstract

Calcium aluminogermanate glasses exhibit high transparency over frequencies ranging from the near UV (0.2 μm) to the mid-IR (5~6μm). They are excellent infrared transmitting materials. In this paper the attack of pure water on the surface layer of two calcium aluminogermanate glasses was studied by IR spectroscopy. Infrared absorption measurements were performed as a function of time and temperature for these glasses. The relationship between the absorbance and immersion time will be discussed in light of diffusion theory and the development of the absorption peak is related to a surface layer formation on these glasses.

Key Words: calcium alumiogermanate glasses, hydrated surface layer, IR spectroscopy.

INTRODUCTION

It is well known that calcium aluminate oxide glasses exhibit high transparency over frequencies ranging from the near UV (0.2 μm) to the mid-IR (5~6 μm) [1-3]. Recent experiments have also suggested that a small addition of silica to calcium aluminate glasses gives the lower intrinsic Rayleigh scattering loss than that observed in fused silica [4], [5]. These properties make them promising candidate for a variety of applications ranging from IR domes, laser windows to infrared fiber optics.

Pure calcium aluminate (i.e. silica and alkali-metal free) glasses tend to be moisture sensitive and some type of protection is normally provided when they are in transmitting windows. Germanate glasses are of interest for optical transmission applications due to their long IR cut-off wavelength relative to silicate glasses.

The corrosion problem of optical glasses in aqueous solution is fundamentally important. In this paper we add germanate composition into calcium aluminate glass system and study the effects of pure water on the surface layer of two calcium aluminogermanate glasses as a function of time and temperature by IR spectroscopy.

The absorption peak at 3400cm^{-1} was observed and was developed as time went on. This peak is due to the OH^- stretching mode. The results will be explained by a general diffusion process and the development of absorption peak is related to hydrated surface formation on these glasses.

EXPERIMENTAL ASPECT

Two different compositions of calcium alumino- Germanate glasses were used in our experiment. The CAG-1 contains CaO (34.170 mole%), Al_2O_3 (35.187 mole%) GeO_2 (30.550 mole%), ZnO (0.061 mole%), BaO (0.032 mole%); and the CAG-2 contains CaO43.090 mole%), Al_2O_3 (31.91 mole%) and GeO_2 (25 mole%). Both of the batches were melted on a Pt plate at 1500℃ for 30min to 1 hour, then fast quenched to the room temperature. The melting atmosphere was the air.

The glass samples were cut into small thin plates using low speed diamond saw with a few mm in thickness. The plates were polished with a series of silicon carbide papers (400, 600, 800, and 1200 grit) before starting any experiments; the final polishing step was done with 0.05 μm Alumina powder in water. The glass samples were immersed in a large beaker of distilled water for a measured time, removed from the water, cleaned ultrasonically in acetone and then in hexane to eliminate adhering liquid water, and the IR absorption spectra were carried out on a Perkin-Elmer 2000 spectrometer. The resolution of the instrument is 0.7cm^{-1} in 400-4500 cm^{-1} region. Then we ground off thin surface layers lightly from corroded samples, immersed glass samples in water for longer time, and the above procedure continued.

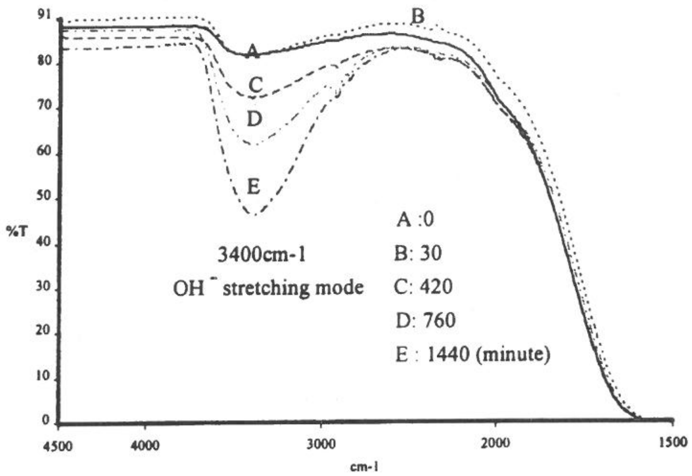

Fig. 1. IR transmission spectra of CAG-1 glass as a function of immersion time in water at 23℃.

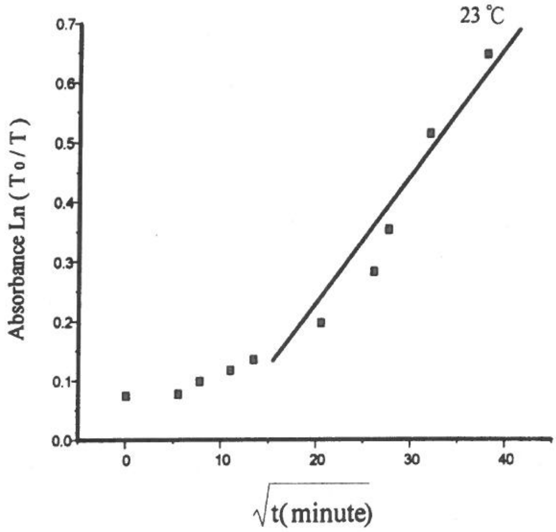

Fig. 2. Development of $3400cm^{-1}$ OH^- band with various duration of immersion for CAG-1 glass in water at 23℃.

Experiments were done at three different temperatures, 23±2℃, 45±2℃ and 65±2℃, respectively. The water was changed frequently to keep the pH value in the range of 6.2~7.5.

RESULTS AND DISCUSSION

The infrared transmission spectra of CAG-1 glass as a function of immersed time at 23℃ is given in Fig.2. The IR cut off (multiphonon edge absorption) is at about 5 ~6 μm for this glass. The absorption peak at 3400cm^{-1} was observed and was developed as time went on. The rate of transparency (the degree of transmission) in frequency ranges outside the absorption peak and the multiphonon edge increases initially [6], then decreases substantially at longer time. The initial increase may arise due to the change in the refractive index and the reflectivity of the hydrated surface of the glass samples [7, 8]. The long time decrease in transparency is due to the surface scattering from hydrated layers of the glass samples.

The hydrated layers are moderately stable in air at room temperature. The intensities of the 3400cm^{-1} absorption bands did not change when a hydrated sample was allowed to sit for a few hours in the ambient laboratory atmosphere.

When a glass is immersed in water or aqueous solution, the hydrated surface layer due to interionic exchange reaction and the dissolution of the glass network may take place. We restrict our study here on the hydrated surface layer only. Since the process is diffusion controlled, the depth of the hydrated layer is proportional to the square root of reaction time [9, 10, 11].

The absorbance of the glass, A, was calculated from IR spectra. And the absorbance is expressed as

$$A = Ln\ (T_0/T) \tag{1}$$

where T is the transmission at the peak of the absorption band and T_0 the transmission in adjacent frequency regions of negligible absorption (base line).

The absorbance of the CAG-1 glass versus the square root of the reaction time is given in Fig.3. The linearity of the absorbance versus $\sqrt{t}$ at long time agrees with a general diffusion process of water into the glass. The non-zero intercept on the $\sqrt{t}$ axis was attributed to the presence of a surface layer left on the initial glass after polishing

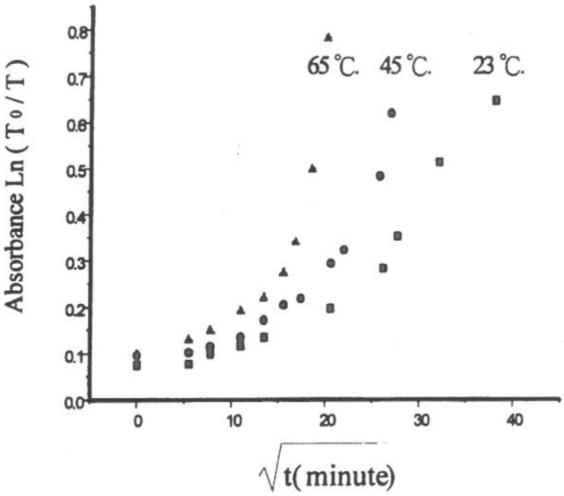

Fig. 3. Development of 3400cm^{-1} OH^- band with various duration of immersion for CAG-1 glass in water at different temperature.

