A Study of Maintenance Requirements for Component Level Diagnostics in Digital Equipment

By Tom Cavanagh and Keith Field

The SMPTE Ad Hoc Group on D-1 Applications was formed by the Working Group on D-1 Component Digital Television Tape Recording (DTTR) to investigate and propose answers to operational questions, such as maintenance, that arise in planning for D-1 television recorders.

Broadcast engineers have been forecasting the digital revolution as imminent for at least ten years, but when the first Type D-1 DTTRs were produced in 1987, a well-defined benchmark for the digital revolution and the all-digital studio was at last firmly established.

Digital television is a reality, not a dream. It could, however, be the beginning of a high-cost nightmare unless it is ensured that local broadcast technicians are capable of maintaining and repairing this new and complex technology. At present, manufacturers too often espouse the view that troubleshooting and repair of the next-generation digital equipment is beyond the capability of broadcast maintenance staffs. However, it is the belief of the Ad Hoc Group that the long-term interests of the industry can best be served by adopting a position that manufacturers are responsible for providing diagnostics, documentation, and training sufficient for a competent maintenance technician to locate faults down to the component level. To address day-to-day equipment maintenance needs, technical management must direct the efforts of its maintenance staff in specific types of activity.

This article will discuss a number of maintenance activities which must coexist in today's analog digital production facility if the established maintenance needs are to be met. Manufacturers must come to understand that most equipment owners have a need for not only emergency repairs but on-line, off-line and preventive maintenance as well, where faults are repaired to the component's level and equipment is maintained to specifications.

Component is defined as any subassembly, sub-subassembly, or part that is used in the manufacture of a DTTR or its interfaces. Because some mechanical assemblies and electronic circuitry are extremely complex in function, the definition of a component does not always remain the same. More specifically, complex function chips such as a Program Logic Array (PLA) or Application Specific Integrated Circuit (ASIC) should be user replaceable if defective, as should amplifiers, MSI and LSI chips, regulators, drivers, decouplers, and similar devices.

In the signal system where several VLSI circuits may be found assembled — for example, encoders as error encoders, decoders or multiple filters — should, although they are sub-subassemblies, be considered as components and be replaced as a unit if defective. A mechanical assembly or subassembly such as a motor or shuttle control is considered a component unless it contains user replaceable/alignable brushes, potentiometers, clutches, etc.

Responsive Maintenance

The repair of failed equipment is an important aspect of maintenance activity. When the equipment is required for use, it becomes the first priority. This maintenance work is done in response to events, hence the term "responsive maintenance." The term "firefighting" is often used to describe this activity.

Generally speaking, if equipment which is necessary for the production or broadcast of programs fails suddenly and without warning, there must be a maintenance technician available to make emergency repairs. That person must have the skills to effect rapid repairs under pressure of time, and must be supplied with the necessary tools and spare parts.

Therefore, maintenance shops must be staffed at all hours when these services are required. The decision as to the urgency of the service must be based on the potential impact of failing to provide the service.

It should be noted at the outset that there is always an impact due to failure, and the amount of reduction of this impact by prompt and efficient maintenance action may or may not be significant, depending upon the circumstances. For example, failure of a key component during a 15-minute newscast might take 10 or 15 minutes to repair and the program could be lost. An equivalent failure during an editing session could be covered by a coffee break with minor inconvenience.

Restoration of service is speeded up by the availability of backup equipment which can be plugged in to replace a failed device. Spare modules for equipment serve a similar purpose. The principle is to reduce the time spent identifying the source of a failure by enlarging the size of the blocks being examined, hence reducing the total number which need to be looked at to find the faulty one, and then to reduce the repair time by rapidly replacing a faulty block by one known to be good. The faulty item must, however, be repaired later, preferably offline when there is no immediate urgency.

Backup equipment or modules may be provided specifically for this purpose (equipment redundancy), or equipment which is not in use, or is being used by a lower priority program, may be appropriated. If the blocks are large enough, operators may be able to isolate the faulty one

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and replace it in the signal path, thus obviating the need for immediate maintenance. Subsequent repair of the faulty item by a maintenance technician remains necessary. Emergency repairs are, by definition, unscheduled, and emergency maintenance activity is therefore not readily subjected to managerial control. Scheduling of staff in terms of time and numbers and assignment of work must be done on a more-or-less statistical basis.

