M-NET DECODER PRODUCTION
A TECHNICAL ANALYSIS

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The contents of this thesis represent my own work and the opinions contained therein are my own and not necessarily those of the Cape Technikon.

CONFIDENTIALITY

The information and data published in this thesis is limited due to the confidential nature of the M-Net decoder. The content of this thesis is subject to approval for publication by M-Net as well as National Panasonic Company.

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ABSTRACT

M-NET DECODER PRODUCTION - A TECHNICAL ANALYSIS

This thesis is a study and analysis of engineering problems encountered during the manufacture of M-Net decoders at National Panasonic Company, Parow factory in Cape Town.

The document initially describes the operation of the decoder and the production system. Thereafter actual engineering problems are stated and their solutions discussed.

The project involves the accurate identification of problem areas on the production line and the systematic solving for each case. Subjects include static electricity, pre-testing and automatic insertion machine defects.

Analysis of these problems provides one with a better perspective towards the production line and its inherent problems. Results and solutions are presented photographically as well as tabulated in the annexure. In some cases, such as defect classification, deductions were concluded that were very different from those initially expected.

A section of this thesis includes a study of signature analysis in detail. This is an alternative technique of rapid fault finding that was applied to the M-Net decoder. Findings include a signature map as well as logical deductions. Other fault finding methods are also discussed in the text. The implementation of a full warranty service provided customer feedback of the decoders during use in the field. Here much information has been analysed and the results discussed.

This thesis should be of high value to any engineer working in a modern production environment where extreme commercial pressure demands concise and efficient technical analysis to ensure competitive survival.

'n OPSOMMING

VERVAARDIGING VAN M-NET-DEKODEERDERS - 'n TEGNIESE ANALISE.

Hierdie tesis is 'n studie en analise van ingenieursprobleme ondervind tydens die vervaardiging van M-Net-dekodeerders by die National Panasonic Company fabriek in Parow, Kaapstad.

Die dokument beskryf aanvanklik die werking van die dekodeerder en die produksiestelsel. Daarna word werklike ingenieursprobleme genoem en hul oplossings bespreek.

Die projek behels akkurate identifikasie van probleemgebiede in die produksiebaan en die sistematiese oplossing vir elke geval. Onderwerpe sluit in statiese elektrisiteit, vooraftoetsing en outomatieese invoegmasjienfoute.

Analise van hierdie probleme voorsien mens van 'n beter perspektief met betrekking tot die produksiebaan en sy inherente probleme. Resultate en oplossings work fotografies uitgebeeld sowel as in die byvoegsel getabuleer.

In sommige gevalle, byvoorbeeld defektiewe klassifikasie was daar gevolgtrekkings gemaak wat baie verskil het van daardie wat oorspronlik verwag was.

'n Gedeelte van hierdie tesis sluit 'n studie van kenteken-ontleding in detail in. Dit is 'n alternatiewe tegniek om onmiddellik foute op te spoor wat op die M-Net-dekodeerder toegepas was. Bevindings sluit 'n kentekenkaart sowel as logiese bevindings in. Ander metodes om foute op te spoor word ook in die teks bespreek. Die toepassing van 'n volledige waarborgdiens het verbruikersterugvoering van die dekodeerders in die veld gebruik, voorsien. 'n Groot hoeveelheid inligting is hier geanaliseer en die resultate bespreek.

Hierdie tesis behoort van hoogstande waarde te wees vir enige ingenieur wat in 'n moderne produksie-omgewing werk, waar uiterste kommersiële druk juiste en effektiewe tegniese analise vereis om mededingende voortbestaan te verseker.

GLOSSARY

AGC	-	Automatic Gain Control
C.A.	-	Customer Acceptance
EPROM	-	Electrically Programmable Read Only Memory
Hz	-	Hertz
IC	-	Integrated Circuit
MUD	-	Multiple Unit Decoder
M-Net	-	Electronic Media Network
M.P.S.	-	Master Production Schedule
N.P.C.	-	National Panasonic Company
P.C.B.	-	Printed Circuit Board
Q.A.	-	Quality Assurance
SA	-	Signature Analysis
SUD	-	Single Unit Decoder
STV	-	Over the Air Subscription Television
TV	-	Television
X1	-	Experiment Number 1

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Note:- Photographic figures are incorporated in the main body of this thesis, while all other figures and tables are to be found in the annexure.

1. INTRODUCTION

A distinct need for accurate technical analysis, problem solving and control of the M-Net decoder production run exists due to the complexity of this new product. National Panasonic Company (Parow factory) has been awarded half the contract to manufacture M-Net decoders, the other half of the contract being awarded to T.E.K. Electronics.

The M-Net "delta" decoder is the first of its kind produced in South Africa. Being micro-processor controlled and incorporating digital electronics, this product is of a different and thus new nature to the Parow factory, which previously manufactured mostly radio and television products.

. The approach in this study was to divide the production system into its relative technical components; trying to improve specific areas by pin-pointing various problems and providing solutions thus implementing a better, more profitable system.

. Components of the system such as Quality Analysis monitoring, fault diagnosis and even packaging are discussed and placed into improved perspective using the methods set out in this thesis, including signature analysis.

. The aim of this study is to produce a useful document to benefit future projects of a similar nature. The thesis will document and explain ideas and techniques used when attempting to master the technical aspects and control that is essential on any such production line.

2. DECODER DESCRIPTION

The M-Net system is an STV (over the air subscription television) system built under licence from OAK Industries Inc.

This system has been introduced into South Africa, and transmission began in Cape Town in September 1987. The reception areas for the Western Cape are shown in figure 2-1. An M-Net encoder encodes video and audio information compiled in the Randburg Head-office.

The M-Net encoders at each transmission point can operate in two modes, i.e.: the Standard Mode and the Scrambled Mode.

Standard Mode: This is a "clear" mode where the video signals pass through the encoder. In the encoder the video signals are clamped and their levels are normalised by the A.G.C. The video is then transmitted to the encoder output without further modification. Audio signals pass through the encoder to the encoder output. In the standard mode, audio information must be sent on the audio carrier, permitting only one channel of audio. The audio and video signals are then sent to the modulator.