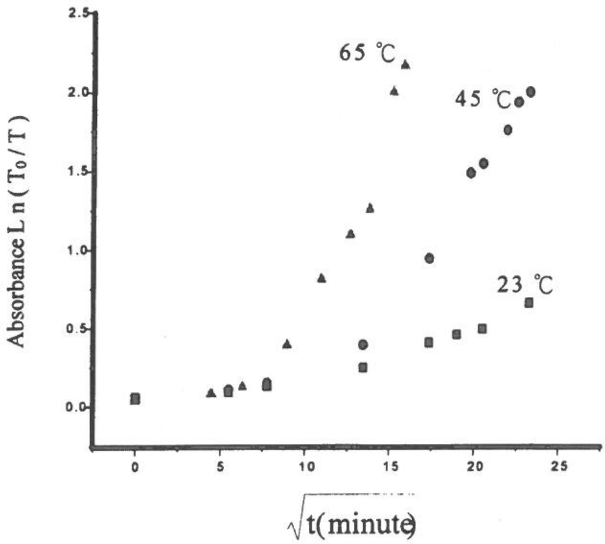

Fig. 4. Development of 3400cm^{-1} OH^- band with various duration of immersion for CAG-2 glass in water at different temperature.

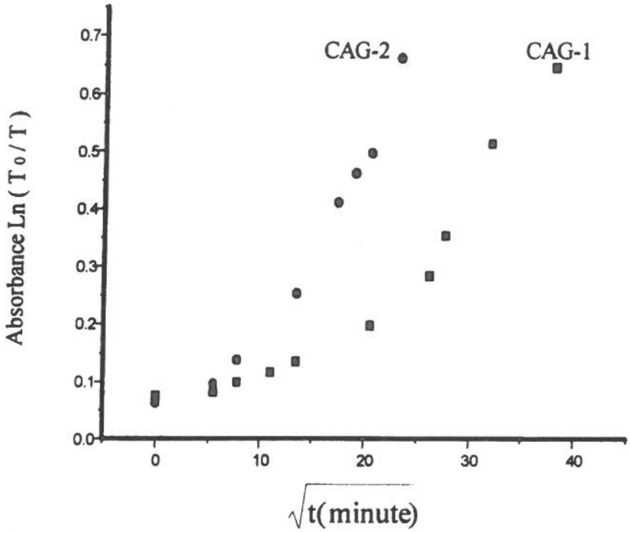

Fig. 5. Development of OH^- band with various during of immersion for CAG-1 and CAG-2 glasses in water at 23℃.

which had to be dissolved away before water attack on the glass could occur [11, 12].

The absorbance versus $\sqrt{t}$ of CAG-1 and CAG-2 glasses at three different temperatures for OH^- absorption peak are given in Figs. 4 and 5, respectively. We find that the diffusion rate for each glass sample is greater at high temperature than that at low temperature.

For comparison purpose, we plot the absorbance versus $\sqrt{t}$ of the OH^- absorption peak for two calcium aluminogermanate glasses, in Fig. 6. It is well known that Al_2O_3 can improve the resistance of glasses to attack by water. This agrees with our experimental observation which the CAG-1 glass with higher Al_2O_3 contents in the glass composition gives the better chemical durability in water than that of CAG-2 glass.

Finally at much longer immersed time, the bladelike crystal was observed on the surface of the glass sample. The origin of this surface deposits will be the next question to answer.

CONCLUSION

We have measured the infrared absorption spectra of two calcium aluminogermanate glasses as a function of time and temperature. By comparing the rate of development of OH absorption peak in two CAG glasses, we find the CAG-1 glass has better water resistance than the CAG-2 glass. When the environment changes to higher temperature, both glass samples show worse chemical durability in water.

The appearance of the bladelike crystal on the glass surface at much longer time may be related to the dissolution of the glass network. We are conducting a further study on the crystallinity and origin of surface deposits analysis by X-ray diffraction technique.

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用紅外光譜術研究鈣鋁鍺玻璃的表面水化層

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摘　　要

鈣鋁鍺玻璃其波長從近紫外光區（0.2μm）到中紅外光區（5-6μm）展現出高的透明度，它是一種高紅外穿透的材料，在這一篇論文中用紅外光譜的技術來研究兩種鈣鋁鍺玻璃被水侵蝕後的表面層，從這些玻璃的紅外吸收光譜的量測可得到時間與溫度的函數的關係，而吸收係數和浸泡時間的兩者之間的關係可由一般的擴散理論及這些玻璃表面層逐漸產生的吸收峰有關連。

關鍵詞： 鈣鋁鍺玻璃，紅外光譜術，表面水化層。

Distributional Property of the Incapability Index C_{pp} Under Edgeworth Series Distribution for Processes with Symmetric Tolerances

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Abstract

Greenwich and Jahr-Schaffrath (1995) introduced an incapability index C_{pp} which provides an uncontaminated separation between information concerning process accuracy and process precision. They proposed a natural estimators and study approximate confidence interval of C_{pp} for both small and large samples under normality. Chen (1998) showed that such natural estimators are UMVUE under normality. However, the true distribution of measurements is never known exactly. In this article, regardless the sample sizes, by assuming the underlying process distributions are close to normal and can be approximated by Edgeworth series, the distribution of the natural estimator for processes with symmetric tolerance is derived.

***Key Words*:** symmetric tolerance; statistical process control

INTRODUCTION

A process capability index is a numerical measure that describes whether a production process is capable of producing items within the specification limits predetermined by the designer. These indices have received substantial attention in the quality control and statistical literature since Burr's (1976) pioneering work. In recent times, there have been many contributions by Sullivan (1984), Kane (1986), Chan, Cheng and Spring (1988), Choi and Owen (1990), Bissell (1990), Pearn et al. (1992). Choi and Owen (1990), Bissell (1990), Pearn et al. (1992).

Greenwich and Jahr-Schaffrath (1995) introduced the incapability index under normality:

$$C_{pp} = \frac{(\mu - T)^2}{[\frac{1}{3}min\{U - T,\ T - L\}]^2} + \frac{\sigma^2}{[\frac{1}{3}min\{U - T,\ T - L\}]^2},$$

where μ is the process mean, σ^2 is the process variance, T is the target value, L and U are the lower and upper specification limits, respectively. This index provides an uncontaminated separation between information concerning the process accuracy and process precision. Greenwich and Jahr-Schaffrath (1995) discuss confidence intervals for C_{pp} based on a small and large samples.

When both the mean μ and the variance σ^2 of the measurement are unknown, Greenwich and Jahr-Schaffrath (1995) proposed an unbiased and consistent estimator $\tilde{C}_{pp}$ of C_{pp} under normality for small samples as the following:

$$\tilde{C}_{pp} = \sum_{i=1}^{n}(X_i - T)^2/nD^2,$$

where $D = \frac{1}{3}min\{U - T,\ T - L\}$. For large samples, by assuming that the fourth moment exists, a natural estimator defined by

$$\hat{C}_{pp} = \frac{(\overline{X} - T)^2}{D^2} + \frac{S_n^2}{D^2},$$

is asymptotically normally distributed with mean C_{pp} and variance σ_{pp}^2/n, where $\overline{X} = \sum_{i=1}^{n}X_i/n$ and $\sigma_{pp}^2 = \frac{4(\mu - T)^2\sigma^2}{D^4} + \frac{4\mu_3(\mu - T)}{D^4} + \frac{\mu_4 - \sigma^4}{D^4}$, $\mu_3 = E[(X - \mu)^3]$ and $\mu_4 = E[(X - \mu)^4]$. Chen (1998) showed that such a natural estimator is UMVUE under normality and the rth moment of the estimator is derived.

For the processes with symmetric tolerance, $T = (U + L)/2$, $U - T = d$ and $T - L = d$, where $d = \frac{U - L}{2}$ is the half length of specification interval (L, U). Hence the incapability index becomes $C_{pp} = (\frac{3}{d})^2[(\mu - T)^2 + \sigma^2]$. The estimator $\hat{C}_{pp} =$

$(\frac{3}{d})^2[(\overline{X} - T)^2 + S_n^2]$ is again an UMVUE of C_{pp} under normality.

There are lots of advantages of normality. However, in the real world, there are a variety of processes that result in a close to but non-normal distribution for process characteristics. An estimator is chosen to perform well under the conditions that are assumed to underly the data. However, these conditions are never known exactly, estimators must be chosen which are robust, and perform well under a variety of underlying conditions. The Edgeworth series distribution is often used to study the effects of nonnormality since it has the advantage of producing the disturbances in the skewness and kurtosis of desired extent. In this article, we study the distribution of $\hat{C}_{pp}$, the natural estimator of C_{pp}, when the underlying distributions of the measured characteristics are close to normal and can be approximated by an Edgeworth series (Hall (1992)).