Reactive Maintenance vs. the Job that Needs to be Done

It is useful, at this point, to investigate how effective a program of emergency maintenance really is.

Remaining on the Air

If a line in the transmission path fails in service, the program is off the air. The goal of emergency maintenance is to restore service as quickly as possible. Emergency maintenance therefore concedes loss of service, and focuses on minimizing the duration. Rapid repair is essential, but the damage in terms of lost audience is likely to be more severe than the duration of the loss of service. If operators or automatic changeover systems cannot very quickly substitute a functional signal path for the failed one, maintenance must take over. Invariably, several minutes or more will elapse and portions of the audience will switch to other channels, where they may remain for the duration of the program period. Loss of continuity in programming thus expands the impact of failure, and even very efficient maintenance cannot compensate.

There may also be a loss of commercial revenues, depending upon the time and duration of the failure. In this case, prompt restoration of service will minimize the loss.

Providing High Technical Quality

There are three prerequisites for the achievement of high technical quality:

- The equipment must be inherently capable of delivering it.
- The equipment must be operated so as to take maximum advantage of its capabilities.
- The equipment must be adjusted and maintained to operate according to its specifications.

Of these, the first two are beyond the control of maintenance. However, maintenance technicians, as technical specialists, are more knowledgeable of the internal function of equipment than operators and are therefore more aware of the implications of operational factors on technical quality.

The maintaining of equipment within its technical specifications is not effectively handled with a program of emergency maintenance, because emergency maintenance is only done in response to reported faults. The success of the program is therefore directly related to the ability of the users (operators and production) to detect the often subtle effects of almost-but-not-quite-within-spec operation. While it might be argued that effects so subtle that a trained operators does not detect them are unlikely to be significant to the home viewer or listener, there is a cascading effect — if all equipment in a signal path is operating just at or outside the limits of its specifications, the overall path will probably be significantly degraded, and yet a cursory examination of the various links in the chain will not reveal the source of the degradation. If all equipment is maintained well within its specs, then the source of any degradation appearing at the ends of the chain can be more readily tracked down.

It is therefore logical to argue that maintaining the specs is really not good enough; the equipment can usually be adjusted to be better than spec, and ought to be adjusted to ensure maximum quality in a complex signal path.

Emergency maintenance is often done under pressure, and the equipment is returned to service in working order. There is no opportunity for a thorough check in such circumstances, and any noncatastrophic conditions will not be repaired. If the faulty equipment is replaced and repaired off-line, there is an opportunity to do a complete checkout, and the chance should not be wasted.

In principle, the necessity for a catastrophic failure to occur before equipment will be adjusted is not conducive to consistently optimum alignment. Equipment which does not fail, and thus receives consequent attention from maintenance, may operate for long periods of time in poor condition before anyone notices and draws it to the attention of maintenance personnel.

Reliability in Technical Operations

Reliability means freedom from failure. Emergency maintenance does not respond to this requirement because it does not occur until after the equipment has failed. Emergency maintenance can only address the question of maximum repair efficiency to minimize the impact of failures on schedules and budgets.

Maximizing the Value Received in Return for the Investment in Equipment

Emergency maintenance activity, as suggested above, does not focus on obtaining maximum quality from equipment. It is therefore usual for equipment operated in such a maintenance environment to tend to be in less than optimum operating condition. Its performance may well be degraded to that which can be obtained from lower-priced equipment, raising the question of how the purchase of the more expensive item can be justified.

The counter-argument is, of course, that this lower-priced equipment, operated in the same environment, would be even worse, and would probably require extra maintenance to maintain even that level of performance. It must be concluded that, in an environment of emergency-only maintenance, good-quality equipment is a good investment, but that the broadcaster does not receive full value for the investment. The minimal attention received by equipment in such an environment is not conducive to promoting an extended lifetime.

Maintenance Procedures

Emergency Maintenance

Emergency maintenance activity is not an efficient and effective means of addressing technical requirements, yet it is an essential activity which must take first priority in a maintenance technician's workload. This contradiction between the necessity for the service and the potentially limited benefits which accrue from its being done as well as possible indicate the scope of the problem faced by maintenance departments, and suggests the potential for friction and misunderstanding between maintenance and operations/production, even in situations where emergency maintenance is conducted in an exemplary manner. Therefore, the strategic thrust in the area of emergency maintenance should be directed towards optimizing the speed of repairs or optimizing the speed of restoration of normal operating conditions.