Scrambled Mode: The "Delta" type encoder scrambles the video signals as well as digitising and encrypting the audio signals. Thus the decoder function is as follows:

a. To tune into the relevant M-Net transmitter of that area.
b. To AGC the input signal to an acceptable, usable level.
c. To unscramble the video signal.
d. To decode the relevant audio channel. Two audio channels are simultaneously transmitted and received, but the user has the option of selecting the desired channel, e.g. Afrikaans or English.
e. To remodulate the "clear" audio and video signals and produce a high quality R.F. signal output on channel 32.

The decoder has a built-in booster with a guaranteed gain of between 3dB and 6dB so that any losses encurred e.g. due to the use of extra fly leads etc., will be compensated for. The booster operates continuously i.e.: even when one is viewing S.A.B.C. transmissions through the decoder's tuner.

Details of the decoder design have been changed or adjusted during the process of manufacture to warrant improvement and elimination of problems encountered.

The decoder has an Intel 8751 micro-processor that controls the decoding and user requests. This I.C. has a plastic package (less heat dissipation than the standard ceramic EPROM version) and is programmed and sealed by Intel in the USA. This package contains several user help codes (fig. 2-2) that indicate faults and transmission status. The micro-computer works in a hand-shaking relationship with other hybrid digital I.C.'s to constitute the digital control network which decodes transmission-encoded signals to produce the correct and sequenced output control and digital logic.

The mechanical construction of the decoder consists of a "snap-off" type P.C.B. where the infra-red receiving circuit and the control board of the insulator are inserted together with the main chassis; however, the separate boards are "snapped-off" prior to encasing where they clip into separate locations. The cabinet consists of a moulded high quality plastic facia with lens and decorative trim. The base is galvanised steel and the backplate and lid are plastic-coated steel. Thus an attractive, robust and easy-to-assemble/service package results.

Due to the confidential nature of the decoder, initially specialised security backplate screws were used whereby a specific tool only could be used - conventional handtools cannot undo such security screws. Should an attempt be made, visible damage would result and the subsequent warranty would become invalid. Later on security stickers were used - here a very thin paper sticker covers the lid join (underside), hence if an attempt is made to open the decoder, the seal would be broken and the warranty would become invalid.

The result of this design is a high quality, flexible and "pirate proof" unit that has proved highly successful in the field and has become increasingly popular in the consumer market.

3. PRODUCTION SYSTEM

Before the analysis of detailed problems encountered on the production line is noted, a brief description of the production system is necessary.

3.1 Production line lay-out

To enable a production rate of approximately 350 per day, a stage time of approximately 1,46 minutes was determined. This effectively meant that the slowest operation on the line was not to take longer than 1,46 minutes. According to this time study, the test positions were divided up and the result is shown in fig. 3-1-1. This figure shows the M-Net assembly sequence as well as its sequence relative to other production lines simultaneously active at the Parow factory of N.P.C. Note that five test rigs are employed; here the electrical functions of the decoder are checked and/or aligned. Fig. 3-1-2 shows a Q.A. analysis, note that this is done strictly as per line layout and also as per sequence of manufacture in practise.

Fig 3-1-3
Production line cropping and inspection stages

Fig 3-1-4
Production line test rigs prior to chassis encasing

Fig 3-1-5
Photographs showing decoder soaking area. Every unit must be switched on for a minimum of 12 hours before final C.A.

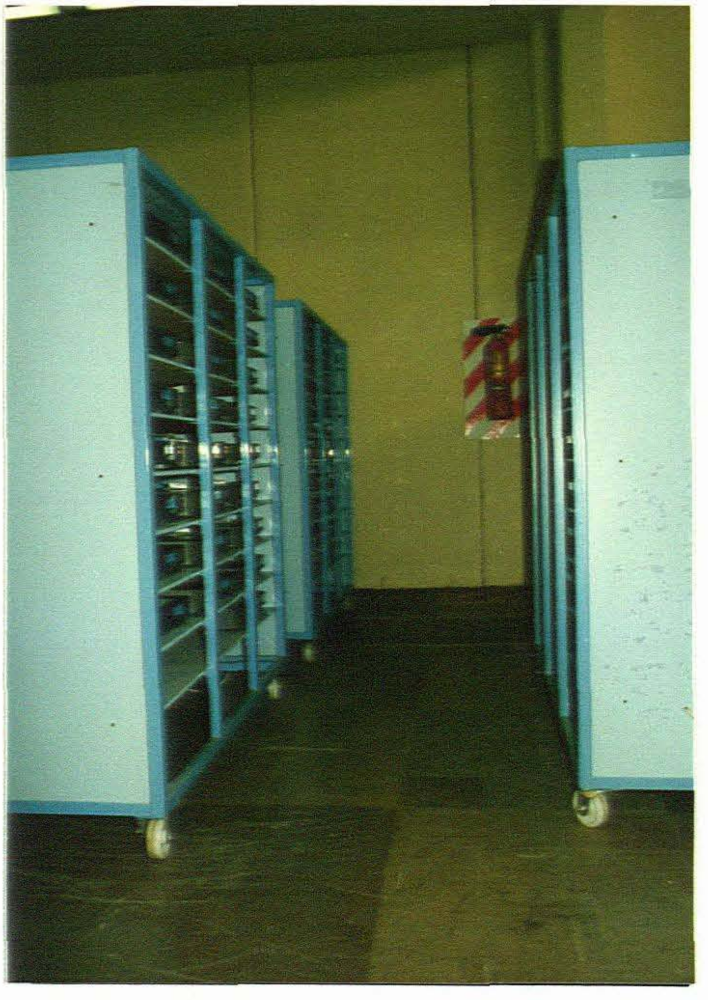


Fig 3-1-6

Production line final Customer Acceptance (C.A.) area
Tests are split into three stages to maximise production flow rate

3.2 Q.A. Monitoring system

"Total quality control is a management system for an entire organisation, not just the manufacturing area". Feigenbaum - "Total Quality Control"

Strict monitoring of production system is essential to maintain control of current failure rates etc. so that something can be done in time before problems become of catastrophic proportion! In order to analyse a manufacturing environment such as that on the M-Net line, standardized input forms are used.

Each operator has a tick sheet which is dated, quantified and has faults accurately recorded on it. The "Q.C." quality control system employed at N.P.C. has different types of tick sheets for different types of tests e.g.: an alignment section records faults and tested quantities on a "Q.C.4-2" sheet by the fault finder - see fig. 3-2-1. A customer acceptance position records on a "Q.C.7-1" sheet, and the faults are repaired and recorded on a Q.C.7-2 sheet - fig. 3-2-2. From these sheets, which are daily gathered and compiled by the Q.A. department, accurate technical analysis can be made on a daily basis.