DISTRIBUTION OF THE ESTIMATOR UNDER EDGEWORTH SERIES DISTRIBUTION

Let X be a variate with mean μ and variance σ^2, the 3^{rd} and 4^{th} cumulants $\kappa_3 = \lambda_3\sigma^3$ and $\kappa_4 = \lambda_4\sigma^4$, respectively. Assume all the higher cumulants to be zero, such that, to the third approximation of the law of error, the frequency function of X is a Edgeworth series defined as $f(x) = \phi(x) - \frac{\lambda_3}{6}\phi^{(3)}(x) + \frac{\lambda_4}{24}\phi^{(4)}(x) + \frac{\lambda_3^2}{72}\phi^{(6)}(x)$, where $\phi(x)$ is the density of the standard normal distributon. Then the expected value $\mu = 0$, and the variance $\sigma^2 = 1$. To ensure the unimodality and positive definiteness of the density function, Barton and Dennis (1952) suggested that λ_3 is chosen such that $\lambda_3 \leq 0.2$, and $\lambda_4 \in (0, 2.4)$.

Lemma 1: [Gayen (1949)]

Let $X_1, X_2, \ldots, X_n$ be a random sample from the Edgeworth series distribution defined as above. Let $S_1 = n\overline{X}$, $S_2 = nS_n^2$, then the joint density of S_1 and S_2 is given by

$$g_{s_1,s_2}(s_1, s_2) = \frac{e^{-\frac{s_1^2}{2n}}}{\sqrt{2\pi n}} \frac{s_2^{\frac{1}{2}(n-3)} e^{-\frac{1}{2}s_2}}{2^{\frac{n-1}{2}}\Gamma(\frac{n-1}{2})}\{1 + \frac{n\lambda_3}{3!}[H_3(\frac{s_1}{n}) + 3(\frac{s_2}{n})H_1(\frac{s_1}{n})] + \frac{n\lambda_4}{4!}[H_4(\frac{s_1}{n}) +$$

$$6(\frac{s_2}{n})H_2(\frac{s_1}{n})] + 3\frac{n-1}{n+1}(\frac{s_2}{n})^2] + \frac{n\lambda_3^2}{72}[n(\frac{s_1}{n})^3 - 3(2n+3)(\frac{s_1}{n})^4 + 9(n+4)(\frac{s_1}{n})^2 - 15 +$$

$$6\frac{s_2}{n}(n(\frac{s_1}{n})^4 - 3(n+3)(\frac{s_1}{n})^2 + 6) + \frac{9}{n+1}(\frac{s_2}{n})^2(n(n+1)(\frac{s_1}{n})^2 - 3(n-1)) + 6 \frac{n(n-2)}{(n+3)(n+1)}(\frac{s_2}{n})^3]\},$$

where $H_\upsilon(x)$ is the Hermitian polynomial of degree υ in x .

Consider the natural estimator $\hat{C}_{pp}$ of the incapability index C_{pp} for a process with symmetric tolerance (i.e. $T = M$) by replacing the parameters μ and σ^2 by the sample mean $\overline{X}$ and the sample vaisrance S_n^2 , respectively. Then

$$\hat{C}_{pp} = (\frac{3}{d})^2[(\overline{X} - T)^2 + S_n^2].$$

Theorem 1: The density of $\hat{C}_{pp}$ is given by

$$f_{\hat{C}_{pp}}(\omega) = \{B_{-3}(\omega)\{\frac{\lambda_3^2(n^2+4n-3)}{72n^4(n+1)(n+3)}(\frac{\omega}{k})^3 + [\frac{\lambda_4}{n^3 4!} - \frac{\lambda_3^2(12T^2+5+\frac{9}{n})}{72n^2}](\frac{\omega}{k})^2 + [\frac{\lambda_3^2}{72}T^4 + (\frac{\lambda_4}{4n} - \frac{\lambda_3^2}{24} - \frac{\lambda_3^2}{8n})T^2 + \frac{\lambda_3}{2n}T - \frac{\lambda_4}{4n} + \frac{2\lambda_3^2}{9n}](\frac{\omega}{k}) + \frac{n^2\lambda_3^2}{72}T^6 - [\frac{n(2n+3)\lambda_3^2}{24} + \frac{n\lambda_4}{4!}]T^4 + \frac{n\lambda_3}{3!}T^3 + [-\frac{n\lambda_4}{4} + \frac{n\lambda_3^2}{8}(n+4)]T^2 - \frac{n\lambda_3}{2}T + \frac{n\lambda_4}{4} - \frac{5n\lambda_3^2}{24} - 14\}$$

$$+ B_{-1}(\omega)\{\frac{\lambda_3^2}{24n^3}[\frac{n^2+4n+9}{n(n+1)(n+3)} - \frac{2T^2}{n-1}](\frac{\omega}{k})^2 + [-\frac{5\lambda_3^2}{18(n-1)}T^4 + \frac{1}{6(n-1)}(\frac{\lambda_3^2(4n+1)}{n^2} - n\lambda_4)T^2 - \frac{\lambda_3}{6n^2(n-1)}T - \frac{\lambda_3^2}{12n^2}(1+\frac{6}{n}) + \frac{\lambda_4}{6}](\frac{\omega}{k})$$

$$- \frac{\lambda_3^2 n}{12(n-1)}T^6 + \frac{1}{6}(-\frac{\lambda_4}{n+1} + \frac{\lambda_3^2 n(2+\frac{3}{n})}{n-1})T^4 - \frac{\lambda_3}{2(n-1)}T^3 - [\frac{\lambda_4}{2(n+1)} + \frac{\lambda_3^2}{n-1}(\frac{n}{4} + 1)]T^2 + \frac{\lambda_3}{2(n-1)}T\} + B_1(\omega)\{-\frac{\lambda_3^2}{12n^3(n+1)}[\frac{3}{n(n+3)} + 2T^2](\frac{\omega}{k}) +$$

$$\frac{\lambda_3^2 n}{18n(n+1)}T^4 + \frac{\lambda_4 + \frac{5}{2}\lambda_3^2}{3n^2(n+1)}T^2 - \frac{\lambda_3}{3n^2(n+1)}T + \frac{-\lambda_3(n+4) + \lambda_3^2(2n^2+5n+12)}{12n^3(n+1)}\}$$

$$- B_3(\omega)\{\frac{\lambda_3^2(2n^2+5n+9)}{36n^4(n+1)(n+3)}\}\}\frac{C}{kn},$$

where $B_l(w) = \int_{-\sqrt{\frac{\omega}{k}}}^{\sqrt{\frac{\omega}{k}}} e^{-Ty} \cdot (\frac{\omega}{k} - y^2)^{\frac{n+l}{2}} dy$, $l = -3, -1, 1, 3$.

$$C = \frac{n^{\frac{n-3}{2}} e^{-\frac{1}{2}(nT^2 + \frac{\omega}{nk})}}{\sqrt{2\pi n}\, 2^{\frac{n-1}{2}} \Gamma(\frac{n-1}{2})}, \text{ and } k = (\frac{3}{nd})^2.$$

[Proof]

Let $k = (\frac{3}{nd})^2$, then $\hat{C}_{pp} = (\frac{3}{d})^2[(\overline{X} - T)^2 + S_n^2] = k[(S_1 - nT)^2 + nS_2]$.

Let $\begin{cases} W = k[(S_1 - nT)^2 + nS_2] > 0 \\ Y = S_1 - nT \end{cases}$

$\Rightarrow \begin{cases} S_1 = Y + nT \\ S_2 = (\frac{W}{k} - Y^2)\frac{1}{n} > 0 \Rightarrow -\sqrt{\frac{W}{k}} < Y < \sqrt{\frac{W}{k}}. \end{cases}$

The Jacobian is $J = \begin{vmatrix} \frac{dS_1}{dW} & \frac{dS_1}{dY} \\ \frac{dS_2}{dW} & \frac{dS_2}{dY} \end{vmatrix} = -\frac{1}{nk}$.

