voltage when the resonator bends. The resonant frequency of these tunistors is near 250 kilohertz, and Q's of 500 or more are obtained with operation in air. The expectation that the temperature coefficient of frequency would be about 40 parts per million per degree centigrade has been confirmed. Similar devices with frequencies to several megahertz should be feasible, and active elements can be added to yield a monolithic tuned integrated circuit with net gain.

Conclusions

Flexural resonators similar to tuning forks offer an attractive way of obtaining stable, high-Q frequency selectivity in monolithic integrated electronic circuits. Size compatibility with these circuits requires orders-of-magnitude reduction in the dimensions of present tuning forks. The consequences of this degree of miniaturization are investigated here. It is concluded that vibration-sensitivity and fatigue remain dominant limiting factors, but that they are *not* made more severe by miniaturization. Frequency shift due to gravitational effects and vibration caused by thermal agitation are increased by miniaturization, but it is shown that these are still not ordinarily the dominant limitations. Air damping rapidly decreases the Q of a resonator when it is miniaturized, but Q's of the order of 100 remain feasible for resonators small enough to be incorporated in integrated circuits. Higher Q's can be obtained by means of encapsulation of the device in a vacuum.

Two devices are described which have demonstrated that flexural resonators can be fabricated by techniques which are compatible with the planar integrated circuit process. The resonant gate transistor has useful applications in the frequency range from 1 to 50 kilohertz; the tunistor extends this range to several megahertz.

The results presented here indicate that the smallest flexural resonators fabricated today do not represent the ultimate miniaturization which is physically possible. Therefore it is predicted that there will be further reduction in the size of such resonators. The challenge which continues to face us is the problem of developing the radically new techniques needed for economically fabricating microscopic resonators with adequate tolerance control. Integrated circuits provide both the incentive and the means for solving this problem.

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NEWS AND COMMENT

Czech Science: Settling Down to Living with the Occupation

Prague. At about noon on the day following the occupation of Prague, a Soviet Army officer led an armed contingent into the big, gloomy former bank building that serves as the administrative center of the Czechoslovak Academy of Sciences. He presented an order that read: "I, Lieutenant Orlov Yuri Alexandrovich, in the name of the Warsaw Pact Armies, order that work be stopped as of 1 p.m. August 22. All workers and members are to leave the building until further notice." As did their countrymen throughout the nation, staff members tried to argue the troops into leaving. "They told us," an Academy employee recalled, "that they had come to protect us from hooligans and counter-revolutionaries." Academy President Fratišek Šorm, an internationally renowned chemist, issued a statement that declared, "There is no precedent for such an order in the history of our science. . . . I protest against this unlawful act."

Precedents and legalities were, of course, no concern of the occupiers. The Academy building was promptly evacuated, and remained in Soviet hands for the next 10 days. (Staff members grudgingly accord the troops one compliment: virtually nothing was disturbed during their stay in the building, except for a small stock of whiskey on hand for visiting foreigners. Unfortunately, this had been replenished by the time a *Science* representative was hospitably received for an early morning visit.)

Though many public buildings in Prague were similarly occupied, the fact is that, in the context of Soviet fears over the liberalization of Czechoslovak society, there was a symbolic aspect to the invasion of the Academy, which is not only an honorary and advisory organization on the American style but also the administrative agency for operating some 140 research institutes with over 13,000 employees at various professional levels. For, even prior to the downfall of the restrictive Novotny regime last January, but especially since then, not only the products of scholarly research but also the scholars themselves have been woven into Czechoslovakia's political processes to an extent unknown in the United States and perhaps in any other nation. It is not uncommon for Europeans who hold academic or research positions also to hold national political office, but Czechoslovak scholars have not only held office but have also held considerable power, which is far less common. Ota Sik, director of the Academy's Institute of Economics, was the author of the economic reforms that caused the Soviets to charge that Czechoslovakia was en-

route to a capitalist system. After Dubcek took over, Šik was appointed deputy premier, a post from which he was ousted soon after the arrival of the occupiers. (Šik was vacationing in Yugoslavia at the time and, at this writing, has not returned.) Five of the Academy's 204 regular and corresponding members hold elective office in the National Assembly, including Academy President Sorm, who is regularly included at the government's ministerial meetings. And while, in the West, apostles of science policy planning often have a hard time getting through to their political leaders, Czechoslovak politicians, by various accounts, have paid serious regard to the claim that science and technology can be systematically managed for purposes of social and economic development. Studies initiated by the Academy's Institute for the Planning of Science and Institute of Philosophy have been acknowledged as the basis for far-reaching attempts to guide the development of Czechoslovak society.