The decoders are produced in batches of 72, and 13 in each batch are sampled by Q.A. auditors as to compliance with M-Net specifications. If a failure occurs, the correct procedure is followed (fig. 3-2-3); the magnitude or seriousness of the fault assessed; and a decision made as to whether the entire batch is to be reworked or not. Table 3-2-2 shows a Q.A. printout of the batch reject reasons during August 1987.

3.3 Observations and analysis

"In any production plant which manufactures a variety of products, it is vital for management to know what any machine is producing, how many items it is producing, the current efficiency at which the machine is running, and if the efficiency is below the expected figure, the reasons why. *In order for any of this information to be* effectively used, it must be current. Effective control is very difficult with out-of-date information." "Computech", September 1987 - see fig. 3-3-1

The printouts in the annexure (refer figs. 3-3-2/7) are daily printouts produced by the Q.A. department for observation and analysis/

assessment by other departments and are of special use when attempting to technically analyse the M-Net production line. These printouts show a high reject rate at rig 2 and 5. Thus a problem has been pinpointed that needs to be resolved. This system can be, and is, applied not only to the M-Net line, but also other production lines in the factory.

3.4 Production control

"Control is the entire process of appraising work. It includes the preparation of performance standards, measurement of work through recording and reporting systems, evaluation of actual performance, and finally, the taking of appropriate management action."

Louis Allen, Management and Organisation, McGraw Hill Kogakusha.

This research project includes the accurate control of the following points, for without this control, few technical and production problems can be resolved. For example, without accurate fault rate monitoring, one cannot observe the result of a particular preventative method.

The objective is to minimise faults and maximise output, which requires the following production control measurements before analysis is done:

1. production quantity measured against programme.
2. production quality measured by aggregate fault rates.
3. section efficiency (labour hours in std. flows produced).
4. section expense control (actual vs target).
5. section material control (unscheduled requisitions)
   (Returns, scrap, total number of sets produced as per kit units issued).

Fig. 3-4-1 shows a downtime sheet of all the downtimes, reasons and technicians responsible for repair, throughout a duration of one week. This is important to establish if any particular problem e.g.: a test rig fuse blowing, is occurring too frequently. Hereby corrective action can be done in time before excessive downtime re-occurs in future.

Fig. 3-4-2 shows a change order request from M-Net. It was decided to use I.C. sockets for the main micro-processor as the replacement of this 40 pin component was resulting in damage to the P.C.B. This action was done using the correct documentation as illustrated in fig. 3-4-3.

3.5 Packaging

"Some years ago, packaging was a minor element in the marketing mix for a product. The traditional packaging concerns of manufacturers are product protection and economy. A third packaging objective, which comes closer to considering the consumer, is convenience. This means such things as size options and packages that are easy to open. A fourth packaging objective, promotion, has received increasing recognition from manufacturers. And a fifth objective, ecology, is becoming increasingly important as people become concerned with the disposal of packaging material and its effects on the environment."

- Kotler - Marketing Management.

The packaging of the M-Net decoder has been entirely locally designed. The objective of the decoder packaging included the need for re-programming of the decoder's memory without tampering with the packaging in any way. This is possible due to openings in the front and rear of the polystyrene holders. Data is transmitted via the infra-red remote control. The 7-segment display is used to monitor the input data. Antennae (input) and T.V. (output) sockets at the rear are accessible through the polystyrene openings, this allows the testing of R.F. signals. The packaging also allows access to the audio/video din-plug socket used for direct video measurement. The plastic fascia, lens and trim with plastic coated steel lid of the decoder all make up an attractive, robust and very modern-looking product.

4. TECHNICAL PROBLEMS WHEN STARTING UP A PRODUCTION LINE

It was essential to identify and solve problems as soon possible on the production line, especially when a company such as National Panasonic Company undertook a new product like the M-Net decoder that had not been manufactured elsewhere before. The long-term future success of such an undertaking is critically determined by the initial standards set and problem areas resolved.

4.1 Static electricity

Component failure of C-mos integrated circuitry was evident on the line. Static electricity

Fig 3-5-1
Heat Shrink Packaging Wrap Machine

during the handling of these components was causing this breakdown. This problem was solved by enforcing the following precautions:

. All workstations, conveyors, test rigs, test benches and insertion positions had to be securely earthed by means of heavy duty braiding and the insertion of an earth stake into the ground.

. Every inserter and person who handled the decoder chassis had an anti-static wrist band connected to the earthed work station - see photo fig. 4-1-1.

. The fault finder tables have anti-static conductive earth mats so as not to build up static electricity at their workstations where much handling occurs.

. Anti-static earthed I.C. feed trays are used.

. Anti-static I.C. transport trays and chutes were clearly labelled as per fig. 4-1-2. Stores handling procedures were clearly and strictly stated and adhered to with regard to static-sensitive C-Mos I.C.'s. Identification of every container and chute is done using the sticker shown in photo fig. 4-1-2.

Special anti-static blowing gun heads and anti-static cloths are used to clean front panel lenses and decals, as static electricity on these insulator (plastic and nylon) parts causes dust build-up.

Anti-static measures like those mentioned above were done at tremendous cost, however initial investment of these precautionary measures saves considerable long-term cost of returns due to C-mos I.C. failure and breakdown because of handling errors.

4.2 Specifications

The specifications to which the decoder is to comply are specified by M-Net. The decoder is sample checked to ensure that all production is within this specification and that the standard set is constantly maintained.

The clarity and unambiguity of specifications is imperative to the ease of manufacture. Due to the new nature of this product, it was difficult to establish specifications other than from those measured from initial prototypes.

Fig 4-1-1
Inserters using Anti-Static Wrist Bands

Fig 4-1-2
Static Protection Warning Stickers

Initially problems were encountered, e.g.:- Audio signal to noise ratios varied according to the batch of IC's received - see fig. 4-2-1 - here a plot of the varied outputs of the IC's is shown - from this an average standard can be established and a PASS or FAIL standard established.

Goods inwards standards also had to be established and changed in accordance with supplier problems. The standard of plastic coating on lids was poor, until a new supplier was established making original set standards obtainable and thus the final product was of an acceptable, as within tolerance to specification, standard to the customer.

S.A.B.S. specifications were also accounted for by sending decoders to the bureau for testing of leakage and R.F. radiation.