Then the joint probability density function of W and Y is given by

$$f_{W,Y}(\omega, y) = g_{s_1, s_2}(s_1, s_2) \mid J \mid = \frac{1}{kn} g_{s_1, s_2}(s_1, s_2).$$

$$= \frac{n^{\frac{3-n}{2}} e^{-(nT^2+\frac{\omega}{nk})/2}}{\sqrt{2\pi n}\, 2^{\frac{n-1}{2}} \Gamma(\frac{n-1}{2})} e^{-Ty} (\frac{\omega}{k} - y^2)^{\frac{(n-3)}{2}} \{1 + \frac{n\lambda_3}{3!}[\frac{y^3}{n^3} + \frac{3(T^2-1)}{n}y + T(T^2-3) + \frac{3\omega}{kn^3}y$$

$$- \frac{3}{n^3}y^3 + \frac{3\omega T}{kn^2}] + \frac{n\lambda_4}{4!}[3 - 6T^2 + T^4 + \frac{4T}{n}(T^2-3)y + \frac{6}{n^2}(T^2-1)y^2 + \frac{4T}{n^3}y^3 + \frac{1}{n^4}y^4 +$$

$$\frac{6\omega(T^2-1)}{kn^2} + \frac{12T\omega}{kn^3}y + \frac{6}{n^2}(\frac{\omega}{kn^2} - T^2 + 1)y^2 - \frac{12T}{n^3}y^3 - \frac{6}{n^4}y^4 + \frac{3(n-1)\omega^2}{(n+1)k^2n^4} -$$

$$\frac{6(n-1)\omega}{(n+1)kn^4}y^2 + \frac{3(n-1)}{(n+1)n^4}y^4] + \frac{n\lambda_3^2}{72}[\frac{1}{n^5}y^6 + \frac{6T}{n^4}y^5 + \frac{15T^2}{n^3}y^4 + \frac{20T^3}{n^2}y^3 + \frac{15T^4}{n}y^2 + 6T^5y$$

$$+ nT^6 - \frac{3(2n+3)}{n^4}y^4 - \frac{12(2n+3)T}{n^3}y^3 - \frac{18(2n+3)T^2}{n^2}y^2 - \frac{12(2n+3)T^3}{n}y - 3(2n$$

$$+ 3)T^4 + \frac{9(n+4)}{n^2}y^2 + \frac{18T(n+4)}{n}y + 9(n+4)T^2 - 15 + \frac{6\omega T^4}{kn} + \frac{24T^3\omega}{kn^2}y + 6(\frac{6T^2\omega}{kn^3}$$

$$- \frac{T^4}{n})y^2 + 6(\frac{4T\omega}{kn^4} - \frac{4T^3}{n^2}y^3 + 6(\frac{\omega}{kn^5} - \frac{6T^2}{n^3})y^4 - \frac{24T}{n^4}y^5 - \frac{6}{n^5}y^6 - \frac{18(n+3)\omega T^2}{kn^2} -$$

$$\frac{36(n+3)T\omega}{kn^3}y - 18(n+3)(\frac{\omega}{kn^4} - \frac{T^2}{n^2})y^2 + \frac{36(n+3)T}{n^3}y^3 + \frac{18(n+3)}{n^4}y^4 + \frac{96\omega}{kn^2} - \frac{96}{n^2}y^2$$

$$+ \frac{9\omega^2T^2}{k^2n^3} + \frac{18T\omega^2}{k^2n^4}y + 9n(\frac{\omega^2}{k^2n^6} - \frac{2T^2\omega}{kn^4})y^2 - \frac{36T\omega}{kn^4}y^3 + 9(\frac{-2\omega}{kn^5} + \frac{T^2}{n^3})y^4 + \frac{18T}{n^4}y^5 + \frac{9}{n^5}y^6$$

$$- \frac{27(n-1)}{(n+1)}\frac{\omega^2}{k^2n^4} + \frac{27(n-1)}{(n+1)}(\frac{2\omega}{kn^4})y^2 - \frac{27(n-1)}{(n+1)n^4}y^4 + \frac{6n(n-2)}{(n+1)(n+3)}\frac{\omega^3}{k^3n^6} -$$

$$\frac{18(n-2)}{(n+1)(n+3)}\frac{\omega^2}{k^2n^5}y^2+\frac{18(n-2)}{(n+1)(n+3)}\frac{\omega}{kn^5}y^4-\frac{6(n-2)}{(n+1)(n+3)n^5}y^6]\}/(kn).$$

Let $C=\dfrac{n^{\frac{n-3}{2}}e^{-\frac{1}{2}(nT^2+\frac{\omega}{nk})}}{\sqrt{2\pi n}\,2^{\frac{n-1}{2}}\Gamma(\frac{n-1}{2})}$, $A_i(\omega)=\int_{-\frac{\omega}{k}}^{\frac{\omega}{k}}e^{-Ty}(\frac{\omega}{k}-v^2)^{\frac{n-3}{2}}y^i dy$, $i=0,1,2,3,4,5,$ 6.

By Lemma 1, the marginal probability density function of $\hat{C}_{pp}$ is equal to

$$f_W(\omega)=\int_{-\frac{\omega}{k}}^{\frac{\omega}{k}}f_{W,Y}(\omega,y)dy=\frac{C}{kn}\{A_0+\frac{n\lambda_3}{3!}[\frac{-2}{n^3}A_3+\frac{3}{n}(T^2-1+\frac{\omega}{kn^2})A_1+(T(T^2-3)+\frac{3T\omega}{kn^2})A_0]+\frac{n\lambda_4}{4!}[\frac{1}{n^4}(-5+\frac{3(n-1)}{n+1})A_4-\frac{8T}{n^3}A_3+\frac{12\omega}{kn^4(n+1)}A_2+\frac{4T}{n}(T^2-3+\frac{3\omega}{kn^2})A_1+(3-6T^2+T^4+\frac{3\omega}{kn^2}[2(T^2-1)+\frac{(n-1)\omega}{(n+1)kn^2}])A_0]+\frac{n\lambda_3^2}{72}[(\frac{4}{n^5}-\frac{6(n-2)}{(n+1)(n+3)n^5})A_6+\frac{1}{n^3}(-12(T^2-1)+\frac{18n+72}{n(n+1)}-\frac{6\omega}{kn^2}\frac{2n^2+5n+12}{kn^2(n+1)(n+3)})A_4+\frac{4T}{n^2}(-T^2-\frac{3\omega}{kn^2}+\frac{3(n+6)}{n})A_3+\frac{9\omega}{kn^4}(-2(n+3)+\frac{6(n-1)}{(n+1)}-\frac{\omega}{nk}\frac{n^2+2n+7}{nk(n+1)(n+3)})A_2+(6T^5+\frac{12T^3}{n}(-2n-3+\frac{2\omega}{kn})+\frac{18T}{n}(n+4-\frac{2(n+3)\omega}{kn^2}+\frac{\omega^2}{k^2n^3}))A_1+(nT^6+3T^4(-2n-3+\frac{2\omega}{kn})+9T^2(n+4-\frac{2\omega(n+3)}{kn^2}+\frac{\omega^2}{k^2n^3})+\frac{6(n-2)\omega^3}{(n+1)(n+3)k^3n^5}-\frac{27(n-1)\omega^2}{k^2(n+1)n^4}+\frac{96\omega}{kn^2}-15)A_0]\}.$$

Define $B_l(\omega)=\int_{-\sqrt{\frac{\omega}{k}}}^{\sqrt{\frac{\omega}{k}}}e^{-Ty}(\frac{\omega}{k}-v^2)^{\frac{n+l}{2}}dy$, $l=-3,-1,1,3.$

Then the marginal probability density function of $\hat{C}_{pp}$ becomes

$$f_{\hat{C}_{pp}}(\omega)=f_W(\omega)=\{B_{-3}(\omega)\{\frac{\lambda_3^2(n^2+4n-3)}{72n^4(n+1)(n+3)}(\frac{\omega}{k})^3+[\frac{\lambda_4}{n^3 4!}-\frac{\lambda_3^2(12T^2+5+\frac{9}{n})}{72n^2}](\frac{\omega}{k})^2+[\frac{\lambda_3^2}{72}T^4+(\frac{\lambda_4}{4n}-\frac{\lambda_3^2}{24}-\frac{\lambda_3^2}{8n})T^2+\frac{\lambda_3}{2n}T-\frac{\lambda_4}{4n}+\frac{2\lambda_3^2}{9n}](\frac{\omega}{k})+\frac{n^2\lambda_3^2}{72}T^6-[\frac{n(2n+3)\lambda_3^2}{24}+\frac{n\lambda_4}{4!}]T^4+\frac{n\lambda_3}{3!}T^3+[-\frac{n\lambda_4}{4}+\frac{n\lambda_3^2}{8}(n+4)]T^2-\frac{n\lambda_3}{2}T+\frac{n\lambda_4}{4}-\frac{5n\lambda_3^2}{24}-14\}+B_{-1}(\omega)\{\frac{\lambda_3^2}{24n^3}[\frac{n^2+4n+9}{n(n+1)(n+3)}-\frac{2T^2}{n-1}](\frac{\omega}{k})^2+[-\frac{5\lambda_3^2}{18(n-1)}T^4+$$

$$\frac{1}{6(n-1)}\left(\frac{\lambda_3^2(4n+1)}{n^2} - n\lambda_4\right)T^2 - \frac{\lambda_3}{6n^2(n-1)}T - \frac{\lambda_3^2}{12n^2}\left(1+\frac{6}{n}\right) + \frac{\lambda_4}{6}\Big]\left(\frac{\omega}{k}\right) -$$