At first glance, replacement of a failed unit followed by off-line repair appears to be the most effective strategy from an operational point of view. In practice, to implement this strategy, it is necessary to have functional spare units on the shelf or designated spare machines within the plant, which can be used to substitute the failed unit. There is, therefore, a planning and prioritizing process and negotiations with production which must be undertaken to determine what, if any, blocks, at what cost, can be substituted following failure and the source of alternative block units for replacement purposes. In-situ repair as a solution in general is the practice today for most broadcasters because:

- The cost of a full set of modules is higher than that of a complete machine.
- It cannot easily be predicted which modules to purchase if the budget only allows a few to be chosen.
- It is too tempting to leave a spare module in defective condition following a substitution.
- Spare modules too frequently will not work on another machine or one that is not the same.
- A spare machine for maintenance is a luxury that no one can afford in a busy production center.

On-Line vs. Off-Line Maintenance

The term "on-line maintenance" refers to maintenance work being done to equipment which is booked to, and being used, by production. This work is therefore subject to severe time constraints. It must be done under pressure, and often under the eyes of an impatient producer or artist, with the knowledge that program schedules and budgets may be directly influenced by the efficiency of the individual maintenance technician.

The urgency to return the equipment to service may dictate that some side effects of failure may not be able to be adjusted; new components may change circuit characteristics, making alignment desirable to optimize performance, but there is pressure to accept a "good enough — let's get back to work" point of view. The slowdown may force production and maintenance to compromise some technical quality in order to minimize the impact of the failure on schedule or budget. Under such circumstances, maintenance staff would come back to the equipment later to finish the job properly.

The term "off-line maintenance" refers to maintenance work being done to equipment which is not booked to or in use by production.

The equipment may be under maintenance because it has been substituted for in the production area following catastrophic failure, as a follow-up to on-line maintenance which could not be completed due to production pressure, or to clear up soft faults which were previously identified but not repaired because of production pressures.

Off-line maintenance tends to be thorough, because there is no pressure to release the equipment immediately for production, although there may be a deadline due to impending production needs. Therefore, equipment subjected to off-line maintenance is likely to emerge from the process in better condition than if the process was online.

Preventive Maintenance

Preventive maintenance is work which is done, not in response to reported faults, but in the expectation that doing it will reduce the number of faults which subsequently occur. An examination of technical writings and discussions with a broad sample of people in the television and radio industry reveals that almost nobody is opposed to the concept of preventive maintenance. However, many who are in the position of administering technical plants feel that they are not able to implement a thorough preventive maintenance program because of time and staff constraints.

It is clear that the process of preventive maintenance consists of identifying potential in-service faults and taking action to prevent their occurrence. Since, by definition, a potential fault has not yet occurred, any work which is defined for a preventive maintenance program must be based, not on current status, but on experience.

The preceding argument is generally true for catastrophic failure of components, but must be revised when considering soft faults, since these usually develop over a period of time and can be anticipated by looking at the current condition of the equipment in comparison to a reference standard. Such maintenance is certainly preventive, but it is more appropriate to refer to it as routine, as it consists of routinely examining equipment and adjusting it, when necessary, to return it to peak operating condition.

Perceived Situation

It appears that manufacturers do not understand that emergency repair does not represent a significant part of the workload for a technician in a well-maintained plant. The high level of skill is concentrated on preventing trouble. Manufacturers of digital equipment appear to be espousing the view that digital video and audio equipment will be so complex that broadcasters' maintenance staffs will be unable to troubleshoot and repair them. This position is predicated on the idea that the majority of their customers are small private stations. They propose to deal with this situation by:

- Providing on-board diagnostics to identify faults to module level.
- Providing a module exchange service so that component-level servicing is done in the factory rather than in the broadcasters' maintenance department.

Impact

The vendor benefits from this arrangement in several ways:

- He can provide a lower level of documentation, since less maintenance is done by the user.
- He can provide less training, for the same reason.
- He can sell the module repair service.
- He can cut costs by providing minimal diagnostics.