Engineering samples on the production line are used as standards for alignment specification as well as mechanical construction standards and quality levels. These samples are constantly checked to be within updated standards and are never adjusted by any personnel other than those of the engineering department.

4.3 Training

"In any troubleshooting situation, knowledge of the circuit under test is critical to your success." - Hewlett Packard, 1976.

Fault Finder training well in advance of the actual manufacture is very important to ensure proficient repair of faulty decoders. Due to the complex digital/R.F. switching nature of the decoder, full explanation (other than that of the software that is confidential) of circuit diagrams and fault symptoms was essential. An eight week training course was conducted during the initial production of the decoders so as to have "hands-on" training and encouragement in repairing the new product. Ongoing assistance by technicians to the fault finders results in an ongoing development, improvement and training of the staff.

Insertion, alignment, CA and every other stage had to have a well trained operator. It is imperative for the future of a project to start correctly.

The best method of operator training is to have the technician or engineer personally train the operator on a specific machine, rather than to have operator-to-operator passing-on of how the job is done. This latter method tends to lead to a lack of thoroughness and passing-on of inherent operator short cuts and bad habits.

4.4 Specialised tools

Special anti-static and "user friendly" IC insertion and extraction tools were bought for ease and safety of assembly. This was a problem that required internal research because no outside supplier could supply adequate tools.

Metal or metal tipped alignment tools cannot be used on ferrite core variable inductors. Nylon tipped tools are successful, but do not last long enough to be practical in a production environment where up to 450 alignments are done each day! The best alignment tools used were those that were relatively small and easy to handle, with a serrated handle for grip, and with ceramic tips. These "twiddlers" are both hard for durability and non-conductive for ease of electrical alignment.

A "jewellers" screwdriver type alignment tool can be used successfully for oscillator frequency variable capacitor adjustment - here stray finger capacitance was insignificant under aligning the oscillator frequency of the 8751 micro-processor.

Tuner alignment and I.F. (39,9 MHz) alignment tools are very susceptible to stray capacitance of the finger - here specially crafted-to-size ceramic tipped tools are used.

Inductor slug-core breakage can occur easily from brutal usage with a ceramic tipped tool, however practise and experience with the use of such a tool can eliminate most breakages. Breakages usually occur when a slug is struck onto the surrounding core thread (sometimes stray flux or glue enters the inductor can), this breakage happens when the aligner attempts to turn a tightly fixed slug (see photo fig. 6-2-8).

Specialised tools can greatly ease production, providing they are economically obtainable or craftable. Sometimes specialised tools are essential e.g.:- to open a specific type of security screw (as mentioned in chapter 2).

5. SIGNATURE ANALYSIS AND FAULT FINDING METHODS

5.1 Introduction to Signature Analysis

Signature analysis (SA) is a fault finding technique used to find defects in digital circuits. A digital signature is usually presented as a four digit hex number, e.g. 32A5. This is the number that represents the digital state at a particular test point or node. Signature analysis, in short, compares a known correct signature with that of the unit under test.

Signature analysis was introduced to the M-Net production line in an attempt to increase fault finding speed and efficiency. This approach was researched for three major reasons:-

1. A distinct need for faster fault finding was evident as very high fault rates resulted in many outstanding faulty units accumulating. This was partly because of the new digital nature of the decoder circuitry.

2. SA had not been tried before and the intent was to demonstrate its potential not only

on the M-Net production line but also as a technique to be applied in future.

3. A signature analyser was available from the company instrument stock thus avoiding any expense and introduction time.

Similar advanced fault analysis approaches were not as feasible as signature analysis for the specific environment studied. These approaches may include:-

1. Digital oscilloscopes to view digital data - this method is very expensive and too slow to use in the pace demanded by a production environment.

2. Specialised test equipment - this is even more expensive and has considerable lag time usually due to specialised construction.

3. Computer interfaced techniques - other than high expenditure and installation problems (possible re-design of existing layout to accommodate off-line repair), sufficient

expertise and experience in this field was not available.

More approaches are discussed in this chapter.

The Signature Analyser itself consists of a shift register with feedback loops controlled by an external clock and specified start and stop pulses (fig. 5-1). Fig. 5-2 shows typical data input to the Signature Analyser illustrating the respective control signals.

The instrument uses standard input probes for the external clock and start/stop signals and a "Signature probe" is used (same as standard oscilloscope probe) as the data input to be sampled.

Basic requirements of SA are as follows:

1. The measurement window framed by the Start and Stop signals must be unique and synchronized to all the modes tested so that consistent signatures are produced. The number of clock edges enclosed must be a constant for each test set-up condition.

2. Data must be synchronous with and stable during the triggering edge of the clock. Data set-up must be included.

3. Start and Stop can be physically tied together. This minimizes the number of connections used.

4. Single sampling of signatures can be used, however continuous cycling is faster and also effective.

The inputs to the instrument are subject to the specifications and tolerances of that specific instrument used. The clock pulse input must be fairly clean; noise spikes and glitches could result in false signatures or bad readings. The maximum input clock rate (10 MHz for the HP 5004A) and the set-up time (this is the minimum length of time during which data and start/stop signals must be present and stable before the selected clock edge occurs) are relevent limits to be considered when applying S.A. to any ciruitry.

5.2 Need for Signature Analysis

The M-Net decoder circuitry includes micro-processor controlled logic. Serial data flow, rapid changing data and address busses, and high speed clocking and switching are all characteristics of the control logic. To successfully monitor and fault find this circuitry, adequate measuring and testing equipment is essential. This engineering problem could be resolved due to the characteristics of S.A.

Oscilloscope usage by means of probes and C.R.T. (cathode ray tube) visual presentation is not suitable for high speed serial data traffic. Even high speed digital fluctuation e.g.:- analog-to-digital converter outputs, is difficult and impractical to view and analyse on a standard C.R.T. High efficiency fault finding would be an impossibility with the restricted usage of only multi-meter and oscilloscope measuring instruments on a digital control circuit of such a nature.

Thus a more advanced and practical trouble shooting technique was needed. Signature Analysis is the perfect tool for analysing and fault finding such circuitry.

Serial data busses and fluctuating logic control lines are perfect inputs for S.A. External clock inputs as well as start/stop timing pulses are freely available in the decoder circuitry.

Although the decoder itself was not inherently designed for SA, the task of applying SA to the M-Net decoder was of considerable benefit as SA can be applied to many more products of this nature in future.