$$\frac{\lambda_3^2 n}{12(n-1)}T^6 + \frac{1}{6}\left(-\frac{\lambda_4}{n+1} + \frac{\lambda_3^2 n\left(2+\frac{3}{n}\right)}{n-1}\right)T^4 - \frac{\lambda_3}{2(n-1)}T^3 - \left[\frac{\lambda_4}{2(n+1)} + \frac{\lambda_3^2}{n-1}\left(\frac{n}{4}\right.\right.$$

$$\left.\left.+1\right)\right]T^2 + \frac{\lambda_3}{2(n-1)}T\Big\} + B_1(\omega)\Big\{-\frac{\lambda_3^2}{12n^3(n+1)}\left[\frac{3}{n(n+3)} + 2T^2\right]\left(\frac{\omega}{k}\right) +$$

$$\frac{\lambda_3^2 n}{18n(n+1)}T^4 + \frac{\lambda_4 + \frac{5}{2}\lambda_3^2}{3n^2(n+1)}T^2 - \frac{\lambda_3}{3n^2(n+1)}T + \frac{-\lambda_3(n+4)+\lambda_3^2(2n^2+5n+12)}{12n^3(n+1)}\Big\}$$

$$-B_3(\omega)\Big\{\frac{\lambda_3^2(2n^2+5n+9)}{36n^4(n+1)(n+3)}\Big\}\Big\}\frac{C}{kn}.$$

Corollary 1: The density of $\hat{C}_{pp}$ is given by

$$f_{\hat{C}_{pp}}(\omega) = \Big\{D_{-3}\sum_{i=0}^{\infty}\frac{(-T)^i}{i!}\left(\frac{\omega}{k}\right)^{\frac{n-3+i}{2}}\Big\{\frac{\lambda_3(n^2+4n-3)}{72n^4(n+1)(n+3)}\left(\frac{\omega}{k}\right)^3 + \Big[\frac{\lambda_4}{n^3 4!} -$$

$$\frac{\lambda_3^2\left(12T^2+5+\frac{9}{n}\right)}{72n^2}\Big]\left(\frac{\omega}{k}\right)^2 + \Big[\frac{T^4\lambda_3^2}{72} + T^2\left(\frac{\lambda_4}{4n} - \frac{\lambda_3^2}{24} - \frac{\lambda_3^2}{8n}\right) + T\frac{\lambda_3}{2n} - \frac{\lambda_4}{4n} + \frac{2\lambda_3^2}{9n}\Big]\left(\frac{\omega}{k}\right) + T^6$$

$$\frac{n^2\lambda_3^2}{72} - T^4\Big[\frac{n(2n+3)\lambda_3^2}{24} + \frac{n\lambda_4}{4!}\Big] + T^3\frac{n\lambda_3}{3!} + T^2\Big[-\frac{n\lambda_4}{4} + \frac{n\lambda_3^2}{8}(n+4)\Big] - T\frac{n\lambda_3}{2} + \frac{n\lambda_4}{4} -$$

$$\frac{5n\lambda_3^2}{24} - 14\Big\} + D_{-1}\sum_{i=0}^{\infty}\frac{(-T)^i}{i!}\left(\frac{\omega}{k}\right)^{\frac{n-1+i}{2}}\Big\{\frac{\lambda_3^2}{24n^3}\Big[\frac{n^2+4n+9}{n(n+1)(n+3)} - \frac{2T^2}{n-1}\Big]\left(\frac{\omega}{k}\right)^2 + \Big[-T^4$$

$$\frac{5\lambda_3^2}{18(n-1)} + \frac{T^2}{6(n-1)}\left(\frac{\lambda_3^2(4n+1)}{n^2} - n\lambda_4\right) - \frac{T\lambda_3}{6n^2(n-1)} - \frac{\lambda_3^2}{12n^2}\left(1+\frac{6}{n}\right) + \frac{\lambda_4}{6}\Big]\left(\frac{\omega}{k}\right) -$$

$$T^6\frac{\lambda_3^2 n}{12(n-1)} + \frac{T^4}{6}\left(-\frac{\lambda_4}{n+1+\frac{\lambda_3^2 n\left(2+\frac{3}{n}\right)}{n-1}}\right) - T^3\frac{\lambda_3}{2(n-1)} - T^2\left(\frac{\lambda_4}{2(n+1)} + \frac{\lambda_3^2}{n-1}\left(\frac{n}{4}\right.\right.$$

$$\left.\left.+1\right)\right) + T\frac{\lambda_3}{2(n-1)}\Big\} + D_1\sum_{i=0}^{\infty}\frac{(-T)^i}{i!}\left(\frac{\omega}{k}\right)^{\frac{n+1+i}{2}}\Big\{-\frac{\lambda_3^2}{12n^3(n+1)}\Big[\frac{3}{n(n+3)} +$$

$$2T^2\Big]\left(\frac{\omega}{k}\right) + T^4\frac{\lambda_3^2 n}{18n(n+1)} + T^2\frac{\lambda_4+\frac{5}{2}\lambda_3^2}{3n^2(n+1)} - T\frac{\lambda_3}{3n^2(n+1)}$$

$$+\frac{-\lambda_3(n+4)+\lambda_3^2(2n^2+5n+12)}{12n^3(n+1)}\Big\}$$

$$-D_3\sum_{i=0}^{\infty}\frac{(-T)^i}{i!}\left(\frac{\omega}{k}\right)^{\frac{n+3+i}{2}}\Big\{\frac{\lambda_3^2(2n^2+5n+9)}{36n^4(n+1)(n+3)}\Big\}\Big\}\frac{C}{kn},$$

where $D_l = \int_0^{2\pi} (sin\theta)^i (cos\theta)^{n+l+1} d\theta$, $l = -3, -1, 1, 3$ are constants.

[**Proof**] Let $y = \sqrt{\omega/k} sin\theta$, then

$$\int_{-\sqrt{\frac{\omega}{k}}}^{\sqrt{\frac{\omega}{k}}} e^{-Ty}(\frac{\omega}{k} - v^2)^{\frac{n+l}{2}} dy = \int_0^{2\pi} e^{-T\sqrt{\frac{\omega}{k}}sin\theta}(\frac{\omega}{k} - \frac{\omega}{k}sin\theta^2)^{\frac{n+l}{2}} \frac{\omega}{k}cos\theta d\theta.$$

$$= \int_0^{2\pi} e^{-T\sqrt{\frac{\omega}{k}}sin\theta}(\frac{\omega}{k})^{\frac{n+l}{2}}(cos\theta^2)^{\frac{n+l}{2}} \frac{\omega}{k}cos\theta d\theta$$

$$= \sum_{i=0}^{\infty} \frac{(-T)^i}{i!}(\frac{\omega}{k})^{\frac{n+l+i}{2}} \int_0^{2\pi} (sin\theta)^i (cos\theta)^{n+l+1} d\theta.$$

Define $D_l = \int_0^{2\pi} (sin\theta)^i (cos\theta)^{n+l+1} d\theta$, then $B_l(\omega) = D_l \sum_{i=0}^{\infty} \frac{(-T)^i}{i!} \frac{\omega}{k}^{\frac{n+l+i}{2}}$, where $l = -3, -1, 1, 3$. The Cororally is proved by substituting the above definitions into Theorem 1.

Notice that D_l are constants which can be found in any elementary calculus textbook.

CONCLUSIONS

Greenwich and Jahr-Schaffrath (1995) introduced a new index C_{pp}, a simple transformation of the index C^*_{pm}, which provides an uncontaminated separation between information concerning process accuracy and process precision. An estimator is chosen to perform well under the conditions that are assumed to underly the data. However, these conditions are never known exactly, estimators must be chosen which are robust, and perform well under a variety of underlying conditions. The Edgeworth series distribution is often used to study the effects of nonnormality since it has the advantage of producing the disturbances in the skewness and kurtosis of desired extent. In this article processes with symmetric tolerance is considered. By assuming that the samples are taken from a distribution which can be approximated by an Edgeworth series with the skewness and the kurtosis factors, the distribution of the natural estimator C_{pp} is derived. Based on the results in this paper, one can test if a process is capable when the incapability index C_{pp} is used.