Thus, Czechoslovak intellectuals, but especially those in the politically well-situated Academy of Sciences, had a big stake in the reforms of the Dubcek regime, and, while virtually all citizens rallied behind their government, members of the Academy did so with special vigor. On 28 August, one week after the invasion, the Academy's 15-member praesidium addressed a proclamation of support for Dubcek's leadership to the National Assembly, the Government, and the Central Committee of the Czechoslovak Communist Party. Noting that "the main residence of the Academy which maintained close scholarly and friendly contacts with the scholars and academies of the socialist countries has been occupied by the troops of these countries," the proclamation went on to acknowledge that reality called for making concessions to the invaders. But, it stated, "the Praesidium of the Academy wishes to stress its conviction that no compromise or concession can be accepted" on the restoration of national sovereignty, removal of the occupying troops, "preservation and further development of democratic principles of life . . . free of all outside intrusion," and legal safeguards for those who did not violate the laws of the republic. The proclamation concluded with the words, "We shall never be able to forget the experience of the recent days, although we might be forced to keep silent about our feelings and thoughts. We wish to say that in our future work, too, we shall follow the principle that it is the duty of scholarship and scholars to seek truth and truth alone and also to defend this truth consequentially."

View from the laboratory window of a major Czech research institute.

It is reported that President Šorm sent a communication to M. V. Keldysh, who is president of the Academy of Sciences of the U.S.S.R. and also a foreign member of the Czechoslovak Academy, asking him to protest the invasion. And telegrams were sent to the Soviet Embassy in Prague, and also to UNESCO, stating, "Dear Comrades, Because we have no possibility to communicate with Soviet scientists, we beg you to tell the Soviet Academy of Sciences, with whom we have good and comradely relations . . . that we protest against the forced, illegal occupation."

Visitors Not Welcome

At some of the research institutes, staff members acted more directly by canceling whatever plans they may have had to visit research centers in the countries taking part in the invasion and, in some cases, by advising prospective visitors from these countries that, at least for the present, they were not welcome. An administrator at one institute reports that he called a Soviet colleague and told him he would not be attending a long-scheduled meeting that was to be held in a few weeks. "He [the colleague] answered, 'We'll delay the conference.' And I told him, 'Until after the army goes.' He said he understood."

Nevertheless, while some scientists, particularly younger ones, talk bravely of turning their backs on professional relations with scientists of the invading countries, others point out that no useful purpose would be served by this tactic, and that, if anything, Czechoslovakia and its scientific community can only stand to benefit from friendly relations with scientists in these countries. These matters are said to have been discussed at a meeting of the Academy leadership and some 100 institute directors, but as Czechoslovakia settles down under the occupation of an estimated half million troops, and the government incessantly urges its people to face up to reality, less and less is publicly said about more and more. However, it was the guess of one knowledgeable person that formal encouragement will be given to strengthening scientific and technical arrangements with Soviet-bloc nations. Such relations now exist, but the fact is that, at the time of the invasion, 600 to 700 Czechoslovak scientists were out of the country for one purpose or another and relatively few of these were in the East. Immediately prior to the invasion, the tendency to look westward was further strengthened when Frederick Seitz, president of the U.S. National Academy of Sciences, visited Prague and held discussions on expanding the exchange agreement between the two academies. What will happen now is not at all certain. But for what it is worth, the Czechs point out that, in the negotiations that led up to the so-called Moscow Agreement on "normalization" of Czechoslovak society, it was agreed that "live" contacts with "the world" are necessary for science and art, and "that the solution of all these problems is and remains exclusively Czechoslovakia's internal affair."

The Czechs hope that Americans will carry through with existing plans for visits to Czech research facilities, but, as one Czech Academy official put it, "we can't in good faith tell visitors that everything here is perfectly safe and that they should bring their families. The situation seems to be without danger now, but visitors with families will have to make their own decision on whether they wish to bring them." Immediately after the invasion the Academy canceled or postponed a number of international conferences that were

NEWS IN BRIEF

• **ARCHES OF SCIENCE AWARD:** Glenn T. Seaborg, chairman of the Atomic Energy Commission, has been named the fourth winner of the Arches of Science Award, which is given annually to an American who has made "an outstanding contribution to the public understanding of the meaning of science to contemporary man." The award, which includes a cash prize of $25,000, is sponsored by the Pacific Science Center in Seattle from funds provided by Pacific Northwest business and industry.