5.3 Setting up

Photo figs. 5-3-12 and 5-3-13 show the connection and use of the 308 analyzer in practice on the production line.

The clock input from the 15 MHz oscillator in the decoder was taken, as this is a clean, precise, square-wave oscillator clearly suitable to externally drive the S.A. instrument.

The Start and Stop signals were joined together for simplicity, however the start was triggered on the falling edge and the stop on the rising edge of a negatively active pulse. This facility of edge-trigger selection is available using control

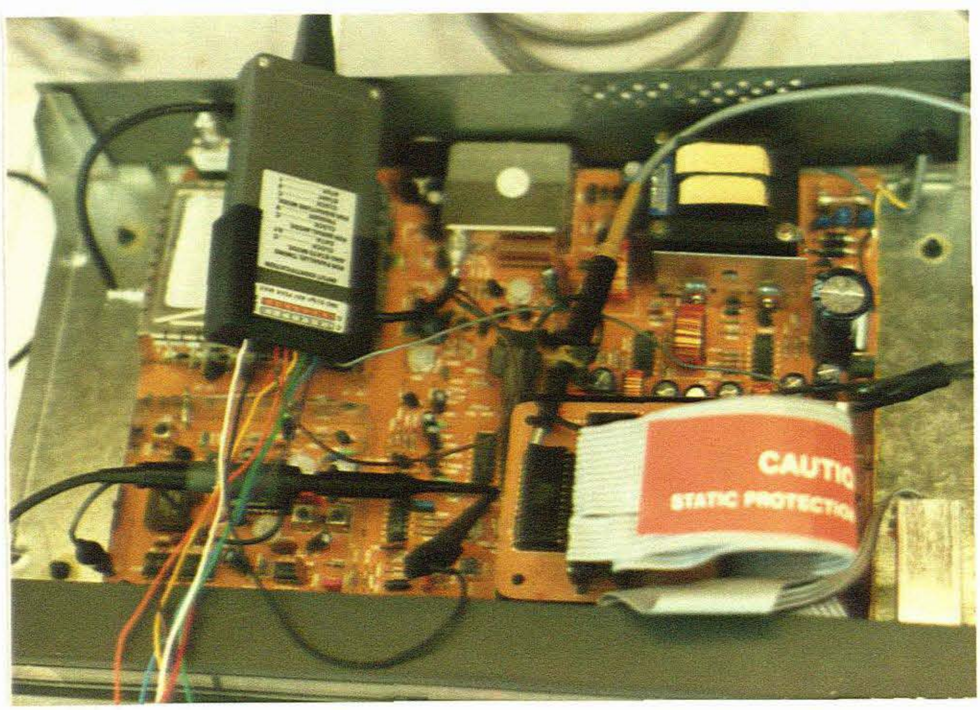
3 (fig. 5-3-5). The input probe is to be varied from test-point to test-point according to the sequence required.

Various trouble shooting techniques of SA fault finding can be employed. Signature tables where a corresponding signature is tabulated according to various test points can be used. Trouble shooting flow diagrams (fig. 5-3-10) are another effective documentation technique. For the decoder fault finding, a signature map such as that shown in fig. 5-3-11 was used. Here a P.C.B. overlay is used with the corresponding signature at each test node shown.

Signature maps are accurate, fast and very effective for efficient fault finding. Here location AND signature information is provided on the same document. Sequential documentation can be provided in the form of a fault dictionary. Here a list of incorrect signatures with their corresponding faults can be listed. This is a fast method of fault finding, however the compilation of such a dictionary can take considerable time and cannot guarantee that the same fault is always the cause of a particular

Fig 5-3-12
S.A. in practice on the Production line

Fig. 5-3-13
Connections to the M-Net decoder



incorrect signature. Fault dictionaries could result in laborious lists of signatures as thousands of four digit signatures can result.

When setting up SA the logic levels must be determined and must be within specification tolerance according to the instrument used.

"We do not care what the actual timing or voltages of the wave forms are, we simply care if the timing and voltages are what they are supposed to be."

James W. Coffron, Practical Troubleshooting Techniques.

This was found to be very relevant and thus, when using a signature map, it can see immediately whether an incorrect signature occurs - thus a fault. If the same signature occurs at two adjacent test nodes, one could assume a short circuit. If NO signature is present i.e.: 0000 is displayed; one can assume that an open circuit, or short- circuit to ground is the fault. If a full count i.e.: FFFF is measured, one can assume that the node is short-circuit to +V. Thus almost instantaneous fault finding can be actioned with the usage of SA.

5.4 Problems that were encountered

Decoding Circuits

"Decoding circuits are usually straightforward combinational logic. Using gates, decoder chips, ROMs or PLAs, most address or control decode lines can be checked with the Signature Analyzer's probe while in the free-run mode. If address or "data valid" control signals are gated into a decode network, care should be excercised that the Data input and Clock signals maintain proper timing (i.e., valid decoded data at the probe should be set-up before the clock trigger edge occurs).

When some, or all, of the decoding occurs within an I.C. (as in several 6800 family circuits), correct decoding is more difficult to verify. But, in field service, or even production environments, it usually doesn't matter what fails in a component, as long as the bad part can be identified. However, when an internal decode does fail, it not only generates a failure over its own address field (by failing to enable), but perturbs other address fields by enabling at the wrong time as well. This can make fault isolation somewhat more challenging, and may encourage the use of sockets or forced chip disable test pins."

H.P. Application Note - 222.

The above states how difficulties can arise when attempting SA on a circuit of decoding nature. This was a distinct problem that was encountered on the M-Net decoder. Due to the random nature of signals that are constantly changing and non-sequenced, the result was constantly changing signatures - thus a "faulty" signature could not be determined. However this disadvantage was only applicable to test nodes where random DATA or TADA (encoded DATA) was present.

To succeed in efficient SA, extremely stable signals are required; the clock and start/stop inputs to the SA must be fairly noise-free and very stable. Due to the commercial low cost nature of the M-Net decoder, such stability is not needed as opposed to the demands of a device such as a high-speed computer, whereby precise stability is imperative to ensure correct operation. Thus SA signatures fluctuated (appearing to show a fault) due to fluctuations in the decoder logic - this is also attributed to temperature fluctuation of the decoder.