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Distributional Property of the Incapability Index C_{pp} Under Edgeworth Series Distribution for Processes with Symmetric Tolerances

製程能力指標 C_{pp} 在 Edgeworth 分佈下之分配

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摘　要

Greenwich and Jahr-Schaffrath (1995) 提出製程能力指標 C_{pp}。該製程能力指標可將製程準確度及製程精確度分開表之。該文中作者提出一個自然估計式 並討論該製程能力指標在常態製程假設下之近似信賴區間。然而製程眞正的分佈一般而言是未知的，因此在本文中我們探討當眞正的製程分佈是非常態但是很靠近常態分佈時，不管其樣本大小如何，若眞正的製程分佈可以 Edgeworth series 逼近時該自然估計式之分佈。

關鍵詞： 對稱容忍區間；統計製程管制

A Power Managed Pipeline Architecture Design for a Palmtop Multimedia Terminal

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Abstract

This paper proposes a power managed pipeline architecture for a palmtop multimedia terminal, which receives information from computer networks sporadically. To process intermittently arriving information under a certain throughput, we need a power managed pipeline architecture, which can control some pipeline stages on and off to save power consumption in a mobile computing environment. The power saving is based on the existence of the idle state of mobile terminals. From the state probability transition equations of the state transition diagram for a power managed pipeline, we will obtain the state probability of the idle state and then obtain the total power consumption which is lower than the traditional pipeline architecture. For simplicity reasons, we use a two-stage pipeline as an example in which we show the state probability of the idle state and the power managed circuit. Finally, the power managed circuits for multiple pipeline stages are also found as a regular structure design.

***Key Words*:** power management, pipeline architecture, palmtop multimedia terminal, state probability.

INTRODUCTION

Recently, research has been done on power management in mobile computing at different levels of computing systems [1,2,3]. The purpose of power management is to save power consumption for extending the recharge period of mobile terminals. Obviously, for mobile users, the longer the recharge cycle in a mobile terminal, the more convenient its operation [4,5]. Usually, the power management mechanism of the mobile terminal can detect the machine status and decide if the system is in "idle state" or "busy state". During idle state, the system can turn off some subsystems in order to save power consumption.

Traditionally the pipeline architecture is used to speed up the execution performance of a task due to the overlap of each subtask execution. For a mobile multimedia application, we also need to use pipeline architecture in order to process multimedia information. But for a mobile application, the multimedia information arrives sporadically, so we should have asserted of control signals to manage each stage of a pipeline processing unit. Then we gain a chance to turn off some stages in order to save power consumption [6,7].

The rest of this paper is organized as follows. In section 2, we will discuss the state probability of each stage of the power managed pipeline architecture. In section 3, we will present total power consumption of this pipeline architecture and show some special cases in which we succeed the power consumption saving. In section 4, we will show the power managed circuits and their latency. The last section draws some conclusions.

THE STATE PROBABILITY

In mobile computing environment, the users issue the commands to the mobile terminal intermittently and the terminal receives multimedia information sporadically from networks. Besides, a palmtop multimedia terminal has to provide enough information processing power to meet the specification requirement of a certain application. To fulfill this throughput requirement, often, there is a pipeline architecture implementation in the mobile terminal. But if we let each stage of the pipeline on all the time, then we may waste a lot of power during "waiting state" or "idle state" under the mobile operation model [8,9].

In our design, the working situation of a pipeline, usually, depends on the information packet or task arrival patterns. The information or task arriving patterns can be a Poisson distribution [10] based on the random combination of computer network transmission characteristics. From the definition of the Poisson arrival process, we learn the probability of K arrivals in an interval T sec is

$$P(k) = p(K \text{ arrivals in T sec}) = \frac{(\lambda T)^k e^{\lambda T}}{K!}$$

$$K = 0,1,2,4,\cdots\cdots,\lambda: \text{The average packet arrival rate} \quad (1)$$

For a simple example, from equation (1), we assume $\lambda T = 1$, then P(0) = O.38, p(2) =0.18, etc. p(0) =0.38 means the probability of no packet arrival in T sec. At the interval T, we can turn off some subsystems in order save power consumption.

The average and variance of packets or tasks arrival in the ionterval T are shown

$$E(K) = \sum_{k=0}^{\infty} KP(k) = \lambda T \quad (2)$$

The variance $\sigma_k^2 = E[K - E(k)]^2 = E(k^2) - E^2(k) = E(k) = \lambda T$ (3)

The average and variance of packets or tasks arrival in the interval T are shown in equation (2) and (3) will eventually effect the power consumption of the receiver devices. These arrival characteristics also effect the state probability of the pipeline operation that will provide a guideline to manage the power supply for each stage of the pipeline.

Fig.1 shows a typical datapath pipeline that has five stages; instruction fetch, instruction decode and register file read, execution or address calculation, data memory access, and write back [11,12].

The control signals provide the coordinates of the operation for each stage. The registers between two stages can store information and control signals temporally.

Fig.2 shows a typical JEPG decoding diagram which can be a pipeline implementation of a palmtop multimedia terminal [15, 16]. The decoder takes the input compressed image data which, by providing table specification (same as the one used by the encoder), then go through aset of procedures and generate the output digital reconstructed image data [13,14].

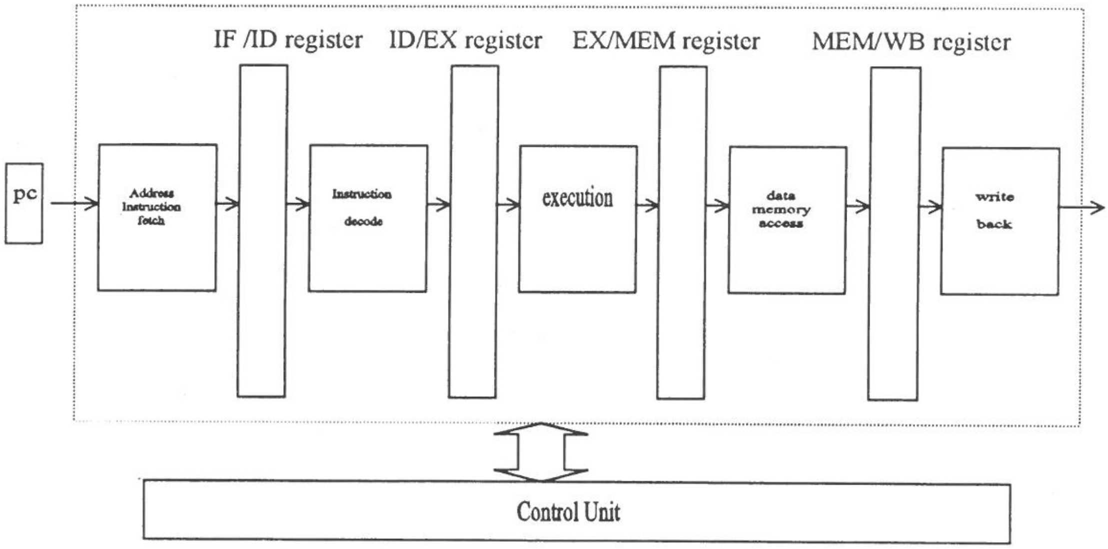

圖 1 A typical datapath pipeline.

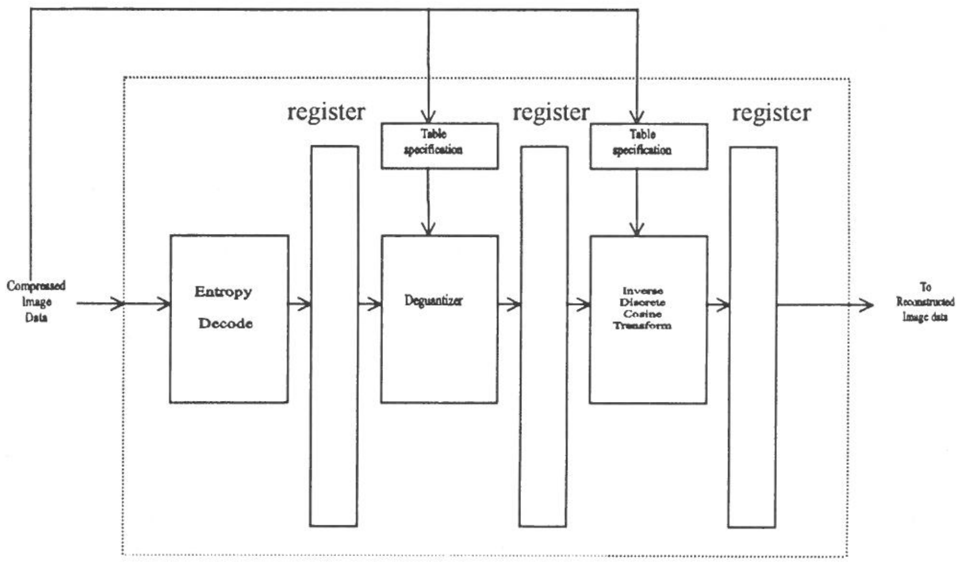

圖 2 A typical JEPG decoding diagram.