The user is impacted by this arrangement in several ways:

- The support needed for component level maintenance is not provided, depriving him of the choice and obliging him to use the vendor's factory service while still maintaining the same level of staff for their knowledge of technical systems.
- The cost and turnaround time of the contracted repair service is beyond his control and is in addition to current budget requirements.
- Many more spare modules must be kept in stock.
- At first glance there appears to be a long-term trend toward a lower workload in the maintenance department but further study shows that just as many staff are required to accommodate a changing workload.

• The training requirements for staff on digital equipment will increase dramatically at first just as they did when color was introduced.

• There will be a reduced need for new and specialized test equipment.

• Fewer components need be stocked.

• Emergency repair through replacement of modules is only the first level of maintenance but does not represent the major part of the maintenance workload, i.e., all problems are not solved by simply changing a module.

• The use of on-board diagnostics to module level improves restoration-to-service time by identifying faulty boards immediately (however, this level of diagnostics would also be provided in the case of in-house component-level maintenance).

Analysis

Certain aspects of the above are worthy of closer scrutiny.

Maintenance Workload

While the module exchange process might suggest a potential staff reduction resulting from reduced workload, the short-term consequences are minimal, due to a need to continue servicing the existing analog plant, and the long-term possibilities are tempered by the fact that there must be a maintenance establishment to deal with such tasks as: mechanical maintenance; power supplies and other non-modular, non-digital units; system problems encompassing several pieces of equipment; problems which are not solved by module substitution, and maintenance of equipment for which no factory repair service is offered.

Skill Level of Maintenance Staff

While the removal and replacement of a module flagged by a flashing red lamp on the panel is essentially an unskilled function, the list of other maintenance activities given above suggests a skill level not significantly lower than would be needed to do full component-level maintenance; in fact, the last item on the list is exactly that.

Training Requirements

The training requirements for specific pieces of equipment will be a function of the nature of the maintenance needed. Thus, less will be required for equipment serviced by module exchange. However, a certain level of understanding of the equipment and appropriate basic training in digital electronics is needed in any case, as previously mentioned.

Spare Modules

To achieve rapid restoration to service, spare modules are used, even in the case where module repair is done in-house. On the basis of experience with factory repairs, it is estimated that twice as many spares would be needed to provide adequate guarantees of equipment availability if no in-house repair service is available. The cost of a complete set of spare modules for a piece of equipment is estimated to be 1.4 times the cost of the equipment itself (given that all modules of the same type will function properly when interchanged from machine to machine). This suggests that the purchase of spare units is more economical than the purchase of sets of modules. The units must not be placed in-service, however, but must be reserved as maintenance spares.

On-board Diagnostics

The provision of on-board diagnostics to module level is essential in any digital maintenance scenario, as it is the only practical way of assuring rapid restoration to service through substitution. The choice of factory repair relieves the vendor of the requirement to supply the more extensive diagnostics necessary for efficient component-level maintenance.

Programmable Chips

Frequent use of PLAs, EPROMs, and PROMs of the same type is anticipated in the DTTR machine design. Without appropriate listings and the ability to program these devices, an unnecessarily high level of user spares will be necessitated, i.e., at least one spare for every chip of the same type but with a different function in the machine with the attendant increase in costs.

Certain other factors must be considered in making this decision:

Cost

The potential cost impact of a move toward factory repair services cannot be accurately assessed, but some aspects of it can be discussed:

• Cost of spare module will rise significantly.

• Cost of training will be slightly lower, due to reduced manufacturer training, but some is still required, and basic digital technology training is still necessary.

• Cost of factory repairs in currently available programs list prices of the order of 25% of the cost of a new board. Experience suggests that the actual cost may be significantly higher, due to shipping and customs expenses.

• Capital cost of equipment may be lower if the manufacturer passes on his reduced costs (less training to provide, less comprehensive documentation, no need for component-level diagnostics).

Experience with Factory Repairs

Experience with outside repair services has been generally unsatisfactory. Excessive turnaround time and cost, and inadequate repair quality have been noted. There is no reason to assume an improved situation in the future. In particular, turnaround time is affected by customs and shipping, which is beyond the control of both broadcaster and manufacturer.