Although precise measurement of the digital output of an analog-to-digital converter (as used within the M-Net decoder) is easily obtainable with SA, further problems were encountered, e.g.: if a 1 KHz tone is being generated as a test audio tone on the decoder (as done at Parow factory), the corresponding digital output can be measured and verified correct. However subtle drift and variation in the audio tone generator at the transmitter would naturally cause variance in the corresponding decoded digital output. Hence fluctuating signatures would occur appearing to signify that the decoder is faulty - but mere audio generator drift was causing this "fault"!

5.5 <u>Signature Analysis vs. alternative techniques as future fault finding tools</u>.

SA involves the exclusive usage of expensive equipment as well as the specialized training and adaptation of this relatively foreign technique to local industry. However, as mentioned above, when applicable, SA can be extremely powerful, and that it proved to be very economic in the long term due to its speed, ease of use and production environment adaptation.

5.5.1 **Alternative Methods of fault finding**: the classic usage of a multimeter and/or a C.R.T. oscilloscope has proved itself effective on many products as well as being familiar to almost every fault finder in the production environment. Often foreign ideas such as SA can meet reluctance-to-change reactions that can hamper the success of SA.

Other methods include the concept of specialized in-house built test equipment, or the purchase of specialized test equipment as shown in fig. 5-5-1-1. Here extreme cost can be encountered and the lack of a universal system often results. Test equipment is often used for one run of one product only, and later, on completion of the run, the equipment is discarded and wasted at extreme cost. Logic probes, modified C.R.T displays and specialized test probes are cheaper methods of making fault finding easier, however their effectiveness is always limited to the variety of applications of such methods.

5.5.2 **Signature Analysis in the future**: although SA was not totally successful as a fault finding method specifically for the M-Net decoder, its power as a future production aiding tool was demonstrated by undertaking this project. SA is a universal tool applicable to any digital logic even if the unit under test was not necessarily designed for SA application.

Future electronic developments have a strong trend towards micro-processor or digital logic control of some nature. The demand on today's modern production lines is considerable due to the highly competitive commercial environment. Improved techniques are constantly needed to keep in pace with future development. SA is a typical example of how this is to be obtained in future.

6. FAULT ANALYSIS AND DIAGNOSIS

The Analysis and Diagnosis of faults is one of the most important, if not THE most critical element of running a production line successfully. To solve this problem, was one of the most important objectives of this project. In practice an entire production line can stop within minutes due to incorrect action or analysis of a fault. Thus technical guidance and control, especially in the production of an advanced product of electronic nature such as that of the M-Net decoder; is imperative to avoid extreme loss or disaster to any production line.

6.1 Impact of Faults on Production

High reject rates do not only reduce output but also create excessive buffer stock; demand storage; load fault finders; induce handling damage and generally minimise production control that could be utilized in other areas of the production lines. At a high production rate such as that of the M-Net decoder (±350 units per day): extensive rework of units can be needed if a fault is only discovered after having produced a full day's production with that fault! In practice this happened when it was found at the Q.A. sampling position that faulty coax-fly leads were evident within the decoder. Subsequently every decoder on the production floor had to be checked. This resulted in the opening of approximately 400 decoders! Thus had sufficient pre-testing being active, the problem and its significant cost could have been prevented.

6.2 Defect Classification

Defects on the M-Net production run were classified as follows:

. Electrical components	off line errors
. Panasert errors	off line errors
. Equipment failure	off line errors
. P.C.B. etching	off line errors
. Handling damage	on line operator error
. Insertion errors	on line operator error
. Solder bridges	on line operator error
. Panasert operator errors	on line operator error
. Alignment error	on line operator error

From fig. 6-2-2 which shows a defect summary for the month of November 1987, the following action was taken:

a) All defects other than electrical components were disregarded due to their insignificance, e.g.: sub-assembly (only 0,5%). Production related errors such as handling damage (13,3%) and insertion (4,1%) errors were highlighted to the relevant staff.

b) An accurate, detailed analysis of IC 702 (refer to fig. 6-3-1 for result) was actioned.

c) Pre-testing of the tuners (5,1%) after having built a tuner test rig was initiated.

d) Crystal pre-testing was initiated.

e) Transistor failure was highlighted to supplier (Siemens) and all faulty components/rejects sent back to the supplier.

f) An R.M.S. Voltmeter at a test position to eliminate IC 402 (1,2% reject rate) failures was installed. This voltmeter checks the audio output prior to soaking, thus saving time if replacement is needed.

Defect classification must distinguish between IC and transistor and diode failure etc. This is important as completely different methods (such as those mentioned above) are to be applied to different types of component failure.

It was concluded that electrical component failure was the most significant fault defect throughout the year because of the following reasons:

Due to the economically conscious nature of the materials used for the decoder, very high quality transistors would escalate the cost of the product considerably. Thus locally encapsulated transistors were used resulting in a significant failure rate (ref. fig. 6-2-3).

I.C.'s were of extremely high quality (hybrid units manufactured by SAMES in Pretoria produced failure rates as low as 3 failures in 600 units!), however, sometimes incorrect insertion (reverse polarity, ref. photo fig. 6-2-7, or insertion without suitable anti-static protection) was done resulting in a blown I.C. This would appear to be a faulty component. But the problem is actually one caused by the on-line operators and NOT the I.C. manufacturer.

Unlike production errors, where operator tuition and instruction can eliminate the problem e.g.: inserter discipline and handling care enforcement, electrical component failures are significantly more difficult to solve. The lasting effect is thus that component failure is a long-term fault lasting throughout the year, whereas production error is more volatile in fault rate monitoring.

Methods of component failure detection and classification are shown in fig. 6-2-5 and fig. 6-2-6. Here detailed analysis of component breakdown was undertaken. Unfortunately, due to the confidential nature of many of the I.C.'s used in the M-Net decoder, this type of detailed analysis was not possible as a comprehensive detail of the I.C.'s inner operational characteristics is necessary. However conclusions and results stated in fig. 6-2-5 and fig. 6-2-6 are certainly applicable to the component failures of the M-Net decoder.

Defect classification as mentioned above during the period of this project (one year) resulted in mostly analysis of electrical component defects. Thus the following sections in this chapter specialise in component failure and subsequent findings and actioning post-analysis.