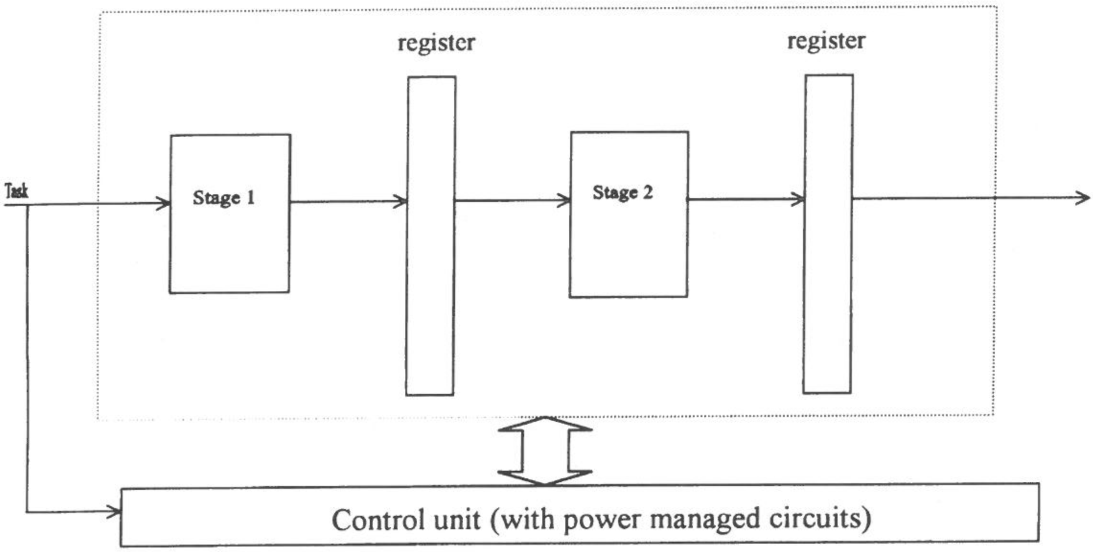

圖 3　A power managed two-stage pipeline.

Fig.1 and Fig.2 show the pipeline implementation that can be used in a palmtop multimedia terminal. Two pipeline architectures can be modified as either grouping a couple of stages into one stage or decomposing a stage into a couple of substages. This modification can provide us with the control complexity and the throughput adjustment. To show the state probability of a pipeline architecture, we first use the two-stage pipeline in Fig.3, which is derived from the merge of a multiple stage in Fig.1 and Fig.2. Table 1 shows the operation status of the two-stage pipeline. "1" represents "busy state" and "0" represent "idle state" for the correspending stage respectively.

Fig.4 shows the state transition diagram. πij represents the state transition probability from state i to state j. When a task arrives, the input equals to 1.

Because the newly arriving task which can be "1" or "0", the state transition may exist between two states. For example, state S_0 (00) can transit to state S_1 (01), but can not transit directly to state S_3 (11) based on the state transition rules. P_0 to P_3 represent the state probability of state S_0 to S_3.

In case of a stationary, non-time-varying probability, the balance equation

Table 1. The operation status of a two-stage pipeline.

Stage \ status	State 0 (S_0)	State 0 (S_1)	State 0 (S_2)	State 0 (S_3)
Stage 1	0	1	0	1
Stage 2	0	0	1	1

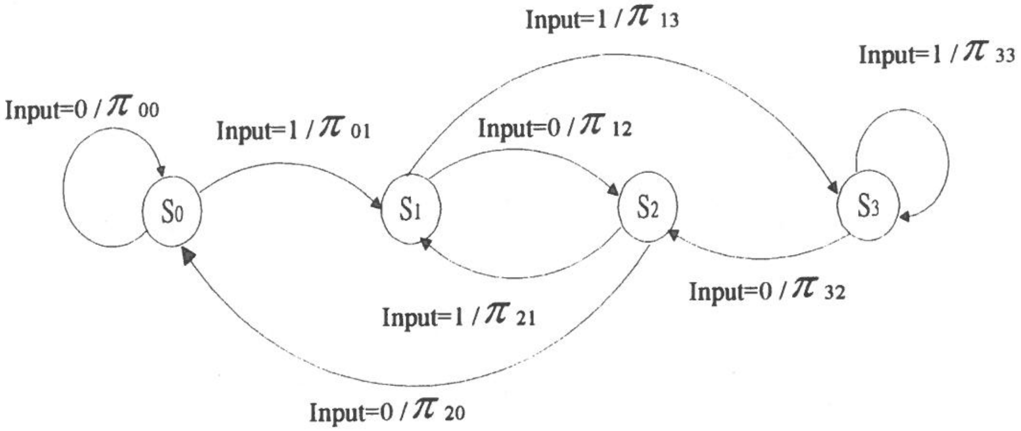

圖 4 A state transition diagram of a two-stage pipeline.

for each state can be shown as the following:

$$State\ 0: P_0(\pi_{00} + \pi_{01}) = P_0\pi_{00} + P_2\pi_{20} \tag{4}$$

$$State\ 1: P_1(\pi_{12} + \pi_{13}) = P_1\pi_{01} + P_2\pi_{21} \tag{5}$$

$$State\ 2: P_2(\pi_{20} + \pi_{21}) = P_1\pi_{12} + P_3\pi_{32} \tag{6}$$

$$State\ 3: P_3(\pi_{33} + \pi_{32}) = P_1\pi_{13} + P_3\pi_{33} \tag{7}$$

$$P_0 + P_1 + P_2 + P_3 = 1$$

$0 < \pi \leqq 1$,

$$P_0 = \frac{\pi_{32}\pi_{20}(\pi_{12} + \pi_{13})}{(\pi_{32}\pi_{20}\pi_{12} + \pi_{32}\pi_{20}\pi_{13} + \pi_{20}\pi_{32}\pi_{01} + \pi_{20}\pi_{01}\pi_{13} + \pi_{21}\pi_{32}\pi_{01} + \pi_{21}\pi_{01}\pi_{13} + \pi_{32}\pi_{01}\pi_{12} + \pi_{32}\pi_{01}\pi_{13})} \tag{8}$$

$$P_1 = \frac{\pi_{32}\pi_{01}(\pi_{20}+\pi_{21})}{(\pi_{32}\pi_{20}\pi_{12}+\pi_{32}\pi_{20}\pi_{13}+\pi_{20}\pi_{32}\pi_{01}+\pi_{20}\pi_{01}\pi_{13}+\pi_{21}\pi_{32}\pi_{01}+\pi_{21}\pi_{01}\pi_{13}+\pi_{32}\pi_{01}\pi_{12}+\pi_{32}\pi_{01}\pi_{13})} \tag{9}$$

$$P_2 = \frac{\pi_{32}\pi_{01}(\pi_{12}+\pi_{13})}{(\pi_{32}\pi_{20}\pi_{12}+\pi_{32}\pi_{20}\pi_{13}+\pi_{20}\pi_{32}\pi_{01}+\pi_{20}\pi_{01}\pi_{13}+\pi_{21}\pi_{32}\pi_{01}+\pi_{21}\pi_{01}\pi_{13}+\pi_{32}\pi_{01}\pi_{12}+\pi_{32}\pi_{01}\pi_{13})} \tag{10}$$

$$P_3 = \frac{\pi_{01}(\pi_{20}+\pi_{21})}{(\pi_{32}\pi_{20}\pi_{12}+\pi_{32}\pi_{20}\pi_{13}+\pi_{20}\pi_{32}\pi_{01}+\pi_{20}\pi_{01}\pi_{13}+\pi_{21}\pi_{32}\pi_{01}+\pi_{21}\pi_{01}\pi_{13}+\pi_{32}\pi_{01}\pi_{12}+\pi_{32}\pi_{01}\pi_{13})\pi_{13}} \tag{11}$$

The exact solutions to the state probability of Fig.4 are shown in equation (8) to (11).

TOTAL POWER CONSUMPTION

The exact solutions, equation (8) to (11) are very long in terms of real algebra representation. To simplify the explanation, we will discuss three typical cases.