Quality of Maintenance Staff

The manufacturers argue that the broadcasters' maintenance staffs are not capable of dealing with the complexity of the new digital equipment. While that may be true in some cases, it is felt that the majority of technicians are skilled and competent, and able to perform the necessary maintenance if supported by adequate documentation, training, and on-board diagnostics — how else would we still be on the air?

EBU Digital Maintenance Studies

The European Broadcasting Union (EBU) has prepared a series of reports dealing with the techniques of maintenance for digital equipment. Their recommendations suggest that maintenance to component level is a practical proposition when supported by the manufacturer with appropriate training, documentation, and on-board diagnostics.

Conclusion

Taking account of the various arguments that have been presented in this article, we conclude that the best interests of the broadcasters will be served by adopting the position that manufacturers are to be requested to supply diagnostics, documentation, and training sufficient to permit a competent maintenance technician to locate faults to component level in an efficient and expeditious manner. The diagnostics to module level are essential; those to component level may be offered as an option. The preferred situation for machine repair to component level is a plug-in analyzer, optimally remote, which strikes a balance between the obligatory built-in first level diagnostics and the need to repair to component level.

An Engineering Guideline for the D-1 DTTR expressing this point of view has been proposed to the TRRT committee, but it is not likely to have a significant impact on manufacturers because first-generation machine design work has already been completed and machines will be delivered soon.

It is noted that the provision of onboard diagnostics and a rapidly maintainable design are concepts which must be addressed by the manufacturer in the earliest stages of design. Consequently, the point of view presented here cannot have significant influence on equipment already in production if the manufacturer chooses to ignore the need for efficient repairability of digital equipment by the client.

Digital equipment is a reality today, but an adequate level of diagnostics, documentation, and training is not. They will only become a reality when and if you, the user, speaks out loudly and clearly. Your statement will be heard only when you insist that diagnostic and technical support requirements be included with equipment.

Engineering Committee Report

SMPTE Study Group on 30-Frame Film Rate: Final Committee Report on the Feasibility of Motion-Picture Frame-Rate Modification to 30 Frames/sec

By Edmund M. DiGiulio

During a meeting of the Motion Picture Association of America (MPAA) on August 15, 1985, the suggestion was made by Allan Cooper, vice-president, technology evaluation and planning, MPAA, that perhaps it would be a good idea for the motion-picture industry to explore the possibility of changing the frame-rate standard for film production from 24 frames/sec to 30 frames/sec. Such a change would enable film production to be directly compatible with the proposed HDTV television standard as well as with existing NTSC television standards. It would also serve to enhance theatrical presentation.

This suggestion was carried to the Film Technology Committee of the SMPTE and to the (then) Engineering Vice-President of the Society, Richard Streeter. The SMPTE Engineering Director for Motion Pictures was encouraged to form a study group for this purpose.

The study group was charged to investigate and report on the effects of such a frame-rate change, and to determine as best it could the effects on the audience of how motion pictures produced and projected at 30 frames/sec would appear to the viewer. Would the higher frame rate lead to a perception of higher quality? They were also to investigate the effects on the projection system as to what changes would be required in existing projectors. If possible, they were to report on the effect on telecines, and on laboratory and production practices. The first plenary session of the study group was at the SMPTE Technical Conference in Los Angeles on October 31, 1985.

This first meeting included representatives from around the world and, as anticipated, the European delegates were quite skeptical and generally opposed to such a change. The European TV broadcasting standard, based on a 50-Hz mains frequency, is 25 frames or 50 fields/sec. Films shot in Europe, specifically intended for television release are, therefore, shot at 25 frames/sec, while theatrical films, which are always shot at 24 frames/sec, are shown on television in 50-Hz countries with no modification. The 4% discrepancy in frame rates is ignored. This makes for a convenient and compatible frame-rate situation in those countries, although a 60-min theatrical program runs for only 57 min and 36 sec on television.

In the U.S. and other 60-Hz countries, such as Japan, film production is generally at 24 frames/sec, whether for theatrical or television release. For television release, a frame-rate conversion from 24 to 30 frames/sec is required during the telecine transfer process. This generally involves the use of digital frame stores and is naturally more costly and complex than the existing telecine transfer process in 50-Hz countries.

The proposal for worldwide production standards for HDTV put forward by both the U.S. and Japanese delegations is based on a 60-Hz standard. Their position is that existing

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