6.3 **Component Pre-testing:**

Pre-testing a specific component having observed that its failure rate is increasing is often the most obvious method of reducing on-line failures, however before actioning such pre-testing, certain questions are to be considered:

a) Is the failure rate high enough to warrant pre-testing?

b) Is a constantly high failure rate predicted, rather than a mere "spike" rise and fall due to exceptional conditions?

c) Does the failure rate significance warrant the cost of specialized test equipment?

d) Are extra, qualified operators available to pre-test?

e) Where and how is the pre-testing to be done?

Fig 6-2-7
Photograph (magnified) showing blown I.C. due to incorrect (reversed) insertion polarity

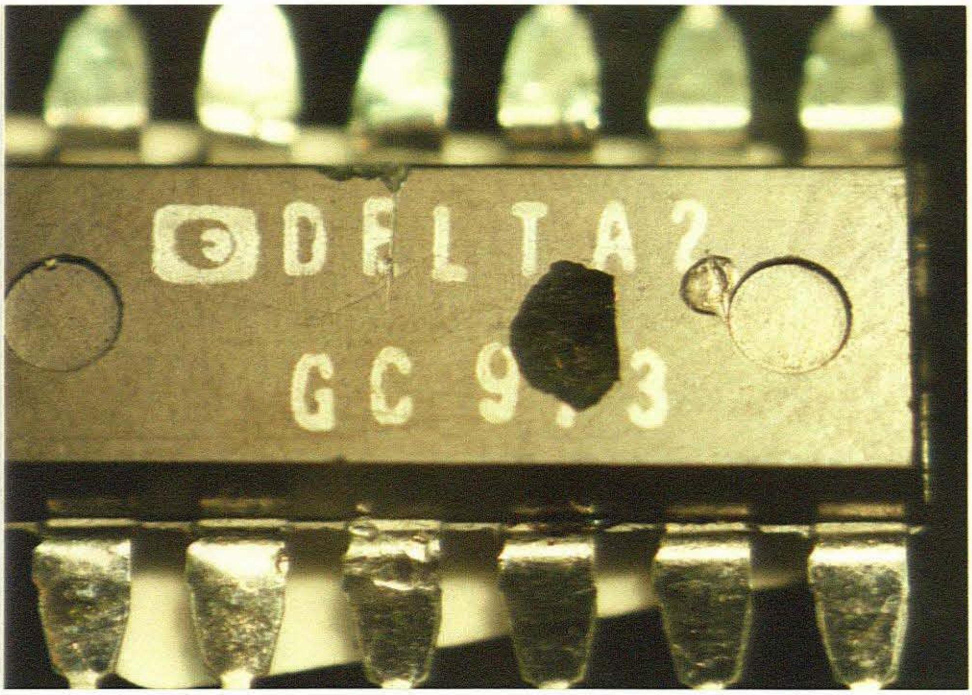
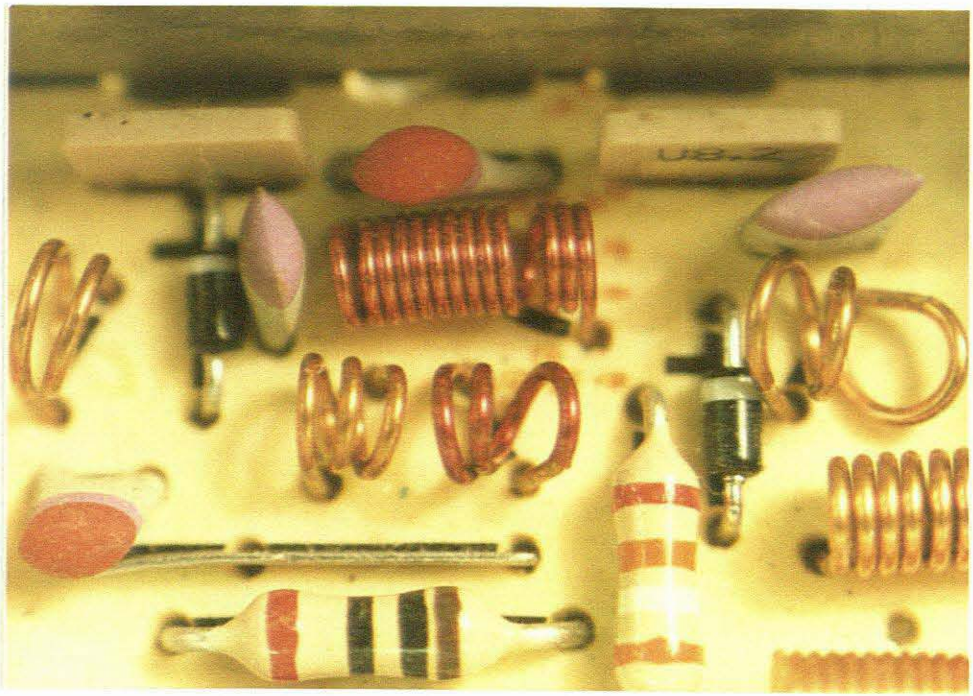


Fig 6-2-8
Photograph (greatly magnified) showing broken slug of variable inductor caused by using incorrectly sized alignment tool.

During the run of M-Net decoders, several components used underwent pre-testing. Figure 6-3-1 shows a printout of I.C. 702 failure rate increase. This component was NOT pre-tested as it was found that the I.C., a phased-lock-loop type component, was incompatible with some tuning loops of specific decoders. Thus pre-testing of this I.C. would be useless as this would and could only be done within one specific decoder. Because of the varying tolerance of tuners and surrounding components to this component, it was incompatible to certain units resulting in a "phase-jittering" symptom. This appeared to be solved by replacement of the I.C., I.C. 702, however it was not the I.C. solely in itself that was responsible for the fault. This is a classic example of where careful analysis of the problem encountered revealed that pre-testing is NOT the solution.

Fig. 6-3-2 shows a Q.A. printout exposing the abundance of tuner failure on line. To combat this problem, a tuner test rig was built and all tuners were tested off line. This pre-testing was successful for certain faults e.g.:- "No Picture" i.e.: dead tuner or broken coxial leads causing grainy pictures. However, the pre-testing did not

Fig 6-3-3
Photograph (greatly magnified) showing tuner coils (inside tuner housing can) which vibrate causing interference when drop testing the decoder



Pre-testing and sorting of crystals into their various frequency limits has proved successful. Here crystals are pre-tested according to which parallel frequency capacitors are to be inserted with them to obtain the correct frequency. This has proved a success not only as a sorting process, but also as a faulty crystal detection system (approximately 1,5% failure rate on arrival to factory).