• **COLORADO RIVER BILL:** Conservationists feel they won a victory in the compromise Colorado River bill passed last week after 20 years of regional disputes over water in the Southwest. Although the $1.3-billion bill provides for extensive water resource development, dams, and irrigation systems on the Colorado River, Congress rejected two proposed hydroelectric dams on the lower Colorado that would have flooded parts of the Grand Canyon. The bill also authorizes the Secretary of the Interior to take steps to preserve the Gila Wilderness area in New Mexico. Besides the conservation measures, the bill also provides for a 400-mile system of aqueducts and dams to provide water for arid areas near Phoenix and Tucson, Arizona; reclamation projects in Colorado, New Mexico, and Utah; and a coal-powered electric plant to take the place of the Grand Canyon dams.

• **CAMPUS SANCTIONS:** Under a compromise adopted last week by House-Senate conferees on the $7.2 million Higher Education Authorization Bill, students who participate in serious campus disturbances could lose federal aid. A major question for conferees was whether or not to make it mandatory for universities to act to discipline students receiving federal aid. The compromise specifies that a university must take action to withdraw federal aid for a period of 2 years from a student who is convicted by a court of crimes resulting from campus demonstrations. (His ineligibility for federal aid would apply at all institutions.) In the case of a student involved in a demonstration on his own campus and who is not convicted of criminal action, the university apparently may exercise discretion in withdrawing federal aid. At the time of the *Science* deadline the language of the conference report on the sanctions was still being refined but sources on Capitol Hill conceded that the meaning of the section is unclear and that details of its application will have to be worked out administratively by the Department of Health, Education, and Welfare. It appears, however, that universities may withdraw federal aid when it is established that the student has willfully and substantially disobeyed university regulations or the orders of college officials. Before denying federal aid to a student the institution must grant him an opportunity for a hearing, at which it must be found that the individual's offenses are of a serious nature contributing substantially to the disruption of the administration of the university. No details on how these hearings are to be constituted or conducted are provided. The overall bill still must be passed by both chambers. The Office of Education estimates that 1.4 million students who now receive federal aid in the form of assistantships, fellowships, scholarships, and work-study grants could be affected.

• **REDWOODS:** A compromise bill to create a 58,000-acre redwood national park, combining three California state parks with $92 million worth of private timberland, has been passed by Congress and sent to the President. The compromise agreement, a substantial increase over the House's original bill (see *Science*, 26 July), designates about 28,100 acres of privately owned timberland for acquisition and exchange. House Interior Committee Chairman Wayne N. Aspinall (D–Colo.) said the park development is expected to cost about $10 million.

• **LISTER HILL CENTER:** A national center for biomedical communications has been approved by Congress as part of the National Library of Medicine. The new center, named after Senator Lister Hill (D–Ala.), retiring chairman of the Senate Committee on Labor and Public Welfare, will provide doctors, scientists, and educators in all health professions with immediate access, via data transmission lines, to the computer-stored information within the National Library of Medicine. No funds have been appropriated.

to have been held in Prague. Among those canceled was an International Symposium on the 50th Anniversary of the Proclamation of the Czechoslovak Republic, but present plans call for going ahead with a number of other meetings, and at this point it is planned to go through with a large series of international meetings scheduled for next year.

The effect of the invasion on the actual conduct of scientific research is difficult to assess, since the troops came in during the traditional vacation season and many institutes were operating more or less on a caretaker basis. There are no reports of any direct interference or intrusions. But as the director of one institute said, "With all the turmoil that we had here even before the invasion, it's been very difficult to keep our minds on our work. I would say that we've done very little work over the past three months." It was especially difficult to attend to work, he said, when the Soviets temporarily stationed several tanks in the institute's parking lot. Other institutes, however, report that their work is on a normal postvacation basis, and so it appeared to be when this reporter strolled through the corridors.

So far there is very little to support any expectation that the invasion would lead to a large exodus of scientists and engineers. Few are known to have left, and, in fact, many who were away at the time of the invasion have since returned. Of those who have remained away or who have since gone, it is said that a fair number are Jews who sense a resurgence of anti-Semitism. The oft-cited reason for staying—the borders are open for exit, and apparently it is at least physically a simple matter to get out—is, as one postinvasion returnee from the United States put it, "This is my country and this is where I want to be." One Academy official expressed confidence that, in any event, the "hard" sciences would be more or less left alone in their professional affairs. "Unlike the writers," he said, "we don't communicate our work to the public. I think we'll be okay."

In any case, a visitor emerges with the impression of a household of warm, intelligent, gentle, and often whimsical people who find that a nasty beast has forcibly taken up residence with them. The intruder won't leave and they won't leave, and so it is necessary to come to terms and work out the best possible arrangement for carrying on with life.

—DANIEL S. GREENBERG