Case 1

If the transition probabilities between states are all equal, i.e.,

$$\pi_{00} = \pi_{01} = \pi_{12} = \pi_{21} = \pi_{32} = \pi_{13} = \pi_{32} = \pi_{33} = \frac{1}{2},$$

Then from equation (8) to (11) we have

$$P_0 = P_1 = P_2 = P_3 = \frac{1}{4} \tag{12}$$

With this set of state probability, the total power consumption $POWER_{total}$ can be represented as the summation of each state power consumption as shown in equation (13).

$$\begin{aligned} POWER_{total} = {} & P_0{}^{*}POWER_{stage1:off,\ stage2:off} + P_1{}^{*}POWER_{stage1:on,\ stage2:off} + \\ & P_2{}^{*}POWER_{stage1:off,\ stage2:on} + P_3{}^{*}POWER_{stage1:on,\ stage2:on} + \\ & POWER_{extra} \end{aligned} \tag{13}$$

Where $POWER_{stage1:off,\ stage2:off} \approx 0$, $POWER_{stage1:on,\ stage2:off} \approx 1/2$,
$POWER_{stage1:off,\ stage2:on} \approx 1/2$, $POWER_{stage1:on,\ stage2:on} \approx 1$.

$$POWER_{total} \approx \frac{1}{4}(0) + \frac{1}{4}(\frac{1}{2}) + \frac{1}{4}(\frac{1}{2}) + \frac{1}{4}(1) \approx 0.5 \quad (14)$$

Equation (14) shows that, when the task arrival probability equals to 0.5, total power consumption can be saved about 50%.

Case 2

If the task arrival probability is close to 1, and then both stages of the two-stage pipeline are almost in the "busy state" simultaneously, hence, there is no power saving in this case.

$P_0 \approx P_1 \approx P_2 \approx 0$, $P_3 \approx 1$,

$POWER_{total}$ in equation (13) can be simplified

$$POWER_{total} \approx 0(0) + 0(\frac{1}{2}) + 0(\frac{1}{2}) + 1(1) \approx 1 \quad (15)$$

Case 3

If the task arrival probability is smaller than 0.5, then both stages of the two-stage pipeline are more often in the "idle state". Hence, total power consumption can be saved more than 50% in comparison with the result of case 1.

THE POWER MANAGED CIRCUITS

To design the power managed circuit, we derive the state table shown in Table 2 from Table 1, the operation status of a two-stage pipeline.

Table 2. State table for a two-stage pipeline.

Present State	Next State	
	input x=0	input x=1
S_0	S_0	S_1
S_1	S_2	S_3
S_2	S_0	S_1
S_3	S_2	S_3

Table 3. State table with state encoding for a two-stage pipeline.

Present State		Input	Next State	
A	B	X	A	B
0	0	0	0	0
0	0	1	0	1
0	1	0	1	0
0	1	1	1	1
1	0	0	0	0
1	0	1	0	1
1	1	0	1	0
1	1	1	1	1

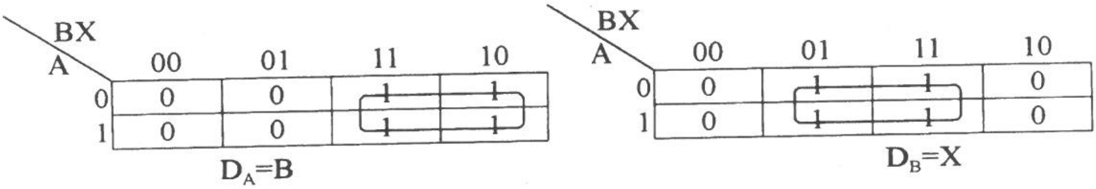

圖 4 Maps for input equations of the power managed circuits.

With state encoding, $S_0=00$, $S_1=01$, $S_2=10$, $S_3=11$, we can obtain the state table shown in Table 3 with the codes assigned.

The flip-flop input equations are obtained from the next－state values as listed in Table 3. They are simplified by means of the maps plotted in Fig.4

Based on the input equations in Fig.4, the logic diagram of the sequential circuit for the power managed circuit of the two－stage pipeline is shown in Fig.5

Fig.5, is a single layer of D-type flip － flop implementation for the power managed circuit of the two-stage pipeline, the circuit has only one clock cycle latency and very limited power consumption in comparison with the power that we can save by turning off some subsystems.

By going through the same procedure of designing the power managed circuit of the two-stage pipeline, we obtain the regular structure of the power managed circuit

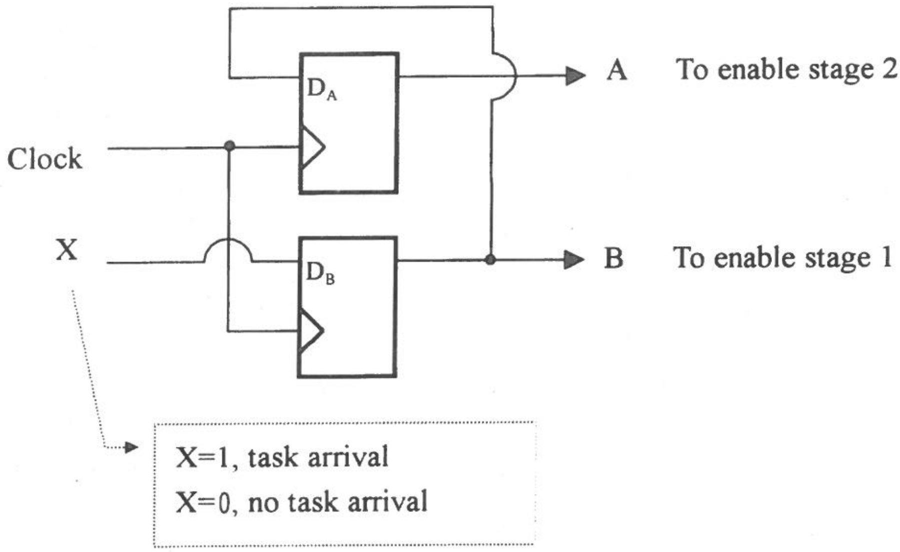

圖 5 Logic diagram for the power managed circuit of the two-stage pipeline.

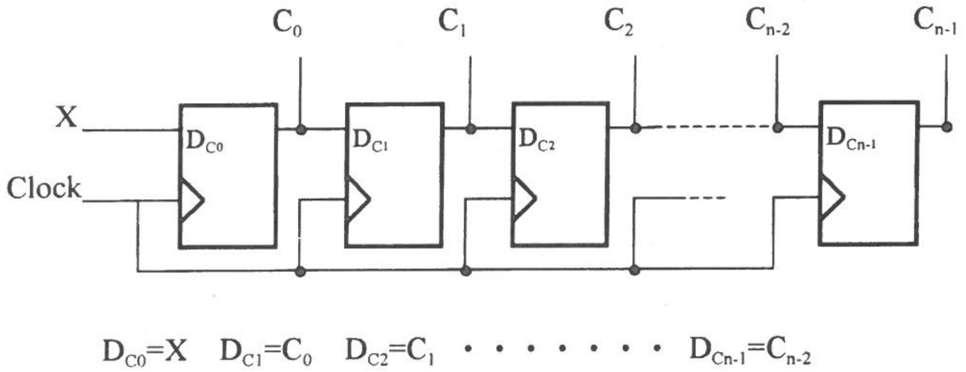

圖 6 Logic diagram for the power managed circuit of the multi-stage pipeline.

for the multi-stage pipeline. Fig.6 shows the input equation and the design. Again, the circuit has only one clock cycle latency and very limited power consumption in comparison with the power that we can save by turning off some subsystems.

CONCLUSION

This paper has presented a power managed pipeline architecture design for a palmtop multimedia terminal. With a minor increase in latency and power consumption, we design power managed circuits to control the two – stage pipeline architecture. Due to the information arriving sporadically from a mobile network, providing the reasonable state transition probability, the state probability of pipeline stage shows that some stages can stay in "idle state". Then we can turn off the stage during idle state in order to save power consumption. In a two-stage pipeline, for the state transition probability value of 0.5, we can have the potential to save 50% power consumption. Finally, following the same procedure as designing the power managed circuit for the two-stage pipeline, we obtain a regular structure design for the power managed circuits of multiple pipeline stages.

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掌上型多媒體手機之電源管理管線架構設計

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摘　　要

本文針對掌上型多媒體手機提出一種具有電源管理功能之管線架構設計。由於必須兼顧多媒體手機接受資料的間歇性與資訊處理之流量考慮，在行動計算環境下，我們需要一種可以電源管理之管線架構以達到節省能源消耗的目的。行動手機管線架構可以省電的基本原因在於機器處於「閒置」機率普遍存在，本文嘗試從一個電源管理型的管線架構狀態轉移圖求出手機「閒置狀態」機率。接著我們估算出具有電源管理之管線架構可提升電源消耗效率。為了簡化說明，我們採用兩級管線架構為例，求出手機閒置狀態機率及設計其電源控制電路。除此以外，我們也提出多級管線架構之電源管理規則性控制電路設計。

關鍵詞：電源管理，管線架構，掌上型多媒體手機，狀態機率。