6.4 Panasert Defects

At the N.P.C. Parow factory a Panasert machine has been used since 1984. This machine was the first of its kind ever to be used in South Africa in 1984. The Panasert machine is a fully automated insertion machine that inserts all axial components e.g.: resistors, diodes and resistor-type inductors (photo fig. 6-4-2).

This machine is pre-programmed for each model produced in the factory, it runs for 24 hours of the day at extreme efficiency (much higher than hand insertion!), and requires minimal maintenance.

Although use of this machine for the M-Net decoder production run dramatically increased ease and speed of production, certain problems arose that required technical analysis, the following are faults detected during this study:

Fig. 6-4-2 shows a photograph (greatly magnified) of a resistor-type inductor that has become open-circuit due to excessive pressure applied to its legs during automatic insertion (Panaserting).

Another typical fault arises when the automatic cropping by the Panasert machine is not sufficient causing short-ciruits to adjacent tracks under the P.C.B. (foil side). This is aided by the stapling effect that the Panasert machine has on the component leg bending.

Panasert errors such as the two types mentioned above might not appear to be very important, but severe production loss and fault rates have occurred due to this. Immediate analysis and solving of Panasert defects is essential because of the extremely rapid operation of the machine.

Fig 6-4-1
Panasert automatic insertion machine at Parow factory in Cape Town

Fig 6-4-2
Panasert damageing of inductors

In practice, entire batches (over 1500 P.C.B. units) have been fault riddled due to Panasert defects! This type of automation machine defect is to be closely monitored and must have immediate feedback after analysis to prevent large volumes of errors.

7. WARRANTY REPAIRS AND LONG TERM FAULTS

As part of the contract between M-Net and N.P.C. to produce M-Net decoders, it was agreed that N.P.C. would provide a one year warranty on each decoder. A faulty decoder in the field is to be repaired and returned within fifteen days at the expense of N.P.C. The introduction and implementation of this warranty was another engineering problem that was a task of this thesis.

7.1 Warranty System

A completely separate and isolated from the production line, warranty repair and administration area was built. This was imperative for control and costing reasons. All replacement parts, unless requested by M-Net, used for warranty repairs are to be paid for by National Panasonic.

To ensure total control, a specific warranty system was established. Here separate documentation (fig. 7-1-1) and system approach/ method was stipulated. Fig. 7-1-2 is a copy of the policy and procedures manual produced by the Q.A. department.

To enable long term technical analysis of faults, an accurate understanding and observation of the warranty system and its content is necessary. Information collected from warranty statistics could and have led to major design changes to improve the decoder's performance in the field.

7.2 Statistical Analysis and Review

Initially, most warranty returns consisted of blown fuses, corrupted memories due to mains switching and mechanical damages. The fuse of the decoder is internally housed for safety reasons, and thus must be opened by the manufacturer only.

This was later changed by mounting an external fuse holder to allow user replacement.

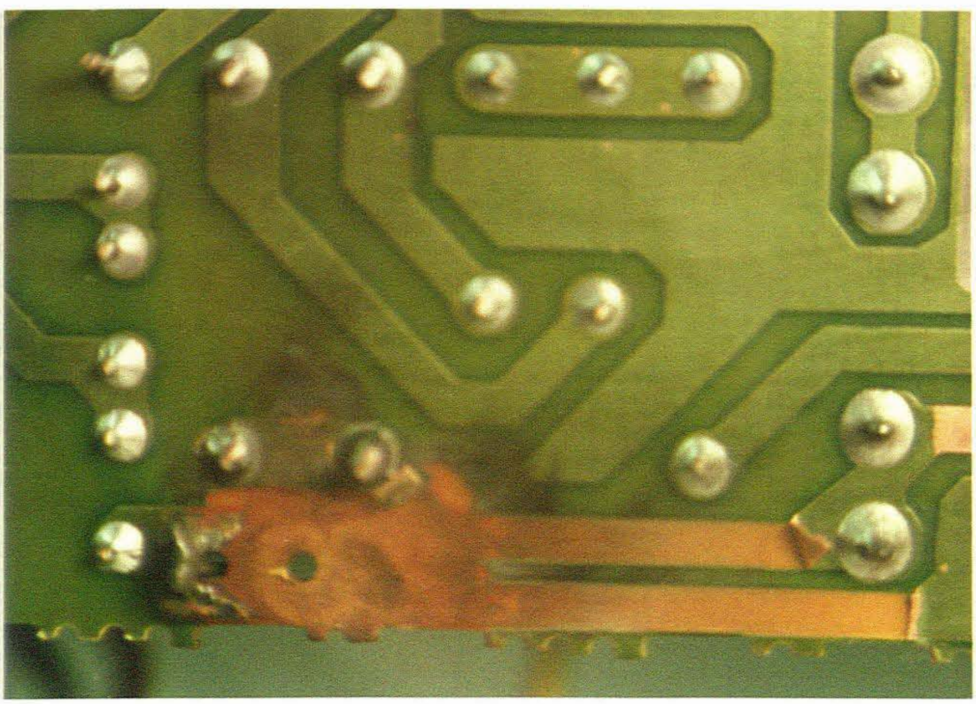
Another problem identified was that the extender P.C.B.'s within the decoder were jumping loose of their sockets during transportation.

This was solved by using tighter sockets. It was found that only one insertion of a board could be done, if another insertion needed to be done (because of faulty replacement), a new socket must be used.

Such changes were implemented, thanks to important analysis from warranty results.

Fig 7-2-5
Photograph of a mechanically damaged (Scrapped) Warranty Decoder that was run over by a vehicle!

Fig 7-2-6
Damaged Foil on Decoder P.C.B. caused by lightning strike



CONCLUSION

The identification and technical analysis of the M-Net production line has exposed a specific field of engineering that had to be mastered before such manufacturing could become successful.

A better perspective of the production line and its problems has resulted; in some cases, such as component pre-testing, this has been directly applied to the system.

Signature Analysis was applied to the production line but was unsuccessful because of specific engineering problems discussed in Chapter 5. However, the reasons for the selection of this method and its benefits have been highlighted and its possible introduction in the future on other such products is very likely.

This research has concluded in an efficient, smooth-running production line with a minimal reject rate. It is strongly felt that a research project such as this is not only of benefit to future engineers attempting to master the task of solving production line problems but also of benefit to National Panasonic Company when introducing future products of a similar nature to the commercial world